# Use of Pine needles as Substrate for Biogas Production

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**Abstract-** This paper describes the results of an experimental investigation taken up to check the suitability and potential of the pine needles as substrate in biogas production under batch digester. There are various lignocellulosic biomasses for biofuel production but the use of pine needles has not been realized so much yet. In the present study two batch digesters (each having two plastic made buckets: one for fermentation and second as gas holder) was used. In the first digester cow dung named as DIGESTER1 and in the second digester named as DIGESTER2 ground pine needles were co-digested with cow dung was used as a substrate. The feed material was collected from local sources. In both the digesters; inoculum prepared from cow dung was used. Biogas production using cow dung and pine needles under batch digester has been compared under similar field conditions. In both digesters tap water was used to make slurry in a ratio of 1:15 by weight. The different parameters like Total solid, volatile solid are measured & pH, biogas production & temperature are measured on daily basis. The surrounding temperature range during the testing period was between $15^0$C-$23^0$C and slurry temperature inside the digester was in range of $17^0$C-$26^0$C. The total volume of biogas production of the 70 days in DIGESTER1 and DIGESTER2 was 2.47 and 5.30 litres respectively and thus observed that pine needles are better substrate in comparison to cow dung.

**Keywords** Anaerobic digestion, Batch digester, Biogas, Cow dung, Pine needles (agricultural waste).

## 1. Introduction

India is a developing country and energy demand of India increasing day by day due to rapid increase in population. As a consequence of that various energy resources have been evolved and lot of emphasis has been given to the use of renewable energy resources. Use of waste materials comes into the categorized as food waste, animal waste and agricultural waste of renewable resources. The waste disposal is the one of the major problem faced by people across the world. In most of the cities the waste is disposed on landfill so that effect our environment in many ways such as surface and ground water contamination, diseases like malaria, typhoid, malaria and odour problem etc. This waste can be utilized as one of the alternative source of energy.

Himachal Pradesh is a state in northern India with latitude 31.007 & longitude 77.088. According to census of 2011 the population of Himachal Pradesh is 68, 64,602 and area of Himachal Pradesh is 55670 $km^2$. The 67% of geological area is covered by forests [1]. Pine needles are available in large quantity in Himachal Pradesh. In the autumn seasons pine needles fall from the tree and cover large area of forest surface. In the summer seasons forest fire is a big problem in this area thus polluting the environment [2]. This pine needle can be utilized for energy generation and thus problem of pollution & waste

disposal can be minimized. A number of authors have conducted study on the topic of generation of biogas using different type of substrate such as cow dung, agricultural waste etc. A number of studies available on the topic of biogas production using cow dung as substrate [3, 4, and 5]. Similarly few works has done on the topic of biogas production using food waste as substrate [6-8] and few works has been done on the topic of biogas production using pine needles as substrate [1,9]. Similarly few works has been done for the comparative study [10, 11, and 12]. On the basis of literature review it can be stated that few study is available on the biogas production using food waste, agricultural waste, cow dung etc.

Anaerobic digestion involves degradation of organic material in the absence of oxygen and production of methane ($CH_4$), carbon dioxide ($CO_2$) and some amount of other gases. The biogas is a mixture of methane and carbon dioxide and it can be used as renewable energy sources. In this paper pine needles were co-digested with cow dung and cow dung also acts as inherent source of inoculum. Co- digestion was adopted because they gives better digestibility, enhanced the biogas generation and methane yield increase from the extra nutrient [1]. Due to the co-digestion; mixing of different wastes (such as pine needles and cow dung) materials can dilute venomous compounds that may slow down the digestion such as ammonia and other complex organic matter such as fats, carbohydrate, proteins and lignin compounds [1]. The compositions of pine needles are; lignin 21.5%, hemicelluloses 11.80% and cellulose content is 61.73% [13]. Pine needles have high cellulose content and this cellulose content is good for production of biogas. No study is available to compare the biogas production using two different substrates like cow dung and pine needles under batch condition. So in this paper cow dung and agricultural waste (pine needles) are used for generation of biogas production and decrease the disposal problem of waste. This paper focuses on the suitability of pine needles for production of biogas in comparison to cow dung.

## 2. Experimental Setup and Instrumentation

The experimental study was conducted in Department of Civil Engineering at Jaypee University of Information Technology Waknaghat, Solan (H.P) India. One of the main objectives of present study was to compare the biogas production & other parameter for different substrate viz. cow dung and pine needles under batch condition. Two Digesters made of plastic buckets was used in this study. In the first digester only cow dung and the second digester pine needles and cow dung used as substrate. The batch digester used two plastic made bucket one for fermentations and second for gas holders. The capacity of both the fermentation bucket was 45 *l* and the diameter of fermentation bucket was 0.30 m at the bottom and 0.37 m at the top. The diameter of both the gas holder was 0.30 m and capacity of gas holder was 30 *l*. The GI fitting plays vital role in the structure of batch digester. This fitting contains ½ inch tank connection nipple, ½ inch nipple, ½ inch valve and gas cork. The digester with cow dung as substrate is named as DIGESTER1 and digester with pine needles as substrate is named as DIGESTER2. The pictorial view of DIGESTER1 and DIGESTER2 is shown in Fig 1.


DIGESTER1 DIGESTER2

**Fig.1**. Pictorial view of DIGESTER1 & DIGESTER 2

## 3. Material and Methods

3 days old cow dung was collected from the local community. The cow dung was diluted with tap water. The pine needles were collected from nearby area of JUIT campus. The pine needles were dried for 2 hour at $70^0$C in oven and then Pine needles are converted to small particles size using electrical grinder. The pine needles before grinding and after grinding are shown in Fig. 2 and 3 respectively.

**Fig.2.** Pine needles before grinding

**Fig.3.** Pine needles after grinding

In DIGESTER1; 1.5 kg of cow dung was mixed with tap water and inoculum. In DIGESTER1 total quantity of slurry was 3 kg cow dung, 25.5*l* water were used because cow dung also acts as inherent source of inoculum while in DIGESTER 2; 1.5 kg pine needles, 1.5 kg cow dung was thoroughly mixed with 25.5*l* of water. In the DIGESTER2 pine needles were co-digested with cow dung. All the lumps were broken and mixture was thoroughly mixed. Mixture was filled in the fermentation bucket. The gas holder was placed in inverted position over the fermentation bucket with opened gas cork. When gas holder sunk bottom of the fermentation bucket then gas cork was closed. The retention period for both batch digesters was 70 days. The experimental were started from 17 Nov 2015 and it ended on 26 Jan 2016 where no uplift in biogas holder was observed. The different type of parameters like pH, BOD, COD, Total solid (TS) and volatile solid (VS) were measured during the experiment. The measurement of pH was made of every 5 days. While BOD, COD, Total solid and Volatile solid were measured before and after the completion of batch digester. The temperature is measured on the daily basis at 3 times in a day (Morning, afternoon and evening). Thermometer having least count $0.5^0$C was used for measure temperature of slurry inside the digester every day. Gas production was also calculated on daily basis by rise in height of gas holder.

## 4. Results and Discussion

The result of the study is summarized and discussed on the basis of digestion performance. The digestion performance of DIGESTER1 and DIGESTER 2 was investigated on the basis of the experimental observation of pH, temperature, total solid reduction (TS), volatile solid reduction (VS) before and after digestion. The temperature was measured on daily basis with the help of thermometer and biogas production was also measured on daily basis.

### 4.1 BOD and COD Reduction

BOD and COD values for both the substrate before and after the digestion were measured. Figure 4 shows the comparison of BOD in both digesters. In the beginning BOD of both substrate are more but with the time BOD of both substrate were reduced. Figure 5 shows the reduction in COD values in DIGESTER1 and DIGESTER2 after digestion. A total reduction in COD values as 30% and 55% was noticed in DIGESTER 1 and DIGESTER 2 respectively. The COD reduction in DIGESTER1 was less as compare to DIGESTER 2. The COD is used to measured the amount of organic matter in waste and predict the potential for biogas generation. The BOD and COD value decrease with time [12].

### 4.2 Total solid and volatile solid reduction

Figure 6 shows the comparison of total solid in both digesters. In the starting total solid is more in magnitude but after digestion the magnitude of total solid decreases in both digesters. The total solid reduction in both digesters was observed as 37.05% and 65.2% in DIGESTER1 and DIGESTER2 respectively. In the DIGESTER1 total solid reduction is less as compare to DIGESTER2 because in the DIGESTER1 cow dung used as feedstock and cow dung contains lignocellulosic rich material that makes anaerobic process quite unoptimum [3].

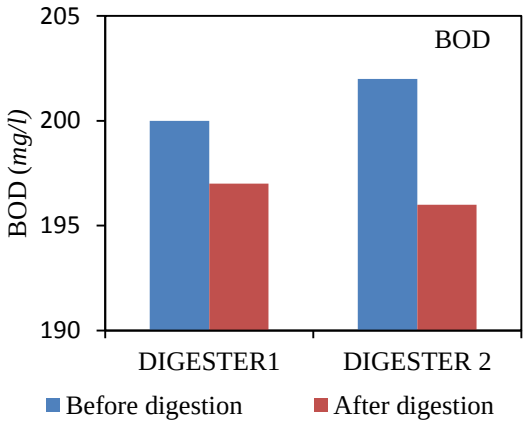


**Fig.4.** BOD reduction

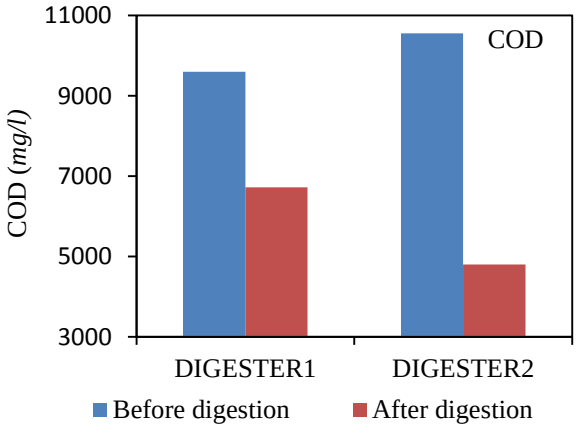


**Fig.5.** COD reduction

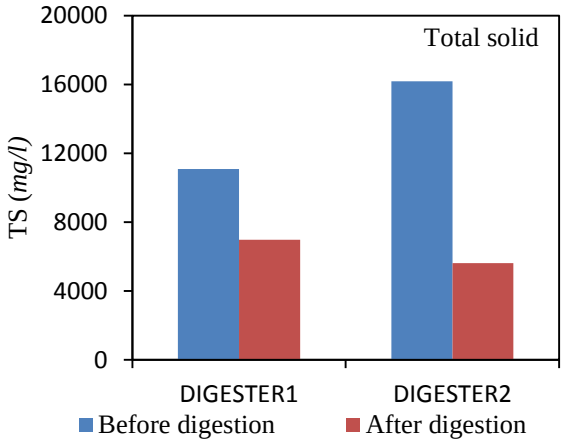


**Fig.6.** Total solid reduction

More percentage of reduction in Volatile solid signifies more generation of biogas [15]. Figure 7 shows the volatile solid reduction in both digesters. The volatile solid reduction in both digesters was noticed as 31.93% and 82.78% in DIGESTER1 and DIGESTER 2 respectively.

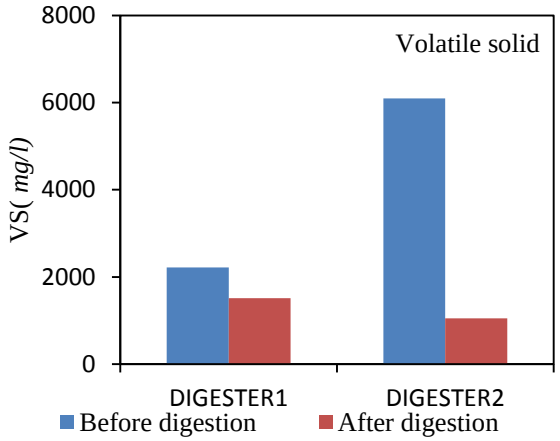


**Fig.7.** Volatile solid reduction

### 4.3 pH

The pH is important due to the fact that Methanogenic organisms are susceptible to acidic condition. The most favorable range of biogas production in anaerobic digestion is 6.5- 7.5. So when the pH is below the 6.5 and above the 7.5 the methane production is less [14]. Figure 8 shows the variation of pH in both the digester with time. In DIGESTER1 value of pH lies in the range of 7.2- 8.1 while in the DIGESTER2 value of pH lies between 6.4-7.3. The pH in this study was unregulated means no acid or basic added to make the pH in favorable condition. In the DIGESTER1 pH lies out of the optimum range of pH required for biogas production and in the DIGESTER 2 pH lies in the optimum range of pH for biogas production. The biogas production in DIGESTER 1 was observed less in comparison to the biogas production in DIGESTER 2 (see: Figure 9)

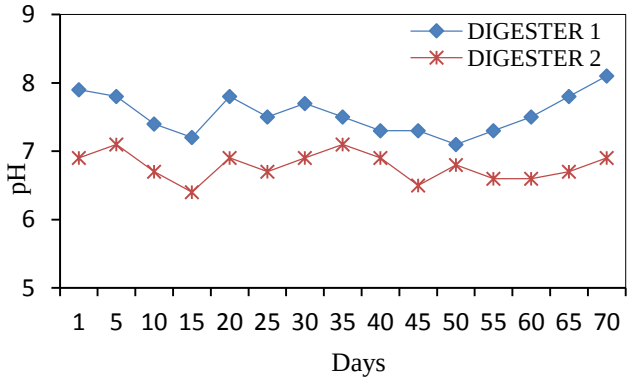


Fig.8. Variation of pH with time

### 4.4 Biogas production

Figure 9 show the comparison of cumulative biogas production (litres) in DIGESTER1 and DIGESTER2. In the DIGESTER1 was used only cow dung and in the DIGESTER2 pine needles were co-digested with cow dung. In biogas production in DIGESTER1 less as compare to DIGESTER2 because in the DIGESTER2 pine needles were co-digested with cow dung so co-digestion raise the biogas generation and also pine needles has high cellulose content [1]. The pine needles compositions are; lignin 21.5%, hemicelluloses 11.80% and cellulose content was 61.73% so cellulose content in pine needles was high so pine needles were used for biogas production. In the starting and ending biogas production is less. In the batch operation it predicts that the biogas production is directly equal to the growth of Methanogenic organism [4]. Figure 9 shows that biogas production in starting is less as bacteria was put into new environment. This is the lag phase of bacterial growth. The cumulative biogas production in DIGESTER1 and DIGESTER2 was 2.4 and 5.3 *l* respectively. The biogas production in DIGESTER2 more as compare to DIGESTER1 because pine needles has high cellulose content, and in DIGESTER2 pine needles were co-digested with cow dung so co-digestion enhanced the biogas generation because co-digestion provide the extra nutrient to increase the biogas production.

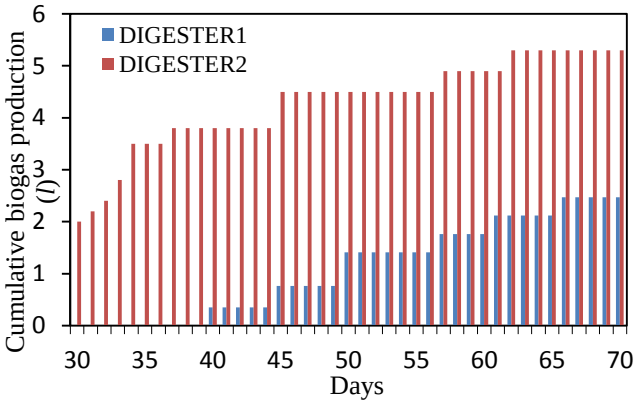


Fig. 9. Cumulative biogas production in both Digesters

### 4.5 Temperature

Temperature plays a major role in the biogas production. Inside the digester slurry temperature is observed more as compare to ambient temperature in both digesters. Inside the digester slurry temperature is more due to the bacterial degradation of the waste [16]. In both the digesters temperature varies from $17^0$C-$25^0$C (mesophilic $20^0$C-$45^0$C and Psychrophilic < $20^0$C). Figure 10 shows the variation of temperature in both digesters.

## 5. Conclusion

The biogas can be used as alternative source of energy such as cooking purpose, lightning, and heating purpose etc. In the present study a comparative experimental study has been carried to check the biogas production potential of two substrates viz. cow dung and pine needles. After studying the various parameters of cow dung and pine needles (agricultural waste) it was observed that biogas production is low when cow dung was used as substrate as

compare to pine needles. The biogas productions in DIGESTER1 (with cow dung as substrate) was 2.4 l while it was 5.3 *l in DIGESTER 2 (with pine needles as substrate).*. It is clear that the biogas production is less in DIGESTER1 as compare to DIGESTER2. Pine needle has more calorific value and cellulose content as compares to cow dung. So pine needles where is considered as a waste can be used for energy generation & it can overcome the waste disposal problem and pollution problem.

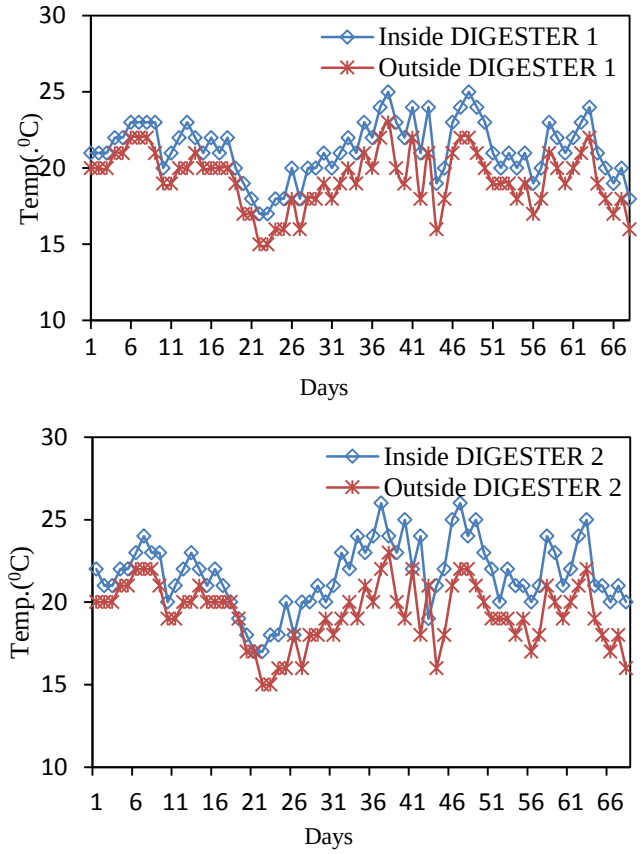


**Fig.10.** Variation of temperature in DIGESTER2 & DIGESTER2

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