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Catalytic Effect of Tungsten on Anaerobic Digestion Process for Biogas Production from Fruit and Vegetable Wastes

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Abstract – ***In the recent years global energy crisis increased at a fast pace. Demand for the use of fossil fuels for cooking and other commercial activities increased along with the increasing population of India. Use of renewable sources of energy viz. biogas for cooking etc can somewhat be an alternative for the excessive demand of fossil fuels like LPG. In this study, the catalytic effect of tungsten for maximizing biogas have been presented. Essentially, anaerobic digestion process have been conducted in batch reactors for a retention time of 15 days at a constant temperature of 27°C. Necessary cumulative and differential plots between yield of biogas and retention time have been studied for individual anaerobic digestion processes at different slurry and catalyst concentrations so as to observe the optimum slurry and catalyst concentration for maximum biogas production. Maximum yield of biogas have been obtained with 5% slurry concentration at 1.5g/l catalyst concentration.***

Keywords – catalytic effect, anaerobic digestion, retention time, slurry concentration, catalyst concentration.

I.INTRODUCTION

Biological conversion of wastes has been demonstrated as one of the most advantageous and effective method of reducing pollution. Anaerobic treatment of solid municipal wastes, especially food wastes is a cost effective technology (1, 2). Although the concept of biogas production is not new but process design for efficient energy production is not fully understood and research & development work is still going on to improve efficiency, reliability and applicability using various biomass (3). Moreover, in India FVW constitute about 5.6 million tonnes annually and currently these wastes are disposed by dumping on the outskirts of cities (4). Most promising alternative process of pyrolysis and incineration is to digest or degrade the organic matter using anaerobic digestion (5, 6).

Anaerobic digestion is a biochemical process in which complex organic wastes (FVW) are converted to a mixture of methane and carbon dioxide collectively called biogas (3*)*. Technically it is a four step process (*7*) namely hydrolysis, acidogenesis, acetogenesis and methanogenesis. Generally two categories of micro-organisms are involved for this type of conversion. The first among them is the acid formers which convert macro molecules like carbohydrates, proteins, starches, cellulose, lipids etc to organic acids (step one and step two). In the third step these organic acids are converted to acetate & finally in the fourth step the acetate is converted to methane & carbon dioxide by a group of organisms called methanogens. Solid retention time for batch digestion is pretty high (8). Time required for first two steps is very high that comsumes most of the time.

Production of biogas can be enhanced by addition of trace elements that serve as micro nutrients for the anaerobic micro organisms. Supplementation of essential trace elements has been shown to maintain and stimulate the digestion process(9-15). Enzymes required for biochemical reactions contain these trace elements in the form of co enzymes and co factors. The roles of trace elements have been reviewed in several publications (16, 17). However, information on the specific trace element requirement for anaerobic digestion process is still limited. The purpose of current study was to present the catalytic effect of tungsten on anaerobic digestion process and also to find the optimum slurry concentration at which maximum biogas yield have been obtained being catalyzed by tungsten at a definite concentration.

II. MATERIALS AND METHODS

A.Collection and preparation of sample

Fruit and vegetable wastes (FVW) have been collected from local market and also from regular household activities like peeling , prior to cooking. Then these wastes have been cut into small pieces and subjected to sun drying for 5 days followed by drying in a hot air oven for 5 to 6 hours at a temperature of 100°C to 105°C. After drying , the wastes have been finely grinded for particle size reduction and the fine powder so obtained was stored in container for use in anaerobic digestion process. The following flow-sheet describes the process pictorially.

Collection of waste samples
↓
Sun drying
↓
Drying in hot air oven
↓
Grinding
↓
Storage in container

B.Characterization of sample

The sample has been characterized and the results have been tabulated as follows.

Parameters	Results
Moisture content (%)	**8.51**
Volatile matter (%)	**77.16**
Ash (%)	**7.07**
Fixed Carbon(%)	**7.25**
Calorific value (cals/gm)	**1913.4**
C:H:N	**83:12:5**

Finely ground FVW have been subjected to hot air oven at a temperature of 105°C for 1hr for moisture content determination and at 450°C in muffle furnace for 30mins followed by 775°C for 1hr for ash content determination. Volatile matter have been estimated by subjecting sample to muffle furnace at 925°C for 7 mins. Fixed carbon have been estimated by deducting the sum of moisture content, ash content and volatile matter from 100; the entire process being recommended by Fuel Research Board and British Standard Institutions.

Karas-Simek calorimeter have been used for estimation of calorific value of FVW.

Results for CHN analysis have been obtained by sample testing from INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE (Dept of Inorganic Chemistry).

C. Methods

Experiments have been conducted in 1L batch digesters essentially made of glass. A set of 12 digesters have been used at a time for experimentation. Working volume of the process was 750ml with 3%, 4%, 5% and 6% respectively. Catalyst was added at the rate of 0.5g/l, 1g/l and 1.5g/l to digesters with the above mentioned slurry concentration such that for each slurry concentration three different processes have been observed with mentioned catalyst concentration.

Pre-digested waste have been used as a source of mixed bacterial community for anaerobic digestion process. After all necessary additions the digesters have been rubber corked and allowed to stand still for 3 days and after that gas volume have been checked at an interval of 24hrs by method of downward displacement of water.


Fig 1. Digester set up Fig 2. Gas jar

D. Limitations

As experimentation have been conducted in batch process so it was not possible to investigate the kinetic parameters. Pre-digested sewage have been used as source of collective bacteria for batch process and so the kinetic growth & death parameters for organisms could not be studied as the present bacteria in sewage was totally unknown. Composition of slurry was measurable only before experimentation. Intermediate concentrations of substrate during different steps of reactions have not been measured.

III. RESULTS AND DISCUSSIONS

A.Optimization of slurry concentration on yield of biogas.

From Fig 3(A), it is evident that total biogas yield have been plotted against slurry concentration. In this graph, a comparison have been made between 4 different processes for finding maximum total biogas yield at a particular slurry concentration. Denoting process with no catalyst as (a), process with 0.5g/l catalyst conc. as (b) and similarly (c) & (d) for 1g/l and 1.5g/l catalyst concentration.

For process (a) yield of biogas is maximum (4.94L/Kg VS) at 4% slurry concentration and minimum(2.48L/Kg VS) at 5% concentration and the yield is somewhat similar at 3% and 6% concentration. For process (b) yield of biogas is maximum (4.19L/Kg VS)at 3% and 6% while minimum(2.08L/Kg VS)at 4% and 5% concentration. For process (c) yield is minimum (2.36 L/Kg VS) for 5% and the yield is average for 3%, 4%

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and 6% concentrations. For process (d) the yield is minimum (2.08 L/Kg VS) for 4% and yield is almost average(3.44 L/Kg VS) for 3%, 5% and 6% concentrations. So process (a) and (b) is of same nature and process (b) and (d) is of similar nature in terms of total biogas yield. Yield of biogas can be improved for processes at certain slurry concentrations by careful addition of catalyst as in process (d) for 5% concentration. So it can be concluded that optimum slurry concentration is 4% with maximum biogas yield. Biogas yield is somewhat similar for 3% and 6%. Fluctuations in gas yield have been seen for 4% and 5% due to certain effect of catalyst in bioconversion by anaerobes.

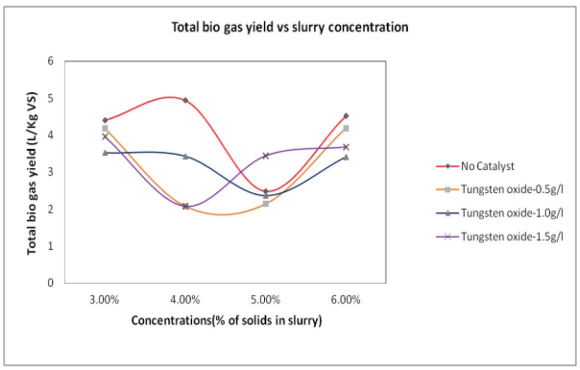

Fig 3(A)

The bar graphical representation of above is as follows :

From Fig 3(B) it is clear that average biogas yield is higher for 3% and 6% slurry concentration though the biogas yield for individual process with no catalyst addition is higher at 4% slurry concentration.

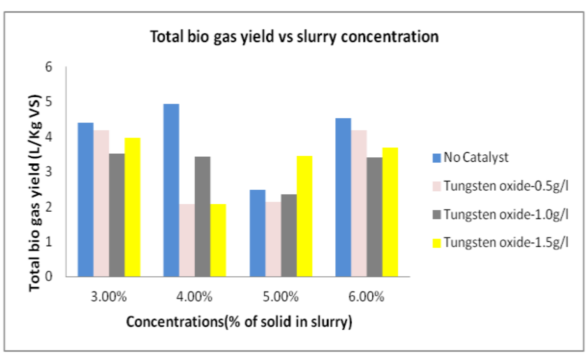

Fig 3(B)

B. Role of catalyst on yield of biogas

From Fig 4(A) it is evident that total biogas yield have been plotted against catalyst concentration and the effect of a particular catalyst concentration on respective slurry concentration have been presented. At 0.5g/l of catalyst concentration, yield is maximum (4.18 L/Kg VS) for 3% and 6% slurry concentration while the yield is minimum (2.08 L/Kg VS) 4% and 5% slurry concentration. At catalyst concentration of 1g/l the yield of biogas is impressive and maximum (3.43 L/Kg VS) for 3%, 4% and 6% slurry concentration while yield is minimum for 5% slurry concentration. For 1.5g/l of catalyst concentration, the yield is maximum (3.96 L/Kg VS) for 3% slurry concentration and the yield is minimum (2.08 L/Kg VS) for 4% slurry concentration.

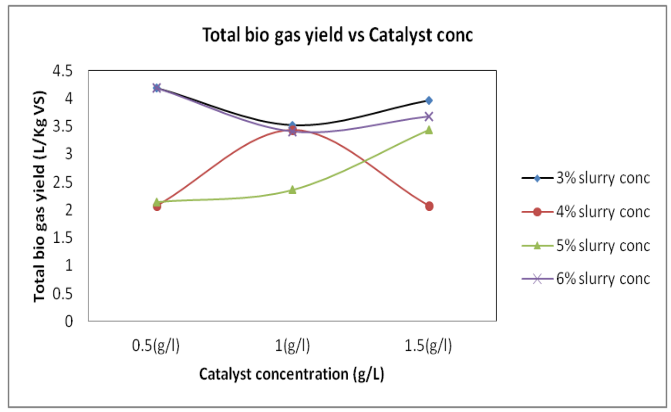

Fig 4(A)

The bar graphical representation of the above process is as follows :

From Fig 4(B) it is clear that the average yield of biogas is high for 3% and 6% slurry concentration irrespective of catalyst concentration. For 4% slurry concentration the yield is somewhat better at 1g/l catalyst concentration and for 5% slurry concentration the yield is good at 1.5g/l of catalyst concentration.

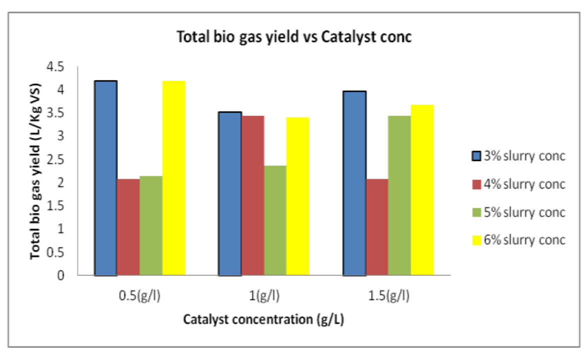

Fig 4(B)

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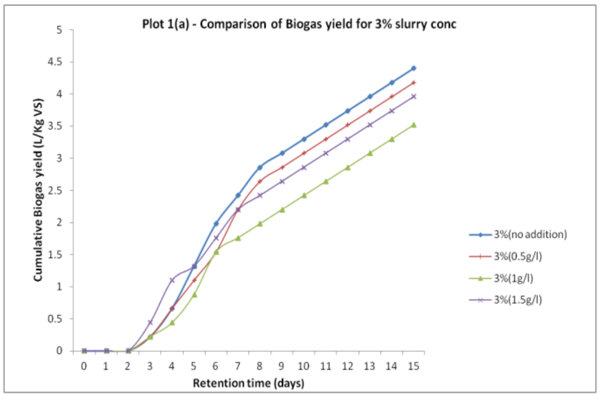
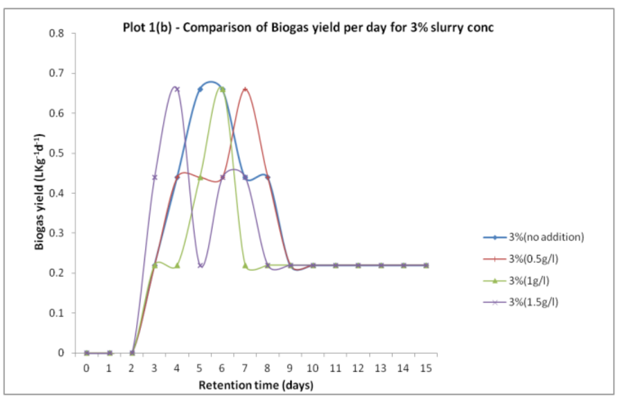
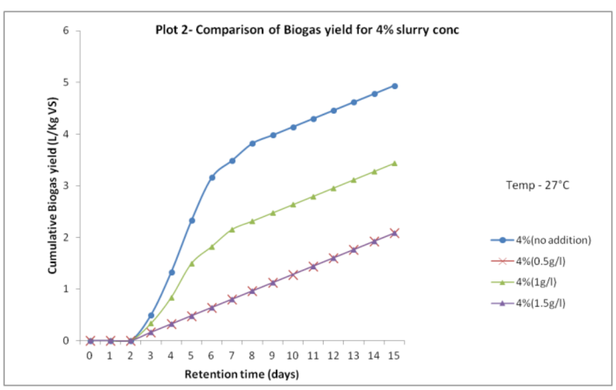
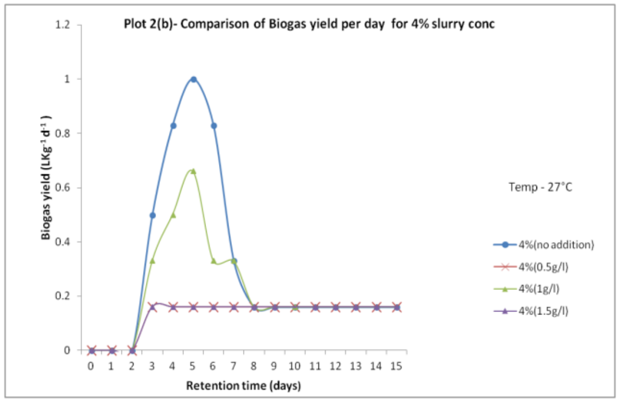
C. Comparative study for yield of biogas with respect to retention time

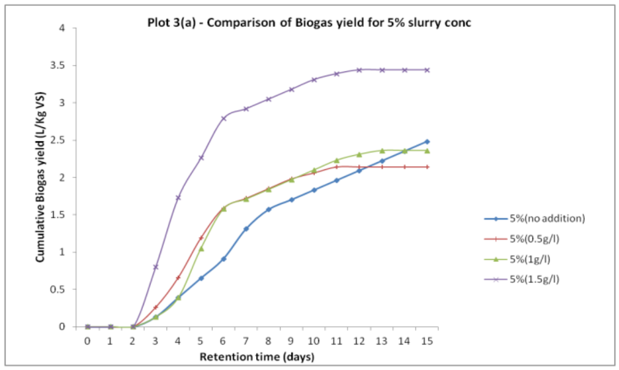
Differential and cumulative plots have been presented for yield of biogas for respective slurry concentrations (3%, 4%, 5%, 6%) with 15 days retention time. The processes have been conducted at 27°C and the pH was 5-7. From the graphs it is clear that the catalyst is effective for 5% slurry concentration as yield of biogas is maximum in that case. From the differential graphs (for per day biogas yield) it is evident that the yield increases upto 4-6 days and then the yield falls gradually.

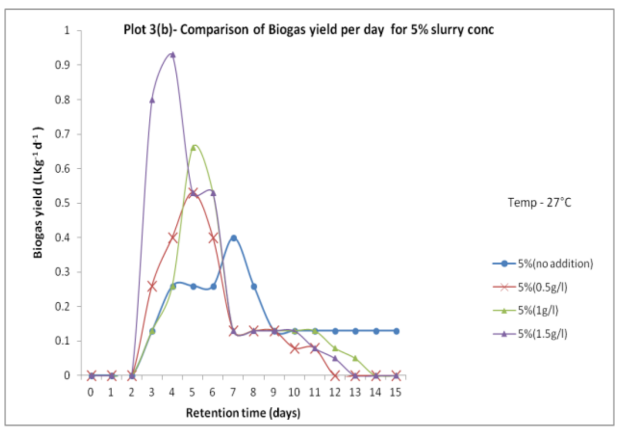


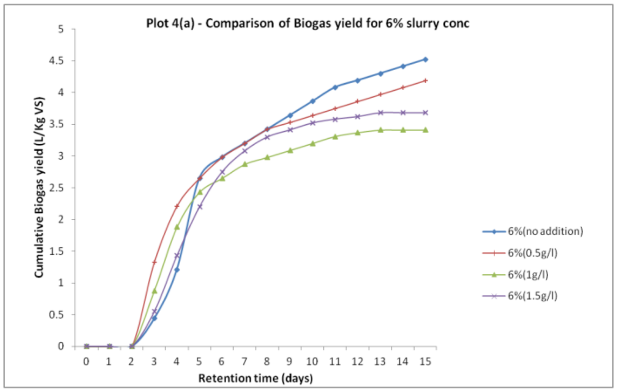


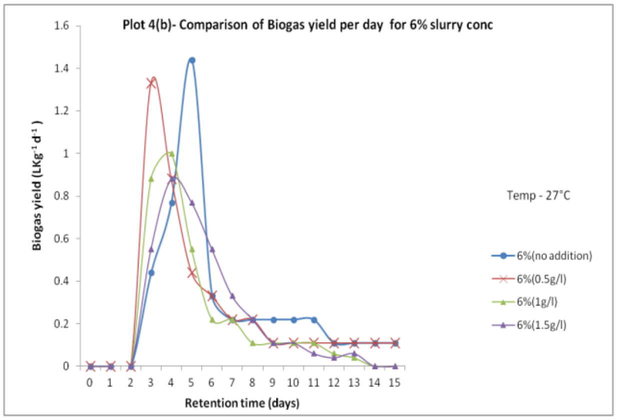












After careful observation of the above processes it can be said that by using this catalyst yield of biogas have been improved at 27°C and the yield is maximum for 5% slurry concentration. Nevertheless, the average yield of biogas is impressive with tungsten.

IV CONCLUSIONS

The present study provides useful information regarding the improvement of biogas yield in anaerobic digestion process by catalysis. Study reveals that biogas yield improved over addition of catalyst as rate of growth of bacteria was enhanced and ultimately conversion of complex wastes to biogas increased. The study also shows that yield per day of biogas by anaerobic digestion increased due to catalysis with respect to non catalytic process. It is of utmost importance to reduce the volume of wastes, for environmental pollution control and faster digestion will lead to better pollution control & less land pollution and also good biogas yield will make availability of gaseous bio-fuel.

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