# Effect of Co-Digestion Agricultural -Industrial Residues: Various Slurry Temperatures

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# Effect of co-digestion agricultural-industrial residues: various slurry temperatures

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**ABSTRACT**

The main objective of this study is to investigate the effect of co-digestion using industrial-agro waste and operating temperature of digester slurry to enhance the biogas and methane yield. The anaerobic digestion process is carried out by using a floating dome type bio-digester with the capacity of 1 $m^3$. The co-digestion of press mud and rice straw with the ratio of 1:1, slurry temperature mesophilic range of (30–40°C) and thermophilic raange of (41–55°C) is used in this study. The maximum generation of daily biogas and weekly methane yield obtained were about 190 L/day and 55% in the case of the thermophilic condition. The lowest generation of daily biogas and weekly methane yield obtained were about 130 L/day and 33% in the case of mesophilic condition. The 10 percentage of cow dung is used as an inoculum of the digester and 30 days of hydro retention time for both the temperature ranges. The methane and biogas yield is at its peak and there was a faster hydro retention time in thermophilic range temperature at 52°C.

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**KEYWORDS**
Co-digestion; floating dome; thermophilic; methane; industrial waste; hydro retention time

## 1. Introduction

The global energy demand is increasing rapidly day by day, and about 88% of this demand relies upon fossil fuels reported (Weiland 2010). To meet this energy demand and the environmental aspects, today there is lot of research focus on renewable energy resource. The development of renewable energy technology can help to reduce the dependence on the non-renewable resources and the problems of environmental degradation related to fossil fuels mentioned (Amon et al. 2007). This biogas technology provides an alternative source of energy in rural India and is hailed as an appropriate technology that meets the basic need for cooking fuel in rural and urban areas. The biogas is produced from organic wastes by concerned action of various groups of anaerobic digestion. This gas primarily is composed of methane ($CH_4$), carbon di oxide ($CO_2$), hydrogen sulphide ($H_2S$), hydrogen ($H_2$), nitrogen ($N_2$) and traces of other gases as reported (Li, Park, and Zhu 2011).

Among the different factors, 'temperature' is a prime factor that affects the activities, survival and growth of microorganisms involved in biogas generation. There are different temperature ranges during which anaerobic digestion can be carried out. These are: psychrophilic ( < 30°C), mesophilic (30–45°C) and thermophilic (45–60°C). However, anaerobes are virtually active in mesophilic and thermophilic conditions (Rao et al. 2010). Co-digestion is a growing technology applied for simultaneous treatment of different solids and liquid organic wastes. Co-digestion improves biogas yield due to (i) the positive synergism established in the digestion medium and (ii) the supply of missing nutrients by the co-substrate (Gupta, Tripathi, and Balomajumder 2011). Co-digestion of press mud and straw can enhance the digestion efficiency and there are possibly technical, economical, and ecological benefits in mixing different feedstock. Agricultural (rice straw) and industrial (press mud) waste are largely available in Tamilnadu, hence this experimental investigation applied them as raw material for biogas and methane generation. The present study mainly focuses on the performance of co-digestion and slurry temperature from different organic wastes of press mud and rice straw. Biogas is a type of bio energy that can be generated from the decomposition of organic materials and it is mainly composed of methane, carbon dioxide and traces of some other gases. An interesting option for enhancing biogas yields of anaerobic digestion of vegetable wastes are co-digestion, which employs a co-substrate that has the benefit of enhancing the biogas yield due to positive synergism established in the digestion medium and the supply of missing nutrients for microorganisms (Sathish and Vivekanandan 2015). The methanogenesis and microorganisms' growth mainly depend on various parameters such as pH, temperature, C/N ratio, organic loading rate, reactor design, inoculums and HRT (Sathish and Vivekanandan 2016). Presently the anaerobic treatment plants using solid waste and sludge wastes are merging of heat treatment leading to lower amounts and higher for sludge to biogas production in end of the digestion process (Sathish and Vivekanandan 2014).

## 2. Materials and methods

The industrial (press mud) waste and agricultural waste (rise straw) are collected from industrial and agricultural farms located at a local small town near Pallavaram. Initially, the press mud is sundried at 1 week and straws are ground to 0.2–0.3 cm size using a grinding machine and further loaded to the digester slurry. Twenty kilograms of fresh cow dung is mixed with 20% of water and is used as an inoculum of the digestion process.

The following equipment are used in this study: (i) a weighing balance to determine the weight of the water sample, (ii)

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a pH meter pen type range between (5 and 10), (iii) a digital thermometer with a thermocouple probe to measure the temperature inside and outside, (iii) a mixing tank for preparing slurry with different substrate concentrations and (iv) biogas measured using a gas flow meter.

### 2.1. *Working of the floating gas holder type biogas plant*

Digester slurry (mixture of biomass and water) is prepared in the mixing tank. The prepared slurry is fed into the inlet chamber of the digester through the inlet pipe. The plant is left unused for some days after adding inoculum, and introduction of more slurry is stopped. During this period anaerobic fermentation of biomass takes place in the presence of water and produces biogas in the digester. By feeding the fresh slurry, the spent slurry is now forced into the outlet chamber from the top of the inlet chamber.

The gas valve of the gas outlet is opened to get a supply of biogas. Once the production of biogas begins, a continuous supply of gas can be ensured by regular removal of spent slurry and introduction of fresh slurry.

## 3. Experimental set-up

In this experimental study a floating drum gas holder type biogas plant was used. The plant was made of fibre material, with a capacity of 1 $m^3$ bio-digester and the total volume of the digester was 1000 L with an effective gas holder volume of 700 L.

The schematic view of the experimental set-up is shown in Figure 1. In this case cow dung is mixed in a ratio of 1:1 waste/water and after the fermentation process it is used as an inoculum for the digestion process. The proportion of the feed material is co-digestion of rice straw and press mud in the ratio of 50:50 with equal amount of water with retention time of 20 in both cases in mesophilic (25–40°C) and thermophilic (45–55°C) conditions. This can be achieved by circulating hot water around the digester with the help of a water jacket which may transfer the heat to the digester slurry as a heat exchanger. A separate water tank provided with the conventional heating element was used for heating the water and a pump was provided to circulate warm water over the water jacket. Inside slurry temperature and outside temperature were monitored regularly with the help of a thermocouple.

The quantities of gas flow were measured with help of a gas flow meter. The pneumatic stirrer is used to agitate the digester slurry regularly during the hydro retention time and to distribute the thickening. The caking of the scum is also prevented. Generally, agitation did not bring a change in the temperature. The temperature of the digester was measured with thermocouples; the initial and final pH of the slurry is measured using a pH redox meter. The methane content and carbon dioxide content were analysed by a gas chromatograph. The pneumatic stirrer was used to agitate the digester slurry regularly, and the fermented slurry was collected from the digester to be used as an organic fertiliser. It is mainly ensured to uniformly circulate the methanogenic bacteria and at the same time develop surface contact of the waste from anaerobic methanogenic bacteria.

## 4. Results and discussion

From Figure 2, it can be noticed that the biogas production is found to be higher in the thermophilic temperature range when

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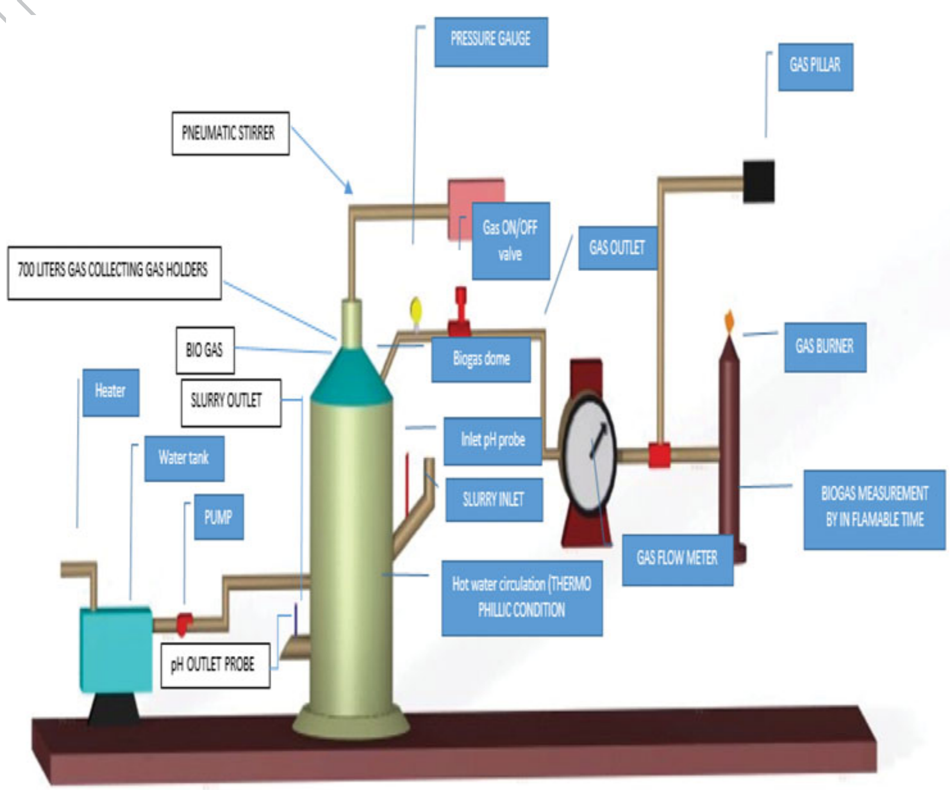


**Figure 1.** Schematic view of the experimental set-up.

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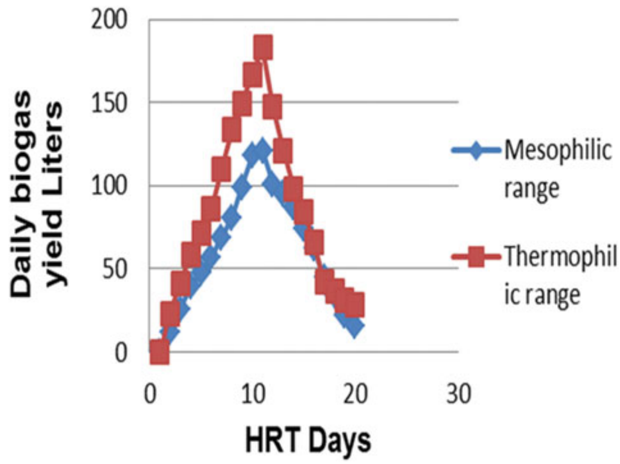


**Figure 2.** Daily biogas with respect to hydro retention time.

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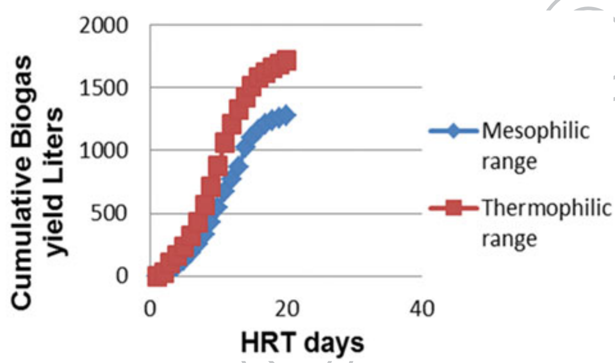


**Figure 3.** Cumulative biogas with respect to hydro retention time.

compared with the mesophilic temperature range. The biogas yield was greatly increased between 10th and 11th days with the gas yield of 183 L/day and 167 L/day in the case of thermophilic temperature range between 50°C and 55°C. The biogas production is found to be in the case of mesophilic temperature range between 40°C and 45°C while biogas yield reported was 118 and 128 L/day. Hence, the temperature improves the biogas yield as well as the efficiency of the anaerobic digester. The digester working in the thermophilic condition was interesting because it resulted in faster reaction rates and high quantity of biogas yield
Q8 compared with the mesophilic condition (Figure 3).

The quantity of biogas yield is measured on a daily basis and a cumulative biogas yield for duration of 20 days of hydro retention time is reported as 1280 L of gas produced in the case of mesophilic anaerobic digestion and 1710 L of gas production in the case of thermophilic anaerobic digestion. Due to the effect of the temperature, the gas generation quantitatively and qualitatively is good at higher temperature. During the acetogenic process more consumption of carbon dioxide by methanogenic bacteria and methane-rich gas generation occur
Q9 in the case of thermophilic condition. The thermophilic digestion process may be a faster reaction with pathogenic bacteria than the case of mesophilic digestion. This is due to the high temperature of operation; digestion kills more pathogenic bacteria and increases the methanogenic bacteria to generate a higher methane yield.

The thermophilic anaerobic digestion process is mainly preferred to increase the biogas production as well as to enhance the methanogenic bacteria. Generally, methanogen bacteria are more stable in the thermophilic range compared with mesophilic range. Figure 4 shows the temperature of the digester slurry in mesophilic and thermophilic ranges. Additionally, increased growth rates of microorganisms and accelerated interspecies hydrogen transfer at thermophilic temperatures lead to faster degradation rates, higher solids destruction, and ultimately to increased biomethane yields at shorter retention times and thermophilic operation provides benefits of short degradation time, good reduction of pathogens, high gas production and good sludge separation.

The optimum pH level was 7.2 in the thermophilic condition and reductions in pH level caused major problems during the mesophilic anaerobic digestion. The biogas production was higher when the pH was 7–7.2. Figure 5 indicates the pH formation with hydro retention time. The anaerobic digestion process strongly depends on the change in pH level of the digester slurry. Biogas yield takes place in the optimum neutral condition of the measure of acid and base property.

In both the cases when the digester temperature increases, the number of microbes also increases and makes the digestion process faster and helps to obtain maximum production

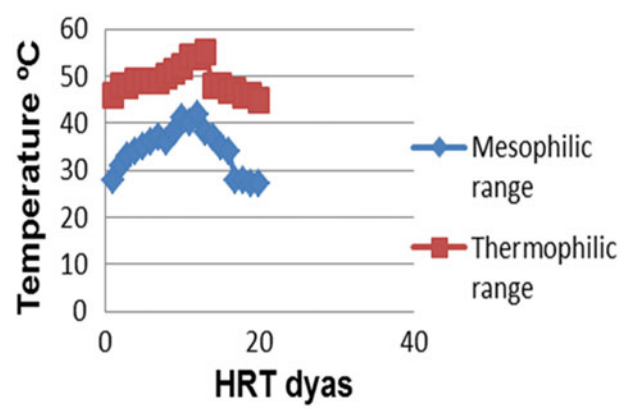


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**Figure 4.** Temperature with respect to hydro retention time.

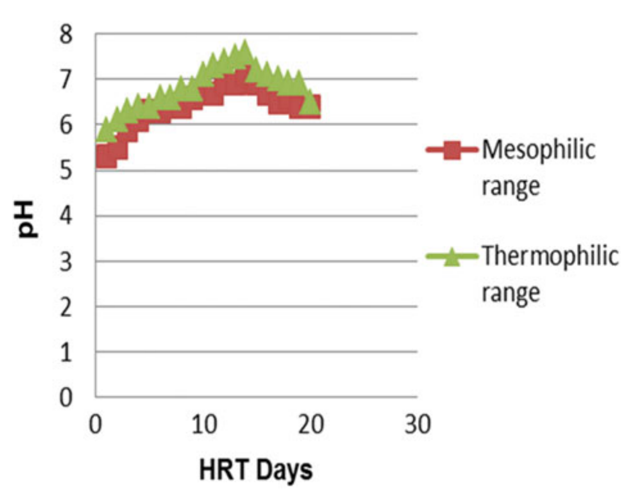


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**Figure 5.** pH with respect to hydro retention time.

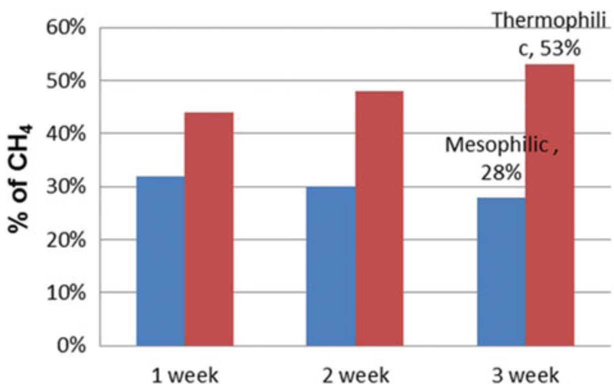


**Figure 6.** Temperature with respect to hydro retention time.

(Figure 6). The results report methane content to be 53.10% during the thermophilic condition compared with 32% during the mesophilic condition. Due to the effect of temperature, the gas generation quantitatively and qualitatively are good at higher temperatures. During the acetogenic process more carbon dioxide is consumed by methanogenic bacteria and methane-rich gas generation occurs in the thermophilic condition.

## 5. Conclusion

The experimental studies suggested that the crop and industrial waste such as rice straw and press mud might be one of the options for efficient biogas yield. The digester working in the thermophilic condition reported high quantity of biogas yield and faster reaction rate when compared with the mesophilic condition. These results show the importance of biogas generation from co-digestion of agro and industrial waste and also the experimental results show high quantity of $CH_4$ generated from the biogas yield with the anaerobic digestion process under thermophilic temperature range using a co-digestion of rice straw and press mud as digestive material. Optimum level of biogas yield was obtained with the thermophilic anaerobic digestion process. Therefore, it is suggested to carry out similar experiments to test the effect of temperature and biogas production from various agricultural and industrial wastes at above 50–55°C.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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