# Biogas generation from combination of food waste and water Hyacinth

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**Abstract:** *The feasibility of biodegradation from a combination waste of food waste and water hyacinth using cow dung as a seeding material was conducted, to determine the daily nutrient content, biogas composition in a bench scale anaerobic digester. The various ratios of food waste and water hyacinth considered for study were 80:20, 70:30, 60:40, and 0:100 for which 450 mL, 470 mL, 430 mL, and 380 mL of biogas was generated respectively. In study the Hydraulic retention time is reduced by using partially degraded waste to enhance gas generation. For different ratio 80:20, 70:30, 60:40, and 0:100, the reduction of BOD are 58%, 66%, 57% and63%. COD is reduction is 68%, 80%, 73% and 66%, total solids is reduction is 19%, 28%, 32% and 40%. The nutrients values of the waste increased at the end of the biodegradation period.*

**Key Words: Biogas, Food Waste, Water Hyacinth, hydraulic retention time, nutrients.**

## INTRODUCTION

In recent years, the ever increasing demand for energy and shortages of fossil fuels almost all over the world have created a renewed interest for utilizing renewable sources such as biomass and wastes which are rich in organic matter for methane generation. Disposal of the wet, putrescible organic refuse presents formidable environmental and economic problems. Vegetables, fruits and flowers are produced in large quantities in markets, and these wastes are disposed along with municipal solid wastes in the landfills or dumpsites and creating a place for vector, pest breeding, odour nuisance and Green House Gas (GHG) emission into the atmosphere (Ezekoye et al., (2009).

Food waste are mainly generated in houses, hotels, hostels, restaurants, the waste produce her includes rotten fruits and vegetables, rice , Chapati, oils etc. Food waste are disposed off by dumping, spreading on land or by feeding to animals. One way of solving the problem is to make use of this waste for production of biogas which could suitably utilized in the surrounding areas and the digested slurry as organic manure. Due to high biodegradability and biochemical methane potential, it can be looked upon as a very useful and promising feedstock for biogas generation. The most promising alternative to incinerating and composting the biodegradable wastes is to digest its organic matter using anaerobic digestion.

Water hyacinth (WH) is a perennial macrophyte belongs to the pickerelweed family. It is a free floating weed known for its production abilities and pollutant removal. It is listed as one of the most productive plants on earth and is considered one of the world's worst aquatic plants. These dense mats interfere with navigation, recreation, irrigation, and power generation. Water hyacinth is blamed for reduction of biodiversity and increased evapotranspiration. It also acts as a good breeding place for mosquitoes, snails and snakes. Therefore, there is a need to manage its spread through suitable control measures. However, the fact remains that the water hyacinth has successfully resisted all attempts of its eradication by chemical, biological, mechanical, or hybrid means. Water hyacinth has attracted the attention of scientists to use it as a potential biomass as it is rich in nitrogen, essential nutrients and has a high content of fermentable matter. (Patil et al.,(2011)).

## Materials and Methods

The materials used for this experiment were discarded food waste (FW), water hyacinth (WH) and cow dung. Pretreatment operations involved weighing about different ratios of food waste and water hyacinth and partially degraded to reduce the hydraulic retention time. The waste (FW and WH) was finely grinded together using crusher and then the crushed waste is blended with cow dung. Water was added to it in the ratio of 1:2 and mixed homogeneously and then fed to a batch digester.

The figure 1 shows the bench scale anaerobic digester used for the study. A 5L borosilicate bottle is used as an anaerobic digester. Graduated 1L capacity gas collector was fabricated with borosilicate glass with 2L aspirator bottle. The gas collector was filled with colored water (methyl orange).The gas generated in the digester displaces the colored water from the gas column to the aspirator bottle. A soft rubber tube is used for the flow of gas.

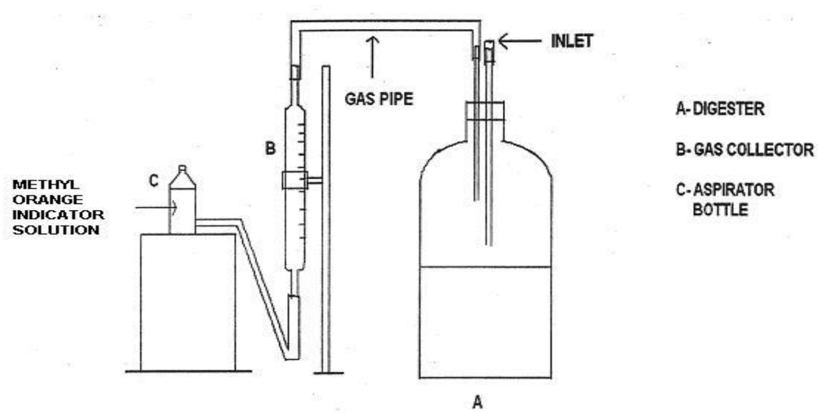


**Figure 1: Bench scale Anaerobic Digester**

**Results and Discussion**

Biodegradation of biomass (Food Waste and Water Hyacinth) in a controlled technological condition produces biogas, which are mainly methane and other gases. The energy obtained during biodegradation of biomass could be described as having modest thermal content, and thus could comfortably serve as cooking gas since energy requirement for domestic heating is low compared to industrial usage. Table 1 to 4 shows the Physico-chemical characterization of combined food waste and water hyacinth of different ratios.

**Anaerobic digestion of different ratio of FW: WH**

- **FW:WH ratio of 80:20**

**Table 1 Results of different parameters of 80:20 ratio of FW: WH**

| Days | pH | COD mg/L | BOD mg/L | Phosphate mg/L | Sulphate mg/L | Nitrate mg/L | TS mg/L |
|---|---|---|---|---|---|---|---|
| 0 | 6.96 | 60800 | 26600 | 513 | 100 | 110 | 2064 |
| 4 | 7.12 | 33600 | 15000 | 1069 | 109 | 117 | 1854 |
| 6 | 7.15 | 19200 | 11000 | 1232 | 118 | 125 | 1678 |

**1. pH**

To maintain a healthy population of methanogens, the pH in an anaerobic digester is typically maintained between 7 and 7.5. The pH is maintained by a balance between the acetogens and methanogens. Acetogens produce acid, and methanogens consume acid (increasing alkalinity) to produce methane gas. Therefore, if the acetogens outpace the methanogens, the pH will drop, which can inhibit methanogens, and ultimately lead to an upset or 'sour' digester. The low pH values indicated that the digester is no longer stable, and conditions are not favorable for growth of methanogens.

From the Table 1 to 4 it was observed that the pH values slightly decreased initially as the water hyacinth content increases and food waste decreases. The maximum pH measured was 7.15. The pH ranged from 6.82 to 7.15. The reason for low pH values at the beginning of digestion is attributed to the fact that initially the acid forming bacterial produces VFA (Ezekoye et al., 2009).Increase in pH after digestion is due to organic nitrogen is reduced to ammonium ions (Momohet al., 2008).

**2. Temperature**

For digester process stability, it is critical to maintain a consistent digester temperature. Abrupt temperature fluctuations can quickly destabilize a digester. The temperature was favorable for the study and it was in mesophilic range from 27 $^0$ C to 30 $^0$ C, which clearly indicates that the biodegradation was due to mesophilic bacterial activity. The low temperature could affect the level of biogas production since temperature profoundly influences the action of methogenic bacteria and rate of hydrolysis. The digester temperatures remained relatively stable except for 0:100 ratio and it was found to be in between 24 $^0$ C to 26 $^0$C throughout the study period of 0:100 ratio which in turn effects on yield of gas. There is an increase in temperature particularly in 70: 30 ratio and it was monitored to be 30 $^0$ C to 33 $^0$ C, which enhances the methanogenic bacteria to yield more gas of 480 mL in 70:30 ratio. The earlier works conducted on anaerobic digestion also have been carried out in mesophillic temperature range from 27$^0$ C to 30$^0$ C.

**3. HRT**

The hydraulic retention time was seven days for the study period and it was reduce by using partially degraded waste and water hyacinth. From the literature the retention time was 40 days using vegetable waste (Dhanalakshmi et al., 2012 ;Velmurugan et al., 2011). The experiments conducted by other literatures are between 40-50 days depending upon the substrate.

From the Figure 1, it can be observed that of BOD and COD values are initially high this may be due to the presence of partially degraded waste and water hyacinth. There a gradual decrease in the values of COD and BODas the retention time increases. The carbonaceous matters present in the digester are utilized by the anaerobic bacteria in turn there is a percentage reduction of BOD and COD. The percentage reduction of COD and BOD was 68% and 58%.

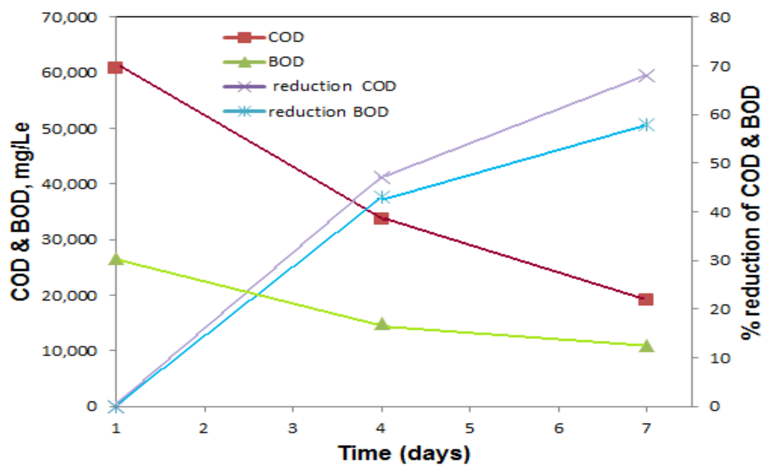


**Figure 1: Variation of COD & BOD with time for 80:20 ratio of FW: WH**

The nutrients are beneficial for the growth of anaerobic bacteria. The rich nutrient helps in better growth of these anaerobic bacteria which in turn increases the yield of gas. The phosphate are increased from 513mg/L to 1232 mg/L , Sulphate to 100 mg/L to118 mg/L and nitrate from 110 mg/L to 125 mg/L. The increment in nutrients like phosphate was about 58%, sulphates content was increased by 15% and nitrate was increased by 12%. The increase in phosphate value found to be 13.43% to 52.89% (Vivekananda and kamaraj 2011)

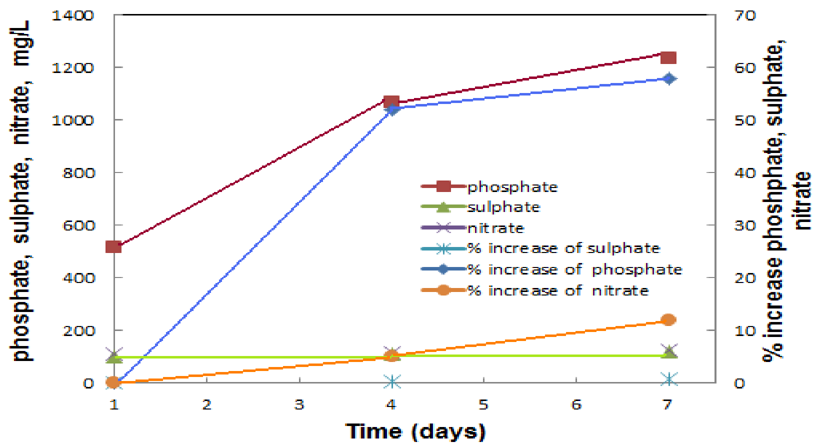


**Figure 2: Variation of phosphate, Sulphate, nitrate with time for 80:20 ratio of FW: WH**

Form the Figure 3 it is observed that TS decreases as the retention time increase. All the organic substances in the digester are utilized by the bacteria which help in the reduction of TS. The initially was 2064 mg/L which was reduced to 1678 mg/L at the end of the study period. The TS reduction observed in 80:20 ratio was 19%. The reduction of TS at end of the digestion depend on the substrate, cellulose, semi-cellulose and lignin (Paepatung et al., 2009).

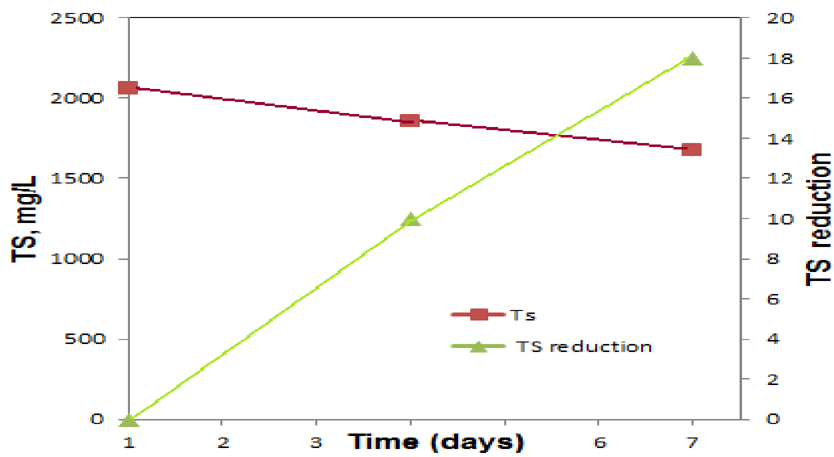


**Figure 3: Variation of TS with time for 80:20 ratio of FW: WH**

- **FW:WH ratio of 70:30**

**Table 2 Results of different parameters of 70:30 ratio of FW: WH**

| Days | pH | COD mg/L | BOD mg/L | Phosphate mg/L | Sulphate mg/L | Nitrate mg/L | TS mg/L | VS mg/L |
|---|---|---|---|---|---|---|---|---|
| 0 | 6.92 | 62720 | 18000 | 1267 | 243 | 127 | 1936 | 1342 |
| 1 | 6.98 | 53760 | 15000 | 1360 | 282 | 129 | 1892 | 1332 |
| 2 | 7.01 | 46400 | 13000 | 1546 | 329 | 135 | 1712 | 1136 |
| 3 | 7.06 | 35200 | 11000 | 1709 | 377 | 141 | 1578 | 1032 |
| 4 | 7.09 | 28200 | 10000 | 1813 | 477 | 148 | 1560 | 100 |
| 5 | 7.07 | 19200 | 8000 | 1883 | 487 | 152 | 1440 | 902 |
| 6 | 7.04 | 12800 | 6000 | 1930 | 534 | 163 | 1376 | 878 |

From the Figure 4, it can be observed that values of COD and BOD are initially high, this is due to the decreases in partially degraded waste and increases in water hyacinth content used in 70:30 ratio. As the retention period increases there a gradual decrease in COD and BOD values. The COD reduction as a direct effect on the yield of gas generation i.e as the cod reduces, the gas production increases. The percentage reduction of COD and BOD was 80% and 66.6% respectively. COD reduction is due to the conversion of biomass to carbon-dioxide and methane.

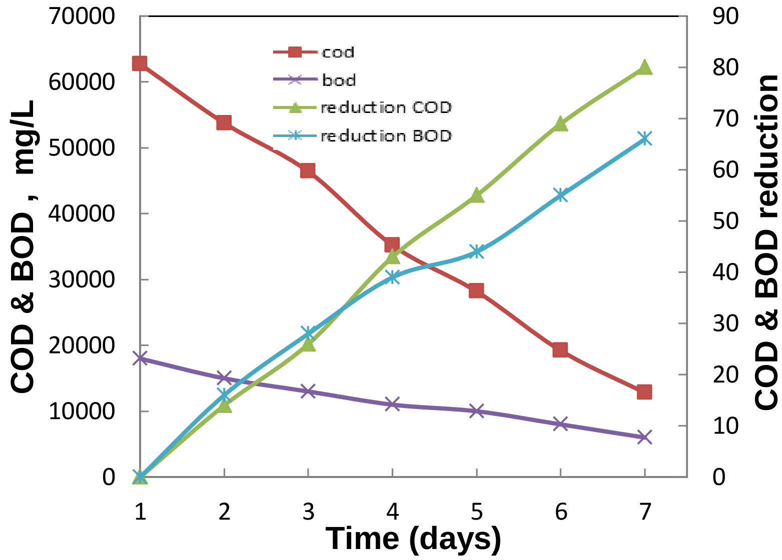


**Figure 4: Variation of COD & BOD with time for 70:30 ratio of FW: WH**

The nutrient content increases as there is increases in water hyacinth and decrease in partially degraded food waste. The phosphate was high compared to Sulphate and nitrates. There is a gradual increase in the nitrate and it is almost in linear form. The sulphate is gradually increased after 4th day of digester loading. This is due to the release of sulphate content by dead bacteria's along with sulphate content is already present in the waste. From the figure 5, the percentage increase of phosphate, Sulphate and nitrate were 34%, 54% and 22% respectively.

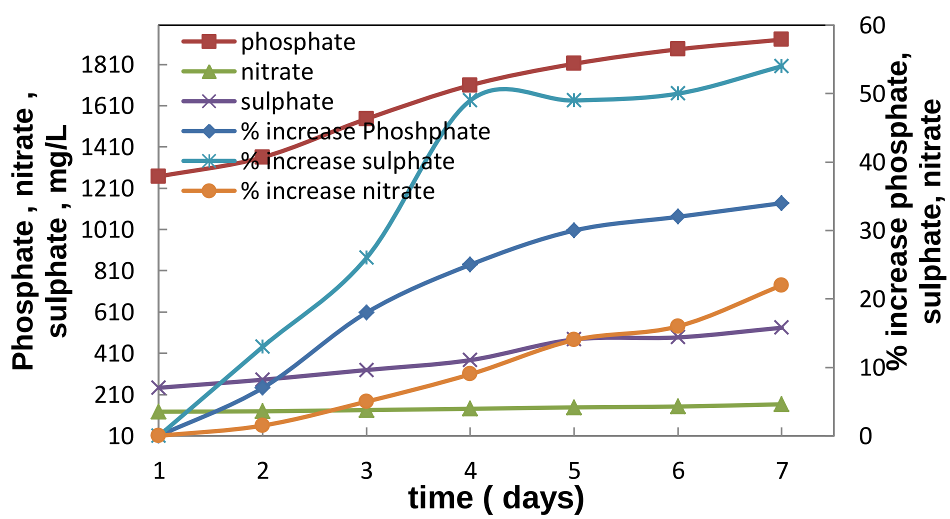


**Figure 5: Variation of Phosphate, Sulphate & Nitrate with time for 70:30 ratio of FW: WH**

From the Figure 6 it is observed that TS decreases along with VS as the retention time increase. The carbonaceous organic matters in the digester are utilized by the bacteria which help in the reduction of TS and VS. The initial TS were 1936 mg/L which was reduced to 1376 mg/L at the end of the study period. The VS was reduced from 1342 mg/L to 878 mg/L. the percentage reduction of TS & VS was 29% & 34%. The VS is an important parameter the optimum VS/TS ratio should be above 0.5 which is favorable for microorganisms to carry out their activity effectively (Metcalf and Eddy, 2003). The VS/TS ratio was 0.62 to 0.69 throughout the study period. Increase of TS in anaerobic process increases the biogas production (Eze et al., 2012).

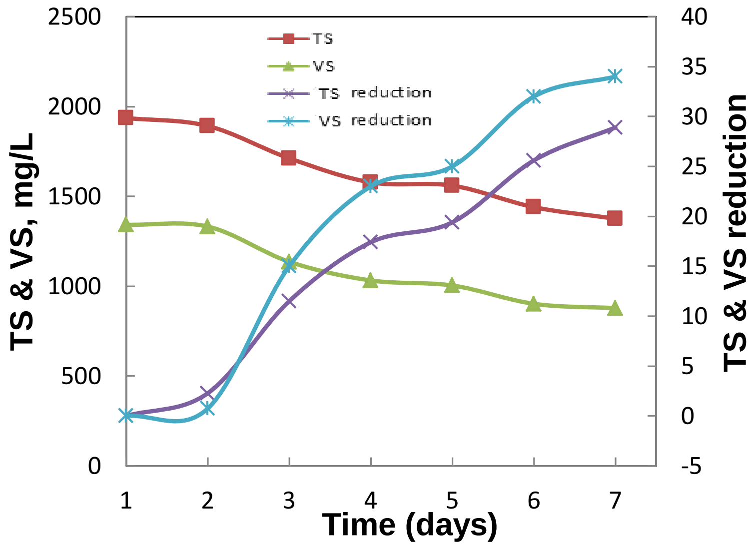


**Figure 6: Variation of TS and VS with time for 70:30 ratio of WH: WH**

- **FW: WH ratio of 60:40**

**Table 3 Results of different parameters for 60:40 ratio of FW: WH**

| Days | pH | COD mg/L | BOD mg/L | Phosphate mg/L | Sulphate mg/L | Nitrate mg/L | TS mg/L | VS mg/L |
|---|---|---|---|---|---|---|---|---|
| 0 | 6.82 | 65200 | 19000 | 1441 | 267 | 116 | 1862 | 1180 |
| 1 | 6.98 | 58200 | 17000 | 1604 | 306 | 124 | 1760 | 1102 |
| 2 | 7.05 | 46400 | 15000 | 1697 | 345 | 132 | 1656 | 1056 |
| 3 | 7.10 | 38400 | 13000 | 1767 | 400 | 142 | 1578 | 1044 |
| 4 | 7.08 | 28600 | 11000 | 1906 | 463 | 150 | 1438 | 942 |
| 5 | 7.09 | 22400 | 9000 | 1941 | 510 | 156 | 1320 | 866 |
| 6 | 7.06 | 17600 | 8000 | 1965 | 581 | 178 | 1260 | 834 |

From the Figure 4.7 shows the plot of COD and BOD with time. It was observed that, there is a sudden fall in the COD value at the 4th day of digester loading and the gas yielded was high for the particular day. This show gradual decrease in COD increases the yield of gas. The percentage reduction of COD was 73% for which the BODwas57%. Less reduction in COD is due to the fiber content of water hyacinth. The COD reduction is 60% (Banu et al.,2007) and COD reduction was 53% - 70% (Satoto et al., 2010) .

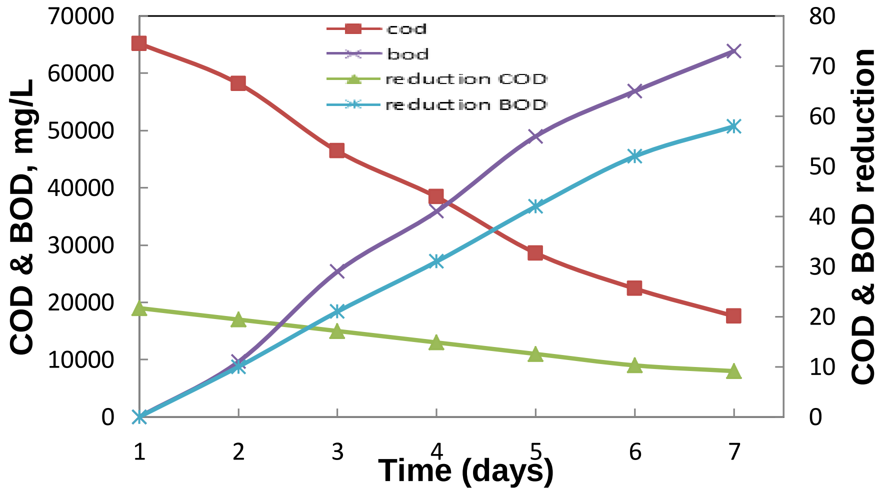


**Figure 7: Variation of COD and BODwith time for 60:40 ratio of FW: WH**

The nutrient content increases as there is increase in water hyacinth. The phosphate is high compared to Sulphate and nitrates. There is a sudden increase in the sulphate in the 5th day of digester loading. Phoshphate are gradually increased but it as reached a high value of 1904 mg/L at the 5th day of digester loading. Again nitrate increased in a linear form and it is increasing gradually. Increase in nutrients is due to the release of nutrient content by dead bacteria's along with nutrient contents that are already present in the waste. It can be observed from figure 8, the percentage increase of phosphate, Sulphate and nitrate were 26%, 54% and 34% respectively.

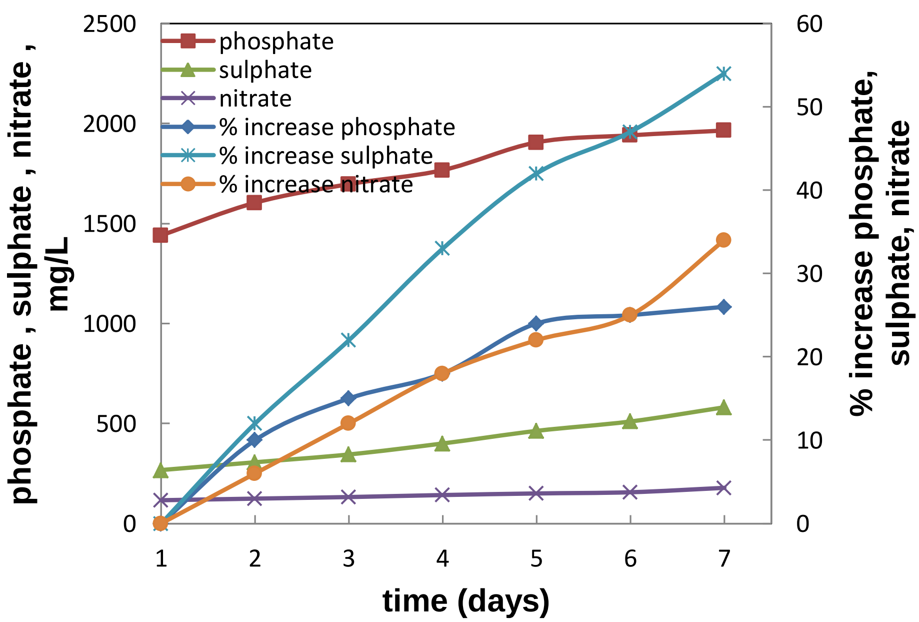


**Figure 8: Variation of Phosphate, Sulphate, and Nitrate with time for 60:40 ratio of FW: WH**

Form the Figure 9 it is observed that TS decreases along with VS as the retention time increase. Compared to previous ratios like 80:20 and 70:30 the TS and VS is comparatively less. This may be due to the less percentage of food waste in the digester. The TS was reduced from 1862 mg/L to 1260 mg/L at the end of the study period. The VS was reduced from 1180 mg/L to 834 mg/L. The total reduction of TS & VS was 32% and 29% respectively. The VS/TS ratio was 0.633 to 0.66 throughout the study period.The results obtained for TS and VS are near by comparable with the results ofOfoefule et al., (2009)

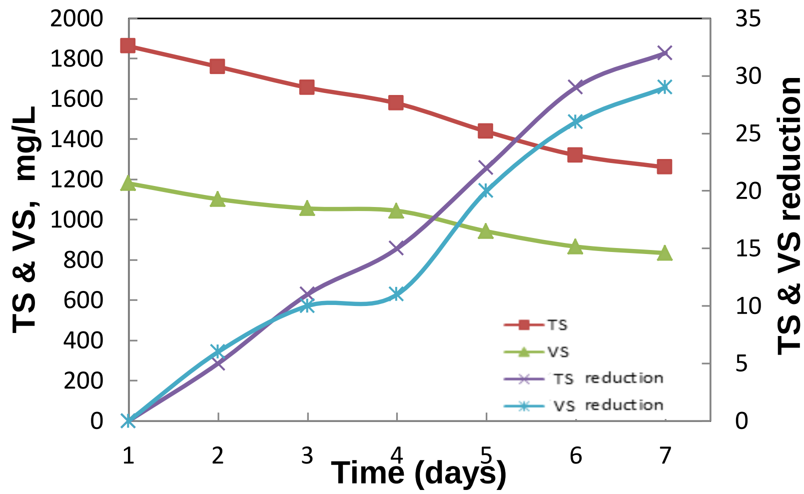


**Figure 9: Variation of TS and VS with time for 60:40 ratio of FW: WH**

- **FW: WH ratio of 0: 100**

**Table 4 Results of different parameters of 0:100 ratio of FW: WH**

| Days | pH | COD mg/L | BOD mg/L | Phosphate mg/L | Sulphate mg/L | Nitrate mg/L | TS mg/L | VS mg/L |
|---|---|---|---|---|---|---|---|---|
| 0 | 6.78 | 67200 | 11000 | 1511 | 322 | 129 | 1620 | 860 |
| 1 | 6.92 | 60800 | 10000 | 1558 | 345 | 134 | 1540 | 820 |
| 2 | 7.01 | 53760 | 8000 | 1627 | 369 | 140 | 1400 | 760 |
| 3 | 7.04 | 44800 | 7000 | 1709 | 424 | 147 | 1280 | 680 |
| 4 | 7.05 | 35840 | 6000 | 1837 | 479 | 160 | 1160 | 620 |
| 5 | 7.07 | 24640 | 5000 | 1895 | 542 | 174 | 1020 | 540 |
| 6 | 7.05 | 22400 | 4000 | 1998 | 589 | 188 | 960 | 480 |

From the Figure 10 shows the plot of COD and BOD with time. It was observed that, the COD value are high compared to other three ratio studied. Even though water hyacinth contributes some BOD there is initially less BOD because as there is no presence of food waste. The percentage reduction of COD & BOD was 66% and 63%. The reduction of COD depends on the nature of water hyacinth and structure of leaf of water hyacinth (Patil et al., 2011 b) The obtained results of COD are comparable with the study conducted by Banu R. et al., (2007) and Satoto et al., (2010).

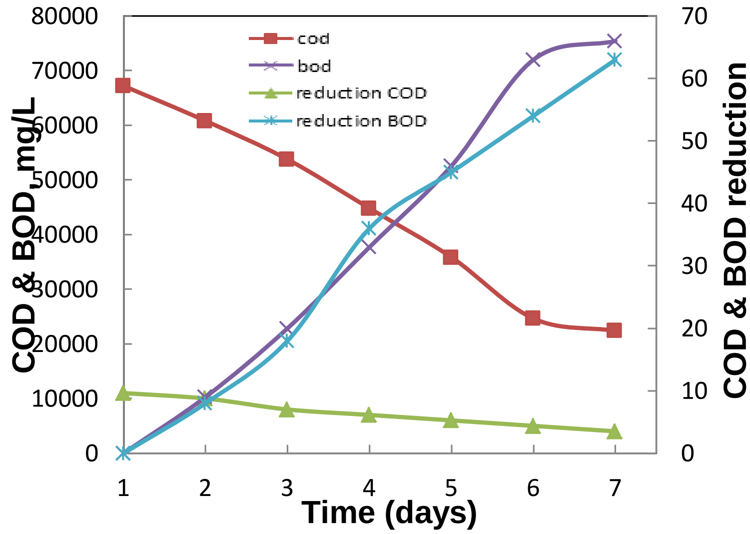


**Figure 10: Variation of COD and BOD with time for 0:100 ratio of FW: WH**

From figure 10 the nutrient content are high initially especially the phosphate, this is due to the characteristics of water hyacinth and the weeds collected in different season for the study . Phoshphate are increased gradually but it as reached a high value of 1837 mg/L at the 5th day of digester loading. Nitrate increases in a linear form. The sulphate is increased at the end of study period. The percentage increase of phosphate, Sulphate and nitrate were 40%, 45% and 31% respectively.

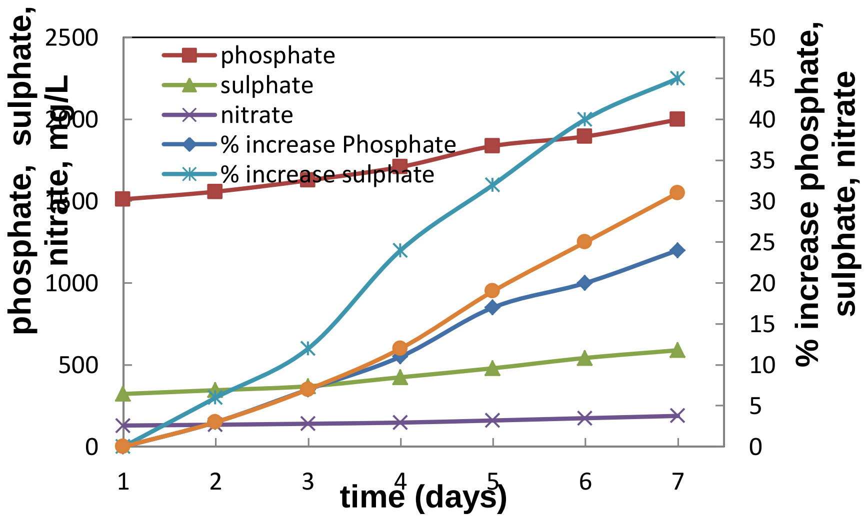


**Figure 11: Variation of Phosphate, Sulphate, and Nitrate v/s time for 0:100 ratio of FW:WH**

From the Figure 12 it is observed that TS decreases rapidly than VS, as the retention time increase. Compared to previous ratios like 80:20, 70:30 and 60:40 ratios the TS and VS is comparatively less. This is only water hyacinth was feed to digester with the absence of food waste. The TS was reduced from 1620 mg/L to 960 mg/L at the end of the study period. The results obtained for TS and VS are near by comparable with the results ofOfoefule et al., (2009), Rajesh et al., (2007) and Ezekoye et al., (2009) The VS was reduced from 860 mg/L to 480 mg/L. The VS/TS ratio was 0.51 to 0.55 throughout the study period.

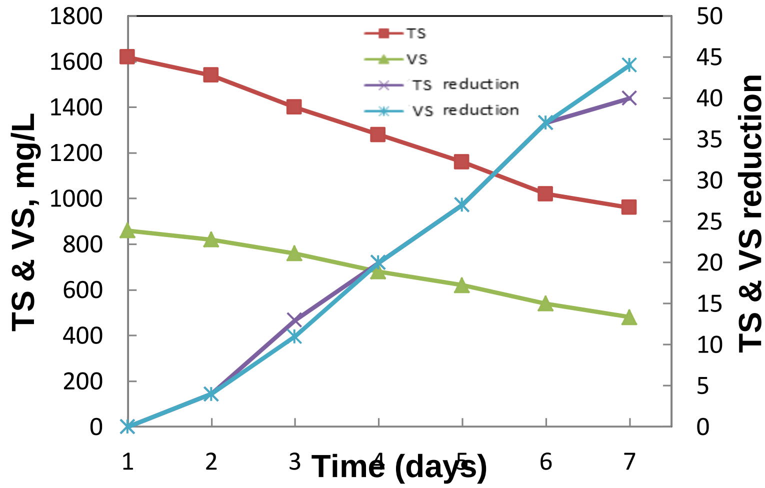


**Figure 12: Variation of TS and VS with time for 0:100 ratio of FW: WH**

- **Biogas generation**

Among the four proportions of waste loaded into digester, the 70:30 (i.e., 700 g and 300 g of Food waste and water hyacinth slurry with 100 g cow dung ) has yielded maximum amount of biogas and it shows that the Food waste and water hyacinth waste has good potential for generation of biogas. The daily variation in gas generation and temperature was recorded for different ratios of waste slurry. The various mix proportions of Food waste and water hyacinth for study were 80:20, 70:30, 60:40, and 0:100 for which the cumulative gas collected is 725 mL, 900 mL, 650 and 540 mL respectively. Thus 900 mL of cumulative gas generated is considered as an optimized gas generation. The least gas generated was 540 mL in 0: 100 ratio of FW: WH, this is because of the density and structure of water hyacinth (Patil J.H et al., 2011). The gas produced is high because high TS and VS are also high (Eze at al., 2012). In all the ratios considered, it took 2 to 3 days for stabilization and the generation of gas was observed from 3rd or 4th day of loading. After the 4th of digester loading there is a gradual decrease in daily yield and the gas production was less towards the end, which shows the decline phase of anaerobic bacteria. After the peak value of gas production there is a fall in daily gas generation, this due to the fact that microorganisms responsible for biogas production have consumed a large amount of the substrate and hence drops in activity (Ilaboya et al., 2010). The method adopted here to measure the amount of biogas does not give the appropriate measurement of biogas generated. This gives only the approximate measurement since the biogas that is inside the digester cannot be measured. The biogas will be collected in the graduated collector only when the digester gets filled completely.

**Table 5: Daily variation of biogas generation for different ratio of FW: WH**

| Days | Cumulative gas collected in ml | | | | |
|---|---|---|---|---|---|
| | FW:WH 80:20 | FW:WH 70:30 | FW:WH 60:40 | FW:WH 0:100 | Gas in l/g of VS for ratio 70:30 of FW:WH |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 450 | 480 | 0 | 0 | 0.54 |
| 3 | 595 | 630 | 430 | 380 | 0.16 |
| 4 | 715 | 760 | 570 | 460 | 0.13 |
| 5 | 715 | 840 | 620 | 510 | 0.06 |
| 6 | 725 | 900 | 650 | 540 | 0.05 |

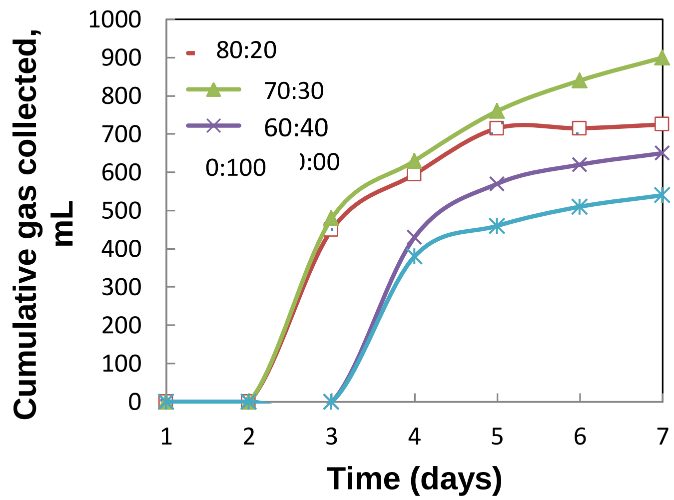


**Figure 13: Daily variation of biogas for different ratio of FW: WH**

**Table 6: The Composition of Biogas**

| Sl no | Ratio | Total gas collected in mL | Methane (mL) | Carbon-dioxide(mL) |
|---|---|---|---|---|
| 1 | 80:20 | 725 | 600 | 125 |
| 2 | 70:30 | 900 | 750 | 150 |
| 3 | 60:40 | 650 | 470 | 180 |
| 4 | 0:100 | 540 | 340 | 200 |

### 4.4 Kinetic Study

It is known that the rate of reaction is proportional to the concentration of reactants (s) raised to small integral power. Most commonly occurring reaction rates in wastewater treatment are Zero order, first order and second order based on power integer of 0, 1 and 2 respectively. The mathematical equations for such reactions are as follows.

$-dC/dt = k$ (Zero order) (4.1)

$-dC/dt = kC$ (First order) (4.2)

$-dC/dt = kC^2$ (Second order) (4.3)

Where, dc/dt = rate of change in concentration, C = concentration of reactant remaining at any time t, k = reaction rate constant.

The plot of time versus concentration of COD, BOD, phosphate, and TS of different ratios are plotted for determining the reaction order are as shown in Figure 14 to 16 . From the data obtained the Figure 15, gives the best fit curve and the reaction rate is first order. The k values and $R^2$ values for different ratio are furnished in Table 7.

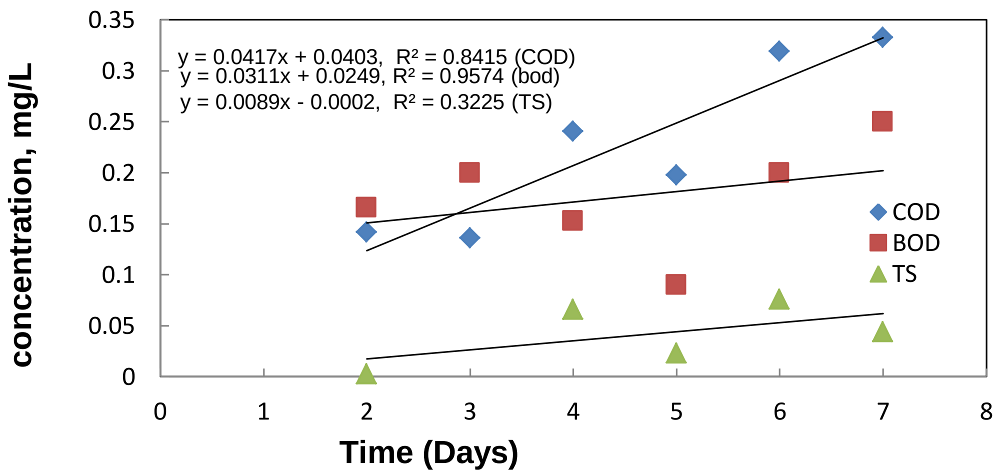


**Figure 14: Zero order kinetics for 70:30 ratio of FW: WH**

The kinetic study results of biomass of 70:30 ratio is as shown in figure 4.17 (a) to 4.17 (c). From the figure it can observe that the rate of degradation of COD was higher and it was found to be 0.3178 mg/L. The degradation rates of BOD, and Total Solids (TS) were 0.531 mg/L, and 0.057 mg/mL respectively. The microbial activity was found to efficiently to degrade all biomass at pH values near neutral. There was no much significant variation in pH was observed. The pH was in the range of 6.92 – 7.07. The COD values were found to be reducing with respect to time of degradation of biomass. The COD values reduced from 62,720 mg/L to 12,800 at end of the biodegradation. The BOD, TS values were reduced from 18,000 mg/L to 9,000, and 1936 mg/L to 1376 mg/L at end of the biodegradation.

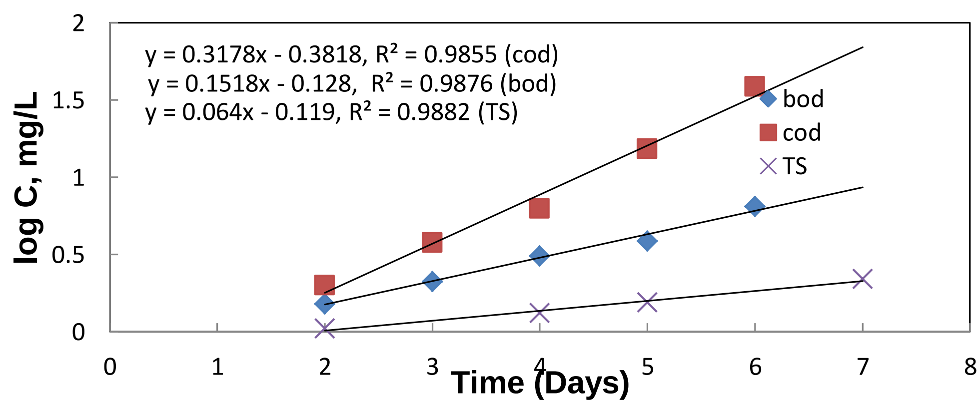


**Figure 15: First order kinetics for 70:30 ratio of FW: WH**

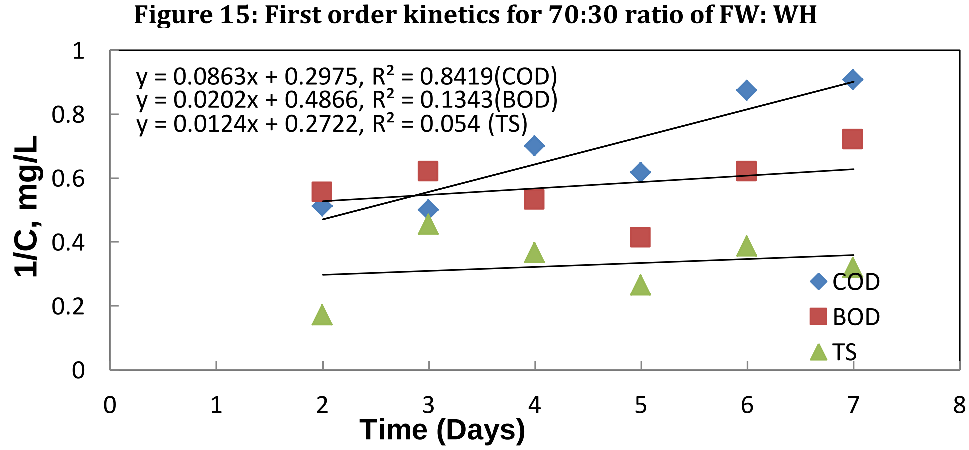


**Figure 16: Second order kinetics for 70:30 ratio of FW: WH**

**Table 7 Reaction rate constant (k) and $R^2$ values for 70:30 ratio of plots of time versus concentration**

| Ratio | Parameter | Zero Order Reaction | | First Order Reaction | | Second Order Reaction | |
|---|---|---|---|---|---|---|---|
| | | k | $R^2$ | K | $R^2$ | K | $R^2$ |
| 70:30 | COD | 0.0417 | 0.845 | 0.317 | 0.9854 | 0.0863 | 0.8419 |
| | BOD | 0.0311 | 0.9574 | 0.151 | 0.9876 | 0.0202 | 0.1343 |
| | TS | 0.008 | 0.8419 | 0.064 | 0.9862 | 0.0124 | 0.054 |

## CONCLUSION

It can be concluded from the study that the combination of food waste and water hyacinth employed for the biogas generation could be a beneficial source to replace fossil fuel. Such waste utilization reduces the cost on environmental management system in solving the problems like eutrophication in lakes and files breeds on the food dumping yard, leachate problem by landfilling. For 70:30 mix proportion, 480ml of gas was generated on the 3rd day from the day of loading and total amount of gas generated was 920 mL at the end of the study period. The gas (methane) production is very less in 0:100 ratio due to the fiber content in water hyacinth and temperature fluctuation in the study period. The nutrients like phosphate, Sulphate, and nitrate are high initially and are been reduced at the end of each study period. The anaerobically digested waste is rich in nutrient content and can serve as very good manure for crops. Hence it will help in the organic farming process. However, the batch experimental studies using food waste and water hyacinth in different ratios using cow dung as seeding material can be a suitable source for biogas production. It is an economical method as its reuse of food waste which is discarded and use of water hyacinth can solve eutrophication of lakes, biogas saves the amount that has to be spent on LPG.

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