*Journal homepage: http://www.journalijar.com*

*INTERNATIONAL JOURNAL OF ADVANCED RESEARCH*

ISSN NO. 2320-5407

**RESEARCH ARTICLE**

# Efficiency of biogas production from cactus fruit peel co-digestion with cow dung

**Teame Gebrekidan, Meseret C. Egigu and Manikandan Muthuswamy ***
Department of Biology, Haramaya University, Haramaya, Dire Dawa, Ethiopia

## *Manuscript Info*

***Manuscript History:***

Received: 12 May 2014
Final Accepted: 23 June 2014
Published Online: July 2014

***Key words:***
Biogas, co-digestion, Cow dung, *Opuntia ficus-indica*, Total solid, Volatile solid

****Corresponding Author***

**Teame Gebrekidan**

## *Abstract*

Production of biogas through anaerobic digestion of organic waste materials provides an alternative renewable energy source and also eco-friendly method. In the present investigation, biogas production from co-digestion of *Opuntia ficus-indica* fruit peel with cow dung in five mix proportion of substrate was evaluated under mesophilic conditions (38ºC) using batch digester. In different proportion of the substrates, total solid and volatile solid, organic carbon, moisture content and pH were measured before and after digestion. The daily biogas production was subsequently measured by water displacement method for 31 days. The physico-chemical parameters of each substrate were significantly varied between before and after anaerobic digestion, and also it was varied between different proportions of the substrates. Assessment of cumulative biogas production revealed that substrate in a mix ratio of 75% cow dung and 25% fruit peel yielded the highest gas production, suggesting this mix ratio of the two substrates is an optimal mix to yield better biogas production. Overall, results indicate that the biogas yield and volatile solid and total solid reduction can be significantly enhanced when cow dung and cactus fruit peel are co-digested.

*Copy Right, IJAR, 2014,. All rights reserved.*

## Introduction

The renewable energy sources can contribute to solve the present and future energy problems. Among the alternative energy sources, biogas production from green energy crops and organic wastes has world wide application as it yields a good quality fuel and fermented slurry, which may be used as a manure or soil conditioner. In addition, it helps to a great extent in the abatement of pollution. Biogas has a very positive impact on the environment since less $CO_2$ is formed during its combustion than it is used for photosynthesis by the plants (Navickas, 2007). Therefore, biogas is an alternative and renewable energy source produced through anaerobic digestion of organic matter whereby the organic matter is converted into a combustible biogas rich in methane and a liquid effluent. In general, biogas consists of 55 to 80% methane and 20 to 45% carbon dioxide. However, depending on the source of organic matter and management of the anaerobic digestion process, small amounts of other gases such as ammonia ($NH_3$), hydrogen sulfide ($H_2S$), and water vapor may be present (Arogo *et al*., 2009). The rate of biogas production depends on a number of factors. The nature of substrate, temperature, pH, loading rate, toxicity, stirring, nutrient contents, inoculums content, nature of the digester, retention time, initial feeding, chemical oxygen demand etc are some of the important factors affecting biogas production (Sagagi *et al*.,2009).

*Opuntia ficus-indica* grows abundantly in northern part of Ethiopia. It is considered to be important energy crop for biogas production because of its high organic matter yield per hectare and high availability to supplement cow dung for biogas production. In addition, this plant can easily be propagated and tolerate drought and poor soil fertility. Given the large production of this species in northern parts of Ethiopia, this study investigated biogas production from *Opuntia ficus-indica* through anaerobic biodegradation alone or in combination with fresh cow dung.

## Materials and Methods

### Substrates and Inoculums

The cactus fruit peel (CP) and cow dung (CD) were obtained from *Opuntia ficus-indica* producing community in Adi-grat *woreda*, Eastern Tigray, Ethiopia and Haramaya University animal farm, respectively. The two substrates were made into five treatments (T1-T5) in sole or combinations. The five treatments were T1, 100% CD; T2, 75%: 25% mix of CD:CP; T3, 50%:50% mix of CD:CP; T4, 25%:75% mix of CD:CP and T5, 100% CP. (Table 1). To facilitate anaerobic digestion, rumen fluid was used as inoculums (Sunarso *et al.*, 2012). Fresh rumen fluid was collected from the nearby slaughter house and filtered through a cloth of 0.5 mm sieve diameter to separate solid content from slurry. Prior to use, the inoculums was starved for a week by incubating at 38ºC to remove the easily degradable volatile solid (VS) present in inoculums (LoNiee-Liew, 2011). Then, 100 mL of inoculums (rumen fluid) were added and the total solid was adjusted to the recommended level (8%) using appropriate amount of distilled water (Tchobanoglous *et al*., 1993).

### Determination of Physico-chemical Properties of the Substrates

Substrates were analysed for total solids (TS), volatile solids (VS), moisture content and pH before and after AD process based on the Standard Methods for the Examination of Water and Wastewater (APHA, 1999). Also the carbon content of the substrates was obtained from volatile solids data using an empirical equation reported by Badger *et al.* (1979).

### Digester arrangement and measurement of biogas

Anaerobic digestion was done in plastic bottles (0.5 mL) arranged randomly in three replications for bench-scale experiments. For this, three plastic bottles containing the slurry, acidified brine solution and empty bottle to collect brine solution were arranged in order (1st to 3$^{rd}$) on the table. The three containers were interconnected with a plastic tube having a diameter of 1 cm. The tube connecting the first bottle to the second was fitted just above the slurry in the first bottle to help gas collection. Thus, the biogas produced by fermentation of the slurry was driven from the first bottle to the second bottle that contained a brine solution so as to displace a volume of the brine solution equivalent to the volume of biogas produced (Itodo *et al.*,1992). The lids of all digester were sealed tightly using super glue in order to control the entry of oxygen and loss of biogas. The temperature of all digesters was maintained at 38 °C by keeping in oven (EED115), which represents mesophilic condition. The digesters were randomly arranged on a table in the lab in three replications.

### Data Analysis

Data were first checked for their normality. Data that were not normally distributed were log-transformed and thereafter subjected to analysis of variance (one-way ANOVA) using SAS version 9.1. Fishers Least Significant Difference (LSD) was used to investigate statistical significance between the different treatments, whereas paired samples T-test was used to investigate statistical significance within a treatment. Difference between means was considered statistically significant at $P<0.05$.

## Results and Discussion

**Table 1: Proportion of different substrate, cow dung (CD) and cactus fruit peel (CP) used in the anaerobic co-digestion in three replication**

| Treatment | Mix ratio | | TS of CD (g) | TS of CP (g) | Amount of fresh substrate | | Amount of water added(ml) | Amount of inoculums (ml) | Total volume(ml) |
|---|---|---|---|---|---|---|---|---|---|
| | %CD | %CP | | | CD(g) | CP(g) | | | |
| **T1** | 100 | 0 | 30 | 0 | 137 | 0 | 138 | 100 | 350 |
| **T2** | 75 | 25 | 22.5 | 7.5 | 100.5 | 33.5 | 141 | 100 | 350 |
| **T3** | 50 | 50 | 15 | 15 | 67.5 | 67.5 | 140 | 100 | 350 |
| **T4** | 25 | 75 | 7.5 | 22.5 | 33.25 | 99.75 | 142 | 100 | 350 |
| **T5** | 0 | 100 | 0 | 30 | 0 | 130 | 145 | 100 | 350 |

**Physico-chemical characteristics of the substrates before and after AD**

The physico-chemical characteristics of CD and CP in sole and mixed in different proportions were determined before and after AD and the results are shown in Table 2. The pH of 100% CD slurry before anaerobic digestion was about 7.29±0.00, whereas that of 100% CP was 6.19±0.10. The pH value of 100% CD was optimum for biogas production, whereas that of 100% CP was less optimal (Yadvika *et al.*, 2004). This might be due to the presence of relatively high ammonia content in cow dung. Mixing the substrates resulted in the rise of pH compared to that of CP alone, but decreased pH from that of CD alone. The pH after AD was found to increase with increasing of CD proportion in the mix, suggesting that CD helps to maintain the pH to meet the optimum required. Mixing substrates is a good way of adjusting the pH value to the optimum (Hills and Roberts, 1981).

**Table 2: Comparison of pH and % moisture content between before and after anaerobic digestion of the various substrates (values are mean ± SE)**

| Treatment | Parameters | | | |
|---|---|---|---|---|
| | Initial $p^H$ | Final $p^H$ | Initial MC% | Final MC% |
| 100%CD | $7.29±0.09^{Aa}$ | $7.78±0.08^{Cb}$ | $77.7±0.23^{Ba}$ | $82.4±0.20^{Ab}$ |
| 75%CD+25%CP | $6.92 ±0.03^{Ba}$ | $8.08 ±0.15^{Cb}$ | $78.1±0.14^{Aa}$ | $81.5±0.14^{Bb}$ |
| 50%CD+50%CP | $6.77 ±0.05^{Ba}$ | $8.47 ±0.12^{Bb}$ | $77.5±0.08^{Ba}$ | $80.4±0.05^{Cb}$ |
| 25%CD+75%CP | $6.30 ±0.11^{Ca}$ | $8.74±0.11^{Ab}$ | $77.3±0.14^{Ca}$ | $80.5±0.17^{Cb}$ |
| 100%CP | $6.19±0.10^{Ca}$ | $8.84±0.01^{Ab}$ | $77.0±0.12^{Ca}$ | $78.5±0.11^{Db}$ |

Means followed by different small letters in row are significant at 0.05 probability levels for paired samples T-test within treatment. Means followed by different capital letter in column are significantly different at 5% level of significance between treatments. CD= Cow dung, CP= cactus peel

Significant differences were seen in pH values between before and after AD (Paired samples T-test, $P<0.05$). Increase in pH value of the substrates after AD may be attributed to production of alkali compounds, such as ammonium ions during the degradation of organic compounds in the digester (Gerardi, 2003). The high pH value recorded after AD for 75%CD+25%CP, 50 % CD+50 % CP, 25 % CD+75 % CP and 100 % CP in this study may be attributed to increased production of ammonia resulting from less organic carbon of cactus peel than cow dung. The pH value increases by ammonia accumulation during degradation of protein while accumulation of volatile fatty acid (VFA) resulting from degradation of organic matter decreases the pH value (Gray *et al.*, 1971).

**Table 3: Comparison of % organic carbon between before and after anaerobic digestion of the various substrates (values are mean ± SE)**

| Treatment | Parameters | |
|---|---|---|
| | %Initial C | %final C |
| 100%CD | $8.58 ±0.06^{Da}$ | $7.9 ±0.05^{Bb}$ |
| 75%CD+25%CP | $10.70 ±0.05^{Ba}$ | $7.90 ± 0.05^{Bb}$ |
| 50%CD+50%CP | $10.10 ±0.05^{Ca}$ | $7.46 ±0.08^{Cb}$ |
| 25%CD+75%CP | $11.73 ±0.17^{Aa}$ | $9.63 ±0.06^{Ab}$ |
| 100%CP | $8.50 ± 0.05^{Da}$ | $6.75±0.02^{Db}$ |

Means followed by different small letters in row are significant at 0.05 probability levels for paired samples T-test within treatment. Means followed by different capital letter in column are significantly different at 5% level of significance between treatments. CD= Cow dung, CP= cactus peel

The mean moisture content of 100% CD, 75% CD+25% CP, 50% CD+50% CP, 25% CD+75% CP and 100% CP were 77.7± 0.23%, 78.1± 0.14%, 77.5± 0.08%, 77.3± 0.14%, and 77± 0.12%, respectively. This result shows that the moisture content of CD was higher than CP ($P<0.05$), but after AD the mean moisture content of 100%CD and 100%CP were 82.4± 0.20 and 78.5± 0.11%, respectively. According to Buysman (2010), CD tends to have more water content than CP, thus increasing the degree of digestion as bacteria can easily access liquid substrate for relevant reactions to take place easily. There was significant difference in moisture content values between before and after AD (Paired samples T-test, $P<0.05$). Since studies on the most favorable percentage of total solids for biogas productions suggest 8% as the optimum TS, the initial moisture content of substrates used for this study was not optimal for wet anaerobic digestion process (Tchobanoglous *et al.*, 1993). Therefore, dilution is required to bring the total solids percentage to 8%.

The percent degradation of organic carbon for 75% CD+25% CP was higher than all (from 10.70±0.05 to 7.90±0.05, i.e., 28% reduction) (Table 3). The results also revealed that there are differences in percentage organic carbon in all mix ratios between before and after AD (paired samples-T-test, $P<0.05$). Comparison of initial and final % organic carbon showed that % organic carbon significantly decreased AD in all substrate types. Organic carbon can be removed in anaerobic digesters either by being converted to cellular materials for growth and reproduction of bacteria or biogas production (Gerardi, 2003). Therefore, the decrease in organic carbon reflects the degradation process during anaerobic digestion (Devlin *et al.*, 2011). The percent degradation of organic carbon for 75% CD+25% CP was higher than all (from 10.70±0.05 to 7.90±0.05, i.e., 28% reduction) (Table 3).

The total solids and volatile solids were determined for all substrates both before and after AD (Figures 1 and 2).When determining TS and VS, it is important to understand that high content of volatile fatty acids (VFAs) in the substrates can produce misleading results since they may volatilize from the substrate when they are first heated and thus give total solids and volatile solids values that are too low. This in turn can produce incorrect estimates of biogas production, which depend on volatile solids (Anna, 2010). The maximum initial TS (before AD) were measured in cactus peel, whereas the minimum TS were measured from cow dung alone (Figure 1). This may show that peel of *Opuntia ficus-indica* contain more biodegradable substrates for biogas production. The total solid content of all mix before AD was between 21.8±0.00% (i.e., 2.18 gram of TS from 10 gram sample) and 22.9±0.01%.

After AD, TS and VS of all substrate types were significantly decreased, but more decrease was observed in mixed substrates than in sole substrates (Figures 1 and 2). This might be because balanced acidogenesis and methanogenesis in mixed substrates than sole substrates. Removal of VS after AD suggests its conversion to biogas. Similar results were reported by Joung *et al.* (2008). The TS content of 22.9% of CP used for this experiment is in the range of 21 to 23% TS reported by (Sadaka *et al.*, 2003). The TS obtained (19.6%) in this experiment for cow dung is in the range of 19 to 22% reported, whereas for cactus peel, 89.3 % (Figure 2). This is in accordance with Fulford (1988) who reported that the composition of animals and human wastes typically consist of 15-48 percent of TS and VS is 77-90 percent of TS.

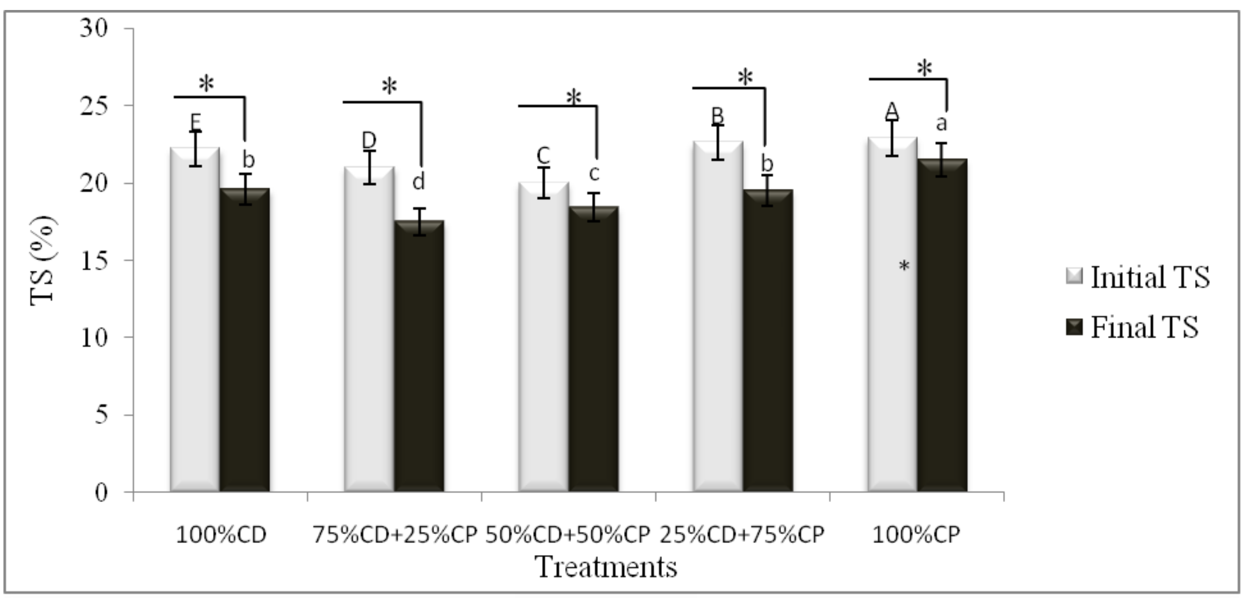


**Figure 1: Values of TS for substrates before and after digestion. Capital letters represent differences between %TS of the various substrates before digestion while small letters represent that of after digestion. Bar graphs with the same capital or small letters are not significantly different, whereas those with different capital or small letters are significantly different. Asterisk (*) shows there was significant difference in %TS between before and after digestion. CD=cow dung, CP=cactus peel, TS=Total solids**

The TS and VS values before digestion was found to vary significantly (*P*<0.05, Figure 1 and 2) with increasing of CP proportion in the mix, suggesting that mixing helps to adjust the TS and VS. Although CP alone has the highest volatile solid for biodegradation than all mix (Figure 2), the mixture with 75% CD and 25% CP resulted in a high reduction of VS and TS amount. The TS and VS values between before and after AD was significant differences (Paired samples T-test, *P*<0.05).

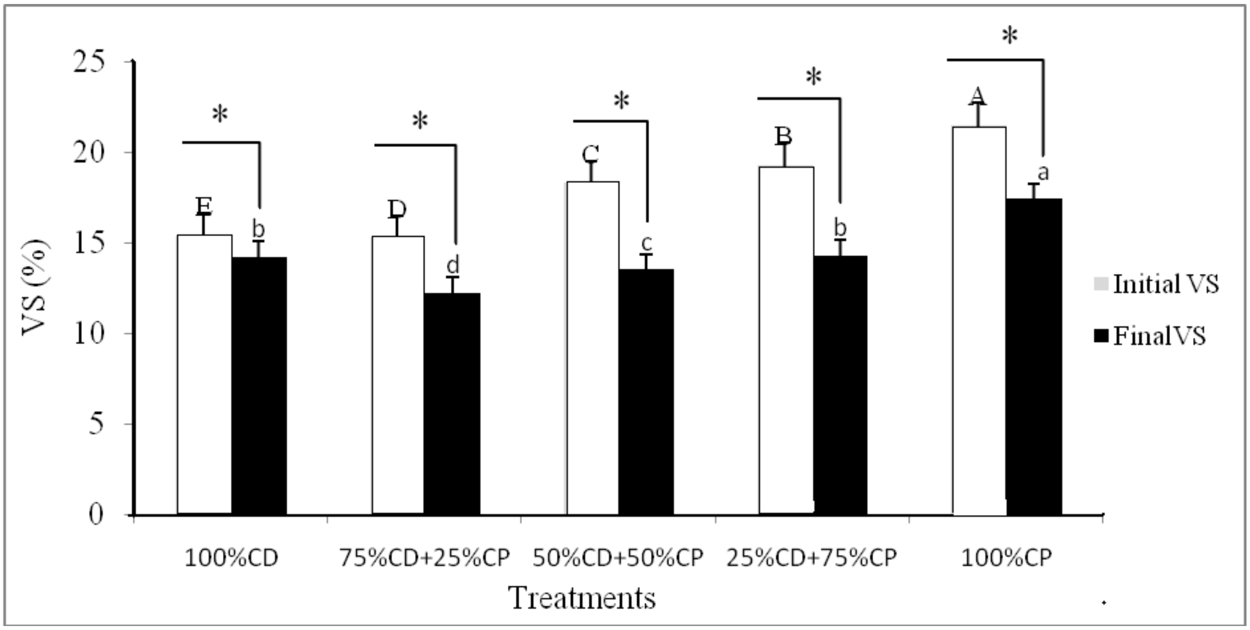


**Figure 2: Values of VS for substrates before and after digestion Capital letters represent differences between %VS of the various substrates before digestion while small letters represent that of after digestion. Bar graphs with the same capital or small letters are not significantly different, whereas those with different capital or small letters are significantly different. Asterisk (*) shows there was significant difference in %VS between before and after digestion. CD=cow dung, CP=cactus peel, VS=Total solids**

As shown in the Figure1 and 2, addition of 25% CP to cow dung alone resulted in an increase of the amount of volatile solids and total solid reduction, from 20%VS, (i.e. from 1.53±0.00 to 1.22±0.01) and 19.7%TS, (i.e. from 2.18±0.00 to 1.75±0.01) compared to the values measured before digestion, TS and VS significantly (*P*<0.05) decreased after digestion for all mix. Thus total solids and volatile solids destruction is a good parameter for evaluating the efficiency of anaerobic digestion (Abubaker and Ismail, 2012), and it is a good indicator of biogas production (Anonymous, 1981).

Co- digestion of several combined wastes can utilize the nutrients and bacterial diversities that could provide buffering capacity (Macias-Corral *et al*., 2008). This demonstrated that the addition of a small amount of CP as co-substrate improved C/N ratio, thereby decreasing the risk of ammonia inhibition to the digestion process in the anaerobic digestion of CD can highly increase VS and TS reduction compared with CD alone. It can be seen that the VS and TS reductions for CD alone were 7.7% and 11.7%, respectively. Most of the volatile solids contained in 100% CD remained unaffected after the anaerobic treatment indicating the low bioavailability of organic material in the samples (Hobson, 1981).

**Average daily and cumulative biogas production**

Gas production was noticed from day one of the experiment in all substrate types. However, the amount of biogas measured varied with substrate type; highest for substrate mix of 75%CD+25%CP and lowest for 100%CD (Figure 4). The fact that gas production occurred on the first day of the experiment suggests the existence of microbes in the added rumen fluid inoculums to act on readily degradable materials of the substrates (Kamthunzi, 2008). In the course of measurement, all substrate types appeared to yield more biogas than CD alone. This may be due to more availability of biodegradable material in CP than CD to serve as a source of energy for microbes (Hobson, 1981). Thus, biogas production is a function of the feedstock's organic content and its biodegradability (Macias-Corral *et al*., 2008).

Biogas production showed fluctuating decline after the first day of measurement and eventually reached 0ml on about 30th day of the experiment (Figure 3). This might be due to the depletion of readily decomposable substrate after the first day (Ahn *et al*., 2009) and/or an increase in ammonium concentration that resulted in an increased pH values. It is also possible that accumulation of toxic wastes due to increasing microbial population in the digester might have inhibited gas production.

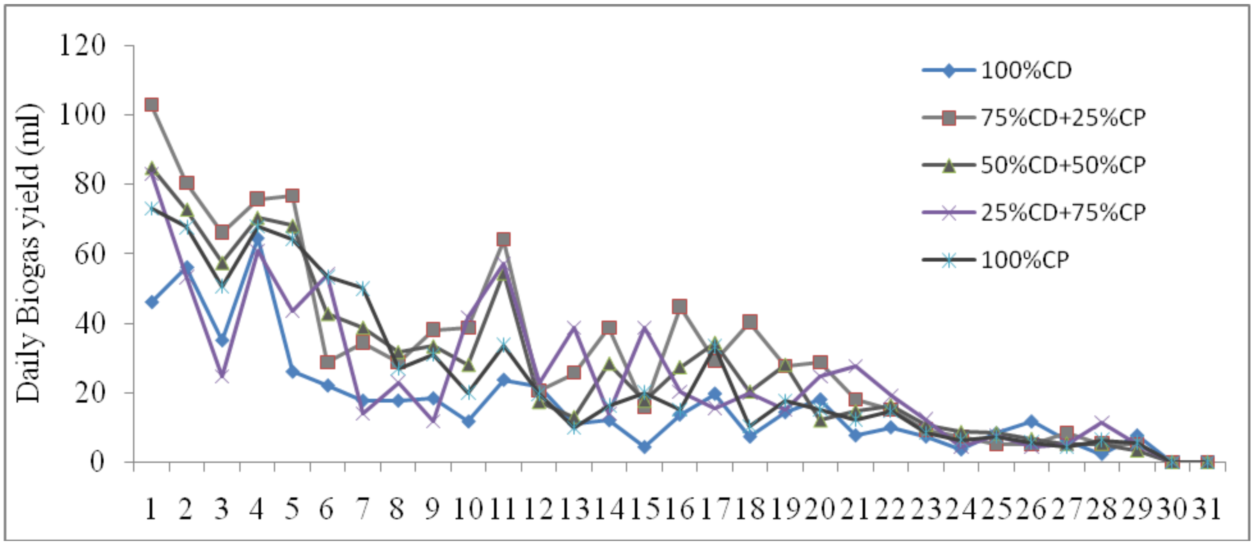


**Figure 3. Daily mean Biogas yield of the different substrate proportion**

There was a significant difference between the substrates in an overall biogas yield ($p<0.05$). Compared to CD alone all substrate types resulted in significantly higher cumulative biogas yield with the highest cumulative biogas production observed in 75%CD+25%CP mix substrate. Cow dung alone resulted less biogas probably due to its partial fermentation that usually takes place in the intestinal tract of the animal (Deublein and Steinhauser, 2008). Though its %VS was higher, the 100%CP did not produce more biogas than the three CD to CP substrate mixtures. This might be due to the less favorable situation of 100%CP to microorganisms as compared to the substrate mixtures. As the proportion of CP in the mix ratio increased from 25% to 75%, the cumulative biogas yield decreased, suggesting less favorable situation with increasing CP proportion from that of 25%. This observation is in accordance with the results of an experiment done by Callaghan *et al.* (1999) using cactus peel and cow dung, where higher cumulative production was produced in the system with the lower concentration of cactus peel. This may be due to the high concentration of total nitrogen (ammonia) resulting from anaerobic breakdown of proteins to inhibit anaerobic digestion (Angelidaki and Ahring, 1993).

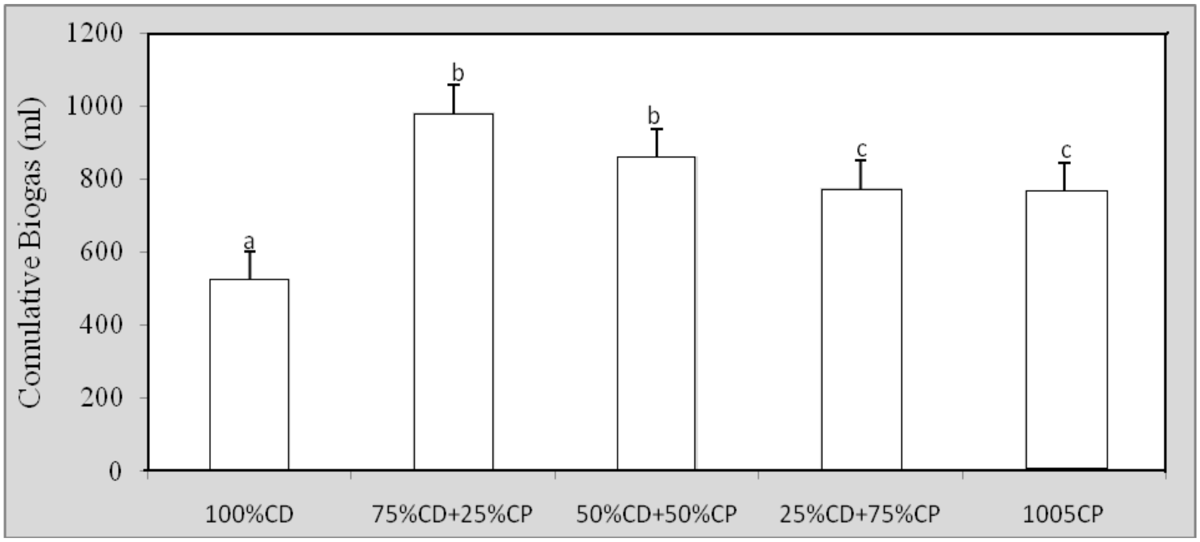


**Figure 4.Cumulative biogas yield of the different substrate combinations (Values are mean ± SE).Bars with different letters indicate significant differences between means while those with same letters show no significant difference between means.CD=Cow dung, CP=cactus peel.**

In general, studies on possible uses of cactus peel have indicated its potential use in biogas Production, followed by fertilizer application as reported (Tarrisse, 2008). Similarly, in this experiment it would appear that cactus fruit peel have potential for biogas production. In addition to this, Volatile solid from TS content of the Cactus peel substrate was 89.3%. This shows that a large fraction of the Cactus fruit peel is biodegradable. This implies that Cactus peel can serve as an important feedstock for biogas production and if suitable materials for co-digestion, such as manure, are not available, Cactus peel can be digested alone.

## Conclusions

It is concluded that, the production of biogas form 100% CD, 75% CD : 25% CP, 50% CD : 50% CL, 25% CD: 75% CP and 75% CD : 25% CP were statistically significant at 0.05 significance level. Cumulative Biogas production of 75% CD: 25% CP, 30.4% higher than that of 100%, 6.8% higher than that of 50% CD: 50% CP, 12.2% higher than that of 25% CD: 75% CP and 16% than100% CP. Therefore, co-digestion of cow dung and cactus fruit peel biomass is one way of addressing the problem of lack of enough feedstock for biogas production. If suitable materials for co-digestion, such as manure, are not available, Cactus fruit peel can be digested alone and is a good opportunity for poor people who have not livestock as a source of energy.

## Reference

Abuabaker, B. and Ismail, N. (2012): Anaerobic Digestion of Cow Dung for Biogas Production. ARPN J. Eng. Appl. Sci., 7:169-172.

Ahn, H., Smith, M., Kondrad, S. and White, J. (2009): Evaluation of biogas production potential by dry anaerobic digestion of switch grass-animal manure mixtures. Appl. Biochem. Biotechnology., 160: 965–975.

Angelidaki, I. And Ahring, B.K. (1993): Methods for increasing the biogas potential from the recalcitrant organic matter contained in manure. 23-32.In: J.Mata-Alvarez, A. Tilche andF. Cecchi (eds.). Proceedings of the Second International Symposium on Anaerobic Digestion of Solid Wastes. Barcelona.

Anonymous. (1981): Biogas technology and utilization. A status Report, Department of Science and Technology, Government of India, New Delhi.20-46.098UUJK, L.

Arogo, J.,Wen,O., Ignosh, J., Bendfeldt, E. and Collins, E.R. (2009): Biomethane Technology.College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University publication., 442-881.

Badger**,** C.M.,.Bogue, M.J. and Stewart, D.J.(1979): Biogas production from crops and organic wastes**.** New Zealand Journal of Science, 22: 11-20.

Devlin, D., Esteves, C.S.R.R., Dinsdale, R.M. and Guwy, A.J. (2011): The effect of acid pretreatmenton the anaerobic digestion and dewatering of waste activated sludge. Bioresource Technology. 102: 4076-4082.

,
Gerardi, M.H. (2003): The microbiology of anaerobic digesters. A John Wiley and Sons. pp. 99-103

Gray, K.R., Sherman, k. and Biddlestone, A.J. (1971): A review of composting-part 1.*Process Biochem*.32-36.

Hills, D. J. and Roberts, D.W. (1981): Anaerobic digestion of dairy manure and field crop residues. *Agric. Wastes* 3:179–189.

Hobson,P.N., Bousfield, S. and Summers, R.(1981): Methane production from agricultural and domestic waste. Applied science publisher. 102:4076–4082.

Itodo, I.N., Lucas, E.B. and Kucha, E.I. (1992): The Effect of Media Materials and its Quality on Biogas Yield. Niger. J. Renew energy. 3:45-49.

Joung, D., Sung S., Ki-Cheol, E., Shihwu, S., SangWon, P. and Hyunook, K. (.2008): Predicting Methane Production Potential of Anaerobic Co-digestion of Swine Manure and Food Waste. Environ. Eng. Res., 13(2):93-97.

Kamthunzi,W.M.(2008): Anaerobic digestion of cattle manure in batch digesters at ambient temperature. Environ Sci. Technol., 3:8-12.

Lo Niee Liew, B.S. (2011): Solid- State Anaerobic Digestion of Lignocellulosic Biomass for Biogas Production. A M.Sc. Thesis Presented to the School of Graduate Studies of the Ohio State University. 44pp.

Navickas, K. (2007): Biogas for farming, energy conversion and environment protection International symposium, Biogas, technology and environment, University of Maribor, Faculty of Agriculture., 25-29.

Sadaka, S.S. and Engler, C.R. (2003): Effect of initial total solids on composting of raw manure with biogas recovery. Compost Sci. Utilizat., 11: 361-369.

Sagagi, B. S., Garba, B. and Usman, N.S. (2009): Studies on biogas production from fruits and vegetable waste.bajopas., 2 :115 – 118.

Sunarso, S., Johari, Z. I., Widiasa, N. and Budiyono. (2012): The Effect of Feed to Inoculums Ratio on Biogas Production Rate from Cattle Manure Using Rumen Fluid as Inoculums. Int. J Waste resour. 2 (1):1-4.

Tarrisse, A. (2008). Natural gas consumption of Turkey and the strategic use of drought tolerant energy crops for biogas production, Thesis, ESE-IER-Lyon III University -September 2008.

Tchobanoglous, G., Theisen, H. and Vigil, S. (1993): .Integrated Solid Waste Management Engineering Principle and Management Issues, 2$^{nd}$, McGraw-Hill ISBN-10: 0070632375 pp: 978.

Yadvika, Santosh, Sreekrishnan, T.R., Kohli, S. and Rana. (2004): Enhancement of biogas production from solid substrates using different technique: *BioresourceTechnology* 95:1–10.