**Proceedings of IOE Graduate Conference, 2015**
**pp. 287–292**

# Co-Digestion of Tannery Waste Blended with Cow Dung and Rice Straw: A Case of Asian Leather Arts and Tanning Industry

Harihar Bhatta[1]*, Bijaya Raj Khanal [2], Ajaya Kumar Jha[3], Bhakta Bahadur Ale[4]

[1,3,4] *Department of Mechanical Engineering Central Campus, Institute of Engineering, Tribhuvan University*
[2] *Renewable Energy Test Station (RETS)/Nepal Academy of Science and Technology (NAST), Lalitpur, Nepal*
***Corresponding author**: hellohari511@gmail.com

**Abstract**

Currently ten tanning industries operational in Nepal collect approximately 20 million of hides and skin of buffalo per year which on processing for leather, produce around 6000 - 8000 kg of wastes per day that are hazardous to environment causing air, water and soil pollution locally due to chemical processing. [7] Till present there has not been any research and project on such waste management and use of it as a useful energy in Nepal. So co-digestion of such waste blended with the cow dung and straw in optimum proportion may be one of the useful solutions to produce biogas as energy and slurry as manure in an environmental friendly way.

In this research, anaerobic co-digestion of tannery waste blended with cow dung and rice straw were analyze in ten different proportion based on Total Solid (TS), varying tannery wastes from 20% to 100% and cow dung from 0% to 70% and rice straw from 0.00% to 33.33% to make the TS of feedstock of around 10% and final feedstock mixture of 300 gram each adding water. The commutative biogas yield and specific biogas yield for 10 sample varied from 3219.33 to 5301.00 mL and 0.116 to 0.196 m3/kgvs respectively. If all tannery waste produced are converted into the useful energy by the co-digestion with cow dung and straw at the best proportion (2:2:1) found by this research will produce 794 to 1058 m3 per day of biogas and 4119 to 5492 kg per day of compost which can be used for cooking 3 meal to 2382 to 3176 people per day saving 542.2 to 728.3 cylinder of LPG per month.

**Keywords**

Tannery Waste – Modified GGC-2047 Model – Biogas Potential

## 1. Introduction

Anaerobic digestion of tannery wastes is an attractive method to recover energy from tannery wastes. This method degrades a substantial part of the organic matter contained in the sludge and tannery solid wastes, generating valuable biogas, contributing to alleviate the environmental problem, giving time to set-up more sustainable treatment and disposal routes. Digested solid waste is biologically stabilized and can be reused in agriculture.

Full-scale anaerobic digestion plants have been particularly successful for treating carbohydrate waste, but for the proteinaceous solid wastes such as leather, slaughterhouse, dairy, cow and chicken manure were reported to yield lower biogas than the carbohydrate rich solid wastes. This is due to result of ammonia toxicity from the large nitrogen fraction in these wastes [1].

The conventional leather tanning technology is highly polluting as it produces large amounts of organic and chemical pollutants. Wastes generated by the leather processing industries pose a major challenge to the environment. Waste from the leather industry, known as limed leather fleshing (LF) , has a low C/N (3-5) and alkaline pH of 10.0 -11.5. This is a major disadvantage for anaerobic digestion due to ammonia toxicity for methanogenesis. This study describes co-digestion of LF with biodegradable fraction of cow dung and rice straw optimized over a rang of C/N and pH to minimize ammonia and to maximize biogas yield [2].

Although the effluent from the tannery waste poses huge potential of biogas as energy when blended with other solid wastes, there is no such tanning industry in Nepal using its wastes as biogas.

The main objectives of this research is to access co-digestion of tannery waste blended with cow dung and rice straw at different proportions to find out optimize case and sizing of biogas digester for a particular tannery industry with financial feasibility of that digester system for same case.

## 2. Materials and Methods

### 2.1 Study area and feedstock collection

For the research study tannery wastes were collected from Asian Leather Arts and Tanning Industry located at Hetuda Industrial State, Hetuda. Cow dung and rice straw was collected from Naubise V.D.C Dhading.

### 2.2 Pretreatment of sample

Feedstock were screened thoroughly and non-biodegradable substrates from sample were removed out and segregated. Then feedstock was grinded into fine particle size for effective digestion process.

### 2.3 TS and VS calculation

Organic nutrient in substrate is determined by total solid and volatile solid (VS). Depending upon its reduction, biogas generation will occur. After collecting sample for anaerobic co-digestion, TS and VS of each sample was calculated by using APHA 1995 Standard [3].

### 2.4 Calculation of initial feedstock mixing ratio

Instead of mixing feedstock in terms of their actual weight, they were mixed based upon total solid in order to get more realistic comparison of biogas production among their different mixing ratio.

When total solid of tannery waste, cow dung and straw was calculated, feedstock were mixed on the basis of their TS value in the ratio of 1:0:0, 3:1:0, 15:4:1, 14:3:3, 1:1:0, 2:2:1, 7:5:5, 1:1:1, 1:2:1, 2:7:1 respectively varying tannery wastes from 20% to 100% and cow dung from 0% to 70% and straw from 0.00% to 33.33% . CN ratio was varied from 4.00% to 36.78%. Feedstock mixture was again mixed with water to make the TS of feedstock of approximately 10%.

Final feedstock mixture of 300 gm for each sample was calculated based on weighted average of feedstock weight and TS. Initial pH and temperature of each proportion of mixture were taken.

### 2.5 Experimental set up and test preparation

Data were collected every day at evening. Plastic syringe of 60 mL and 20 mL were used having least count 1 mL. In order to prevent leakage from the gap between the bottle mouth and cork, binding tape was used. Beside, weekly replacement of cork was done to ensure no leakage through rubber cork.

### 2.6 Instrument used

Instrument used during research are listed in table 1.

**Table 1:** Instrument used

| SN | Equipment | Parameter measured |
|---|---|---|
| 1 | Biogas analyzer (GASBOARD-3200 P) | Proportion of CH4 and CO2 in biogas |
| 2 | pH Meter (Seven Multi SK40, Switzerland) | pH of feedstock and mixture |
| 3 | Muffle furnace | Volatile solid (VS) of feedstock |
| 4 | Hot air oven | Total solid (TS) of feedstock |
| 5 | Digital weighting machine | Weight of feedstock |
| 6 | SAW4 Multi-gas detection alarm | Proportion of CH4 and CO2 in biogas |

### 2.7 Potential energy from tannery waste

Potential energy from tannery waste produced was estimated using the Biogas Calculation Tool Version 3.1 provided by AEPC.

### 2.8 Methodology adapted for the research

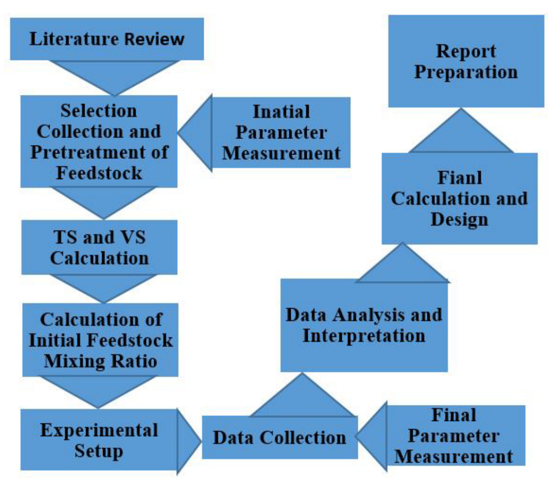


**Figure 1:** Methodology adapted for the research

## 3. Result and Discussion

### 3.1 Biogas produced each day

Volume of biogas produced during reaction period was measured by determining the displacement of plastic syringe plunger due to the pressure created through accumulated gas inside the reaction bottle.

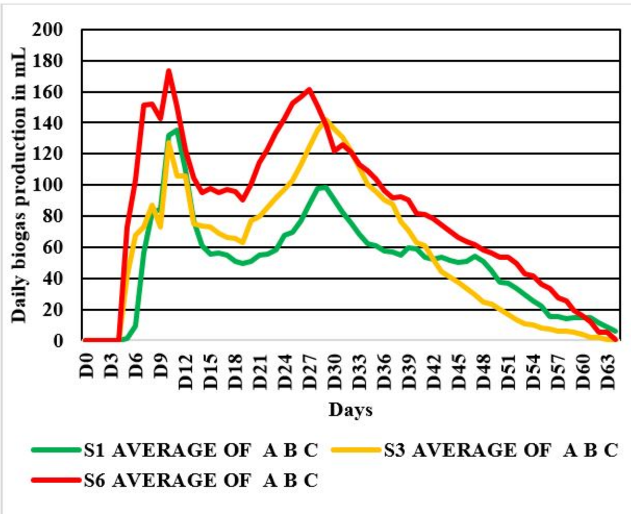


**Figure 2:** Daily biogas production for highest, medium and lowest case of sample

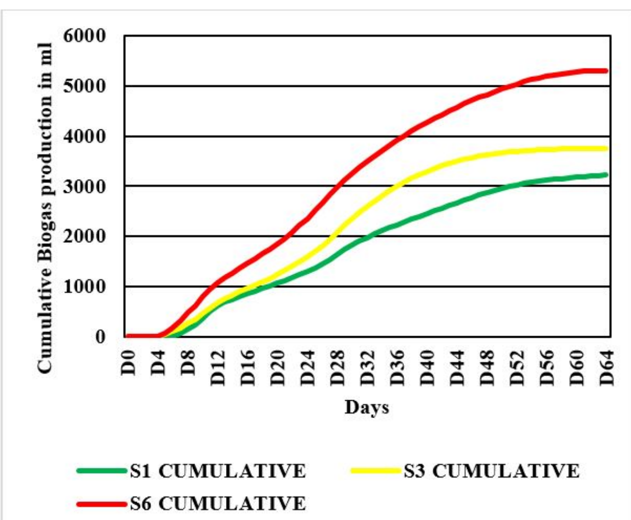


**Figure 3:** Cumulative biogas for highest, medium and lowest case of sample

In all ten sample group, biogas generation increased and subsequently reduced after reaching peak value. The rapid initial biogas production was due to readily biodegradable organic matter in all the substrates and due to the presence of high content of the methanogens. Decrease in biogas production after reaching peak value may be due to decrease in amount of nutrient for microorganisms and due to decrease in microbial activities [4].

Cumulative increased in biogas generation observed above shows that production pattern for all mixing ratio were almost similar yet rate of biogas production and maximum biogas production may differ.

### 3.2 Biogas production and methane content

The most important parameter to determine the energy content of feedstock is through biogas volume and methane content. The percentage of methane varies from lowest 42.9% at sample S1 to 55.0% highest at sample S6 while the carbon dioxide volume varies from 40.6 to 44.9%. With co-digestion the percentage of methane had increased in biogas production and percentage of carbon dioxide had decreased.

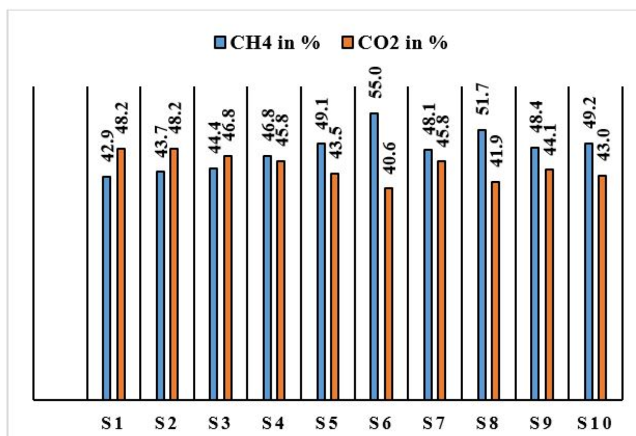


**Figure 4:** CH4 versus CO2 in biogas produced for each sample group

With the co-digestion fraction of methane contained in biogas increased supporting the co-digestion produced more amount of methane. The methane contained in sample group varied from 1380.37 mL in S1 sample to 2913.78 mL in S6 sample.

The biogas yield per kg of feedstock including water varied from 10.73 for S1 to 17.67 for S6 and biogas yield per kg of feedstock varied from 38.22 for sample

S7 to 52.93 for sample S6. Biogas yield in m3/kgvs varied from 0.116 for S1 sample to 0.196 for S6 sample.

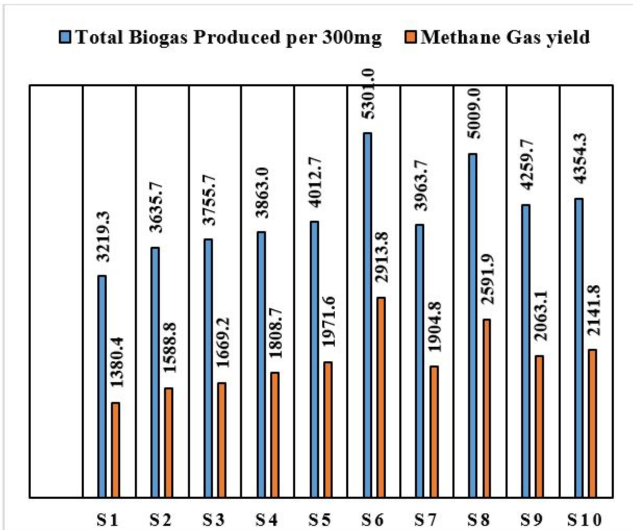


**Figure 5:** Methane gas yield each sample group

**Table 2:** Biogas yield for each sample

| Reactor | Cum. biogas yield | Biogas yield in liters | | | |
|---|---|---|---|---|---|
| | | per kg of feedstock incl. water | per kg of feedstock | $m^3$/ kgvs | L/ kgvs |
| S1 | 3219.33 | 10.73 | 47.09 | 0.116 | 115.89 |
| S2 | 3635.67 | 12.12 | 43.93 | 0.129 | 129.24 |
| S3 | 3755.67 | 12.52 | 45.76 | 0.136 | 135.53 |
| S4 | 3863.00 | 12.88 | 46.23 | 0.143 | 143.35 |
| S5 | 4012.67 | 13.38 | 41.30 | 0.141 | 141.40 |
| S6 | 5301.00 | 17.67 | 52.93 | 0.196 | 195.71 |
| S7 | 3963.67 | 13.21 | 38.22 | 0.144 | 144.12 |
| S8 | 5009.00 | 16.70 | 49.05 | 0.191 | 190.72 |
| S9 | 4259.67 | 14.20 | 39.41 | 0.158 | 157.90 |
| S10 | 4354.33 | 14.51 | 38.52 | 0.156 | 155.58 |

## 3.3 Potential of biogas energy from tannery industry

Currently ten tanning industries operational in Nepal collect approximately 20 million of hides and skin of buffalo per year which on processing for the leather produce around 6000 - 8000 kg of wastes per day. [7] If all these waste are converted into the useful energy by the co-digestion with cow dung and straw at the best proportion (2:2:1) found by this research will produce 794 to 1058 m3 per day of biogas and 4119 to 5492 kg per day of compost. Same amount of biogas can be used for cooking 3 meal to 2382 to 3176 people per day saving 542.2 to 728.3 cylinder of LPG per month. If same biogas is converted into the electricity with nominal electrical CHP engine efficiency of 30% will produce electrical output of 1310.0 to 1746.7 kWh/day and heat energy of 72.8 to 97.0 kW/day. If same energy is used for the lightening purpose only then 715 to 953 number of lamps can be lighted for 5 hours each day.

The total volume of digester is calculated to be 4120 to 5493 m3 for hydraulic retention time of 55 days being all the tannery industry located in the Terai region.

All this calculation is based on the software Biogas Calculation Tool Version 3.1 provided by AEPC. [5]

## 3.4 A case of Asian Leather Arts and Tanning Industry

### 3.4.1 Waste per day

The average monthly collection of hides and skin of buffalo of Asian Leather Arts and Tanning Industry is 300 processing 10 hides and skin per day on average producing 80 kg/day of the tannery waste.

### 3.4.2 Potential of biogas

If all these waste are converted into the useful energy by the co-digestion with cow dung and straw at the best proportion (2:2:1) found earlier by this research will produce 10.6 m3/day of biogas and 55 kg per day of compost. This amount of biogas is capable of cooking 3 meal to 32 people per day saving 7.3 LPG cylinder per month and NR 10950 at the rate of NR 1500 per cylinder. If same biogas is converted into the electricity with nominal electrical CHP engine efficiency of 30% will produce electrical output of 17.5 kWh/day and heat energy of 1 kW/day. . If same energy is used for the lightening purpose only then 10 number of lamps can be lighted for 5 hours each day.

### 3.4.3 Sizing of biogas plant

Sizing of biogas plant is based on the software Biogas Calculation Tool Version 3.1 provided by AEPC.[6]

The total volume of digester is calculated to be 55 m3 for hydraulic retention time of 55 days being Asian Leather

Arts and Tanning Industry located in the Terai region.

Main Biogas Plant Features:

- Modified GGC 2047 biogas plant
- Number of digester 1
- Biogas plant volume 55 $m^3$
- Gas storage volume 18 $m^3$
- Digester volume 36.6 $m^3$
- Diameter 3.3 m
- Height 4.3 m
- Compost pit retention time 30 days
- Hydraulic retention time 55 days
- Compost pit total volume 20 $m^3$
- Total feed 666 kg/day
- Water for dilution 466 kg/day

### 3.5 Financial analysis

Financial analysis of bio digester is based on “A Report on Baseline and Feasibility Assessment of the Waste to Energy Projects for Potential Financing under Market/ Non-Market Mechanisms” published by the AEPC-Nepal [5].

**Table 3:** Financial results

| SN | Description | Value | Remarks |
|---|---|---|---|
| 1 | Present value | 1,089,600.07 | |
| 2 | Net present value @ 10% Discount Rate | 250,557.07 | NPV indicates the project will add value to the firm |
| 3 | IRR | 14.96 | IRR is greater than market rate of return so project is financially feasible |
| 4 | Payback period | 5.85 | |

Biogas plant is financially feasible with 14.96 IRR and a payback period of 5.85.

**Table 4:** LCOE with subsidy

| | |
|---|---|
| Initial cost | 839,043.00 |
| Present value of free cash flow | 883,386.00 |
| Total cost | 1,722,429.00 |
| Present value of electricity generated | 39,233.00 |
| LCOE | 43.90 NR/kWh |

**Table 5:** LCOE without subsidy

| | |
|---|---|
| Initial cost | 1,058,750.00 |
| Present value of free cash flow | 917,123.00 |
| Total cost | 1,975,873.00 |
| Present value of electricity generated | 39,233.00 |
| LCOE | 50.36 NR/kWh |

**Table 6:** Levelized cost of LPG saved with subsidy

| | |
|---|---|
| Initial cost | 839,043.00 |
| Present value of free cash flow | 883,386.00 |
| Total cost | 1,722,429.00 |
| Present value of LPG saved | 7,640.00 |
| LCOLPG | 231.11 NR/kg |

**Table 7:** Levelized cost of LPG saved without subsidy

| | |
|---|---|
| Initial cost | 1,058,750.00 |
| Present value of free cash flow | 917,123.00 |
| Total cost | 1,975,873.00 |
| Present value of LPG saved | 7,640.00 |
| LCOLPG | 258.61 NR/kg |

The LCOE is calculated assuming 10% debt interest rate and equity cost of capital 20%. The annual escalation rate being 6% and depreciation rate 15%.

### 3.6 Efficient Lighting Scenario

In the base year 2013, 30% of the total energy consumed in the lighting was though incandescent lamps, 20% through fluorescent lamps, 36% through CFL, 7% through LED and remaining 7% through others.

In this scenario it was assumed that by 2016, 80% of the incandescent bulbs and 25% of the fluorescent and CFL bulbs will be replaced by LED bulbs. Similarly, by 2019, 90% of the incandescent bulbs and 100% of the fluorescent and CFL bulbs will be replaced by LED bulbs. The conversion factor taken in this thesis was 0.25 for incandescent bulbs and 0.67 for fluorescent and CFL bulbs.

## 4. Conclusion

The following conclusions were drawn from this research study:

- During the 65 days of batch anaerobic digestion, the highest cumulative biogas production was 5301 mL at the mixing ratio of 2:2:1 of tannery waste, cow dung and rice straw with an average methane content of 55% for C/N ratio of 29.34% with 29.96 TS. And the lowest cumulative biogas production was 3219.33 mL at the mixing ratio of 1:0:0 of tannery waste, cow dung and rice straw with an average methane content of 42.9% for the C/N ratio of 4.00% with 43.88 TS. The best proportion for biogas production found by this research was 2:2:1 of tannery waste, cow dung and rice straw based on their TS.

- The final pH of the sample were in range of 6.9 to 7.4 indicating the neutral region.

- The specific biogas yield were 0.116, 0.129, 0.136, 0.143, 0.141, 0.196, 0.144, 0.191, 0.158 and 0.156 m3/kgvs for the sample S1, S2, S3, S4, S5, S6, S7, S8, S9, S10 respectively. This concluded that specific gas generation of mixture of tannery waste, cow dung and rice straw was more than that of tannery waste alone.

- If all tannery waste produced in tannery industry of Nepal are converted into useful energy by the co-digestion with cow dung and straw at the best proportion (2:2:1) found by this research will produce 794 to 1058 m3 per day of biogas and 4119 to 5492 kg per day of compost, saving 542.2 to 728.3 cylinder of LPG per month.

- A case study of Asian Leather Arts and Tanning Industry was found to be technically and financially feasible with 14.96 IRR at 10% discounted rate, hence wet anaerobic co-digestion of tannery waste, cow dung and rice straw could be one of the promising way for converting the hazardous waste to the useful energy in environmental friendly way with the slurry as manure.

## 5. Recommendation

Following are listed recommendation for continuity of research on wet anaerobic co-digestion of tannery waste blended with cow dung and rice straw:

- Study of slurry composition for different sample and its investigation for hazardless should be done.
- More accurate result will be obtained if data are taken exactly after 24 hours each day, controlled temperature and air tightness was maintained.
- Change in temperature and pH value of mixture should be measured daily by providing appropriate lab facilities.
- Other analysis like microbial analysis during the digestion period and nutrient level analysis should be carried out.
- This research may be fruitful to the new researcher in same field and to the tannery industry to generate renewable energy and hazardous waste management in an environmental friendly way.

## Acknowledgments

Authors are thankful to the family of CES, Mechanical Department, and Soil Test Lab of Department of Civil Engineering, Chemistry Lab of Department of Science and Humanities for providing necessary equipment for measuring total solid, volatile solid and lab setup. The authors are grateful to BSP-Nepal for providing biogas analyzer and AEPC-Nepal for providing biogas detector during the research period.

## References

[1] Shanmugam P. and Horan N.J. Optimising the biogas production from leather fleshing waste by co-digestion with MSW. Master's thesis, Environmental Engineering, School of Civil Engineering, University of Leeds, Leeds LS2 9JT, UK, 2009.

[2] J. Kanagaraj, K.C Velappan, N.K Chandra Babu, and S. Saddula. Solid waste generation in the leather industry and its utilization for cleaner environment – A Review. Technical report, Central leather research institute, Adyar, Chennai, 2006.

[3] USA American Public Health Association Washington DC. Standard methods for the examination of water and wastewater, 20th ed.

[4] Ajay Kumar Jha, Jianzheng Li, Liguo Zhang, Qiaoying Ban, and Yu Jin. *Comparison between Wet and Dry Anaerobic Digestions of Cow Dung under Mesophilic and Thermophilic Conditions*. PhD thesis, State Key Laboratory of Urban Water Resource and Environment, School of Municipal and Environmental Engineering, Harbin Institute of Technology, Harbin 150090, P. R. China, 2013.

[5] AEPC Nepal. A Report on Baseline and Feasibility Assessment of the Waste to Energy Projects for Potential Financing under Market/Non-Market Mechanisms. Technical report, AEPC, Nepal, 2015.