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Effect of Potassium Chromate on the Anaerobic Digestion of Holy Basil (*Ocimum sanctum*)

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ABSTRACT

Anaerobic digestion involves the degradation and stabilization of organic materials under anaerobic conditions by microbial organisms and leads to the formation of biogas. Heavy metals would be stimulatory or inhibitory to anaerobic microorganisms is determined by the total metal concentration, chemical forms of the metal etc. Hence in the present work, the effect of different concentrations of Chromium as Potassium Chromate, a soluble form of chromium, on anaerobic digestion of Holy Basil (Holy Basil) was investigated in batch reactors for 45 days. The temperature and biogas were noted daily. The Total Solids (TS), Volatile Solids (VS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Kjeldhal Nitrogen (TKN) and Phosphorous were analyzed at an interval of 5 days. The overall performance of the digester was enhanced with 2 mM concentration of the digester whereas the performance dwindled at 4 mM and 8 mM metal concentration when compared with the control digester.

Introduction:

Anaerobic digestion of crop residues is a technologically simple method [1, 2] with the twin advantage of energy production and environmental conservation. It is best suited for agrarian countries where the availability for plant residues is substantial. Anaerobic digestion involves the degradation and stabilization of organic materials under anaerobic conditions by microbial organisms and leads to the formation of biogas (a mixture of carbon dioxide and methane, a renewable energy source) and microbial biomass [3,4]. It is a complex process requiring the presence of several different microorganisms. Many heavy metals are part of the essential enzymes that drive numerous anaerobic reactions [4]. Whether heavy metals would be stimulatory or inhibitory to anaerobic microorganisms is determined by the total metal concentration, chemical forms of the metals, and process-related factors such as pH and redox potential [5, 6, 7]. Few trace elements, like iron, manganese, molybdenum, zinc, copper, cobalt and nickel accelerated the process of methanogenesis while cyanide and heavy metals at elevated concentration have some toxic effect on the anaerobic process [8]. Heavy metals can be present in significant concentrations in municipal sewage and sludge. The heavy metals identified to be of particular concern include chromium, iron, cobalt, copper, zinc, cadmium, and nickel [9].

Hence the present study was aimed at assessing, by batch digestion, the effects of chromium on the biogas yields of locally available plant residue: Tulasi (Holy basil) which was collected from the famous Simhachalam temple, Visakhapatnam, where it is otherwise discarded as waste.

Materials and Methods:

Collection and Preparation of Material:

Ocimum sanctum Linn. (Labiatae), commonly known as holy basil, is a herbaceous plant found throughout the south Asian region. The plant grows wild in India, but is also widely cultivated in homes and temple gardens [10]. It is cultivated for religious, medicinal uses, as well as for its essential oil. Holy basil was collected from the famous Simhachalam temple, Visakhapatnam, where it is otherwise discarded as waste. The leaves were washed with distilled water; air dried in shade, blended and the paste is used as a substrate.

Experimental Set Up:

In each digester bottle, 1500 ml was slurry (6% TS w/v) of the substrate, and heterogenous cowdung (10% TS v/v) was added as active inoculum. The experimental set up was designed as reported by Singh and his associates [11]. Chromium (Cr) in the form of soluble Potassium Chromate, was added to the digester at a concentration of 2mM, 4mM and 8mM and the overall performance of the digester was evaluated by comparing with a digester wherein heavy metal was not added externally that acted as a control.

Analysis of the Parameter:

Biogas produced in the digester was measured once a day by reading the level of saline water displaced by gas pressure [11]. The contents of the digester were mixed once a day by shaking them manually for 5 minutes. The experiment was carried out for a period of 45 days. The pH was maintained in the range of 6.8 to 7.2. The total solids (TS), volatile solids (VS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Kjeldhal Nitrogen (TKN), Phosphorous were analyzed at a regular interval of 5 days using standard methods [12].

Statistical Analysis:

The data was subjected to statistical analysis using regression. Statistical analyses were performed using MINITAB statistical package (Minitab Statistical Software, Version 14, State College, Pennsylvania, USA) software used for regression analysis [13].

Results and Discussion:

Throughout the study period the pH of the feed was maintained within the acceptable range of 6.8 to 7.2 [14, 15].

Temperature and Biogas:

The temperatures diverged between 30.3 ^{0}C - 35.6 ^{0}C, 30.3 ^{0}C - 35.6 ^{0}C and 31.5 ^{0}C - 35.4 ^{0}C for 2mM, 4mM and 8mM Chromium concentration respectively. The feed temperature during the study was in the range of 30.3 ^{0}C to 35.6 ^{0}C, which is recommended for efficient mesophilic anaerobic digestion [15, 16]. A maximum of 840 m3/day of biogas is produced on day 5 with an average production of 200.17m3/day and cumulative biogas of 0.513dm^3/kg with 2mM Chromium concentration. An average biogas of 149.9m^3 with a cumulative biogas of 0.382dm^3/kg was obtained at 4mM Chromium concentration. The cumulative biogas production were 107.71m^3/day, 0.276 dm^3/kg respectively at 8mM Chromium concentration. 2mM Chromium concentration has caused an increase in the biogas generated when weighed against the others and control. (Figure 1)

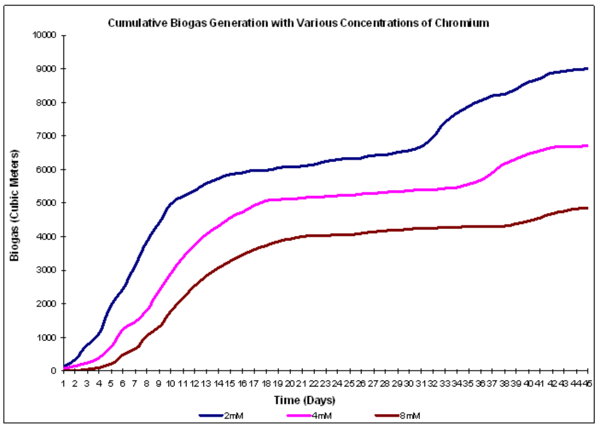

Figure 1: Comparison of cumulative biogas at 2mM, 4mM and 8mM Chromium

Solids:

The Total Solids (TS) and Volatile Solids (VS) in the feed material decreased as the digestion period increased. Chromium concentration of 2mM has shown a creeping increment from 11.18%, 1.11% after 5 days to 73.08%, 61.36% at the end of 45 days of Total Solids (TS) and Volatile Solids (VS) respectively when compared with the control. Chromium concentration of 4mM showed a degradation efficiency of 65.38% for TS and 49.29%for VS. The performance of the digester with 8mM has been shrinked and only a maximum reduction of 47.44%, 42.50% of TS and VS were recorded. Chromium concentration of 2mM has enhanced the Solids reduction in the digester when compared with control.

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD):

The decrement in BOD and COD was shown after a five day interval and reached its upper limit of 77.23% and 70% past 45 days with a Chromium concentration of 2m. At 4mM concentration, the reduction in BOD and COD was not enhanced but the performance of the reactor was almost all similar to the control digester with a maximum reduction of 73.58% and 65.25% of BOD and COD respectively. Chromium molarity of 8mM has diminished the BOD and COD reduction in the digester but the maximum reduction of 52.18% and 50.25% was displayed after 45 days (Figure 2 and 3). Process performance and process stability can be judged by lower COD and BOD values indicating better degradation [17, 18] which was observed in the digester with 2mM Chromium concentration.

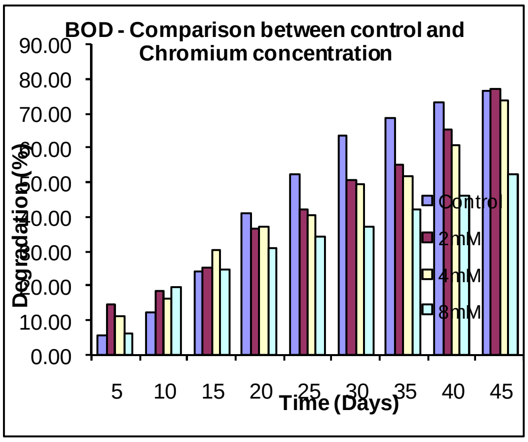

Figure 2: Trends in degradation of Biological Oxygen Demand with 2mM, 4mM and 8mM Chromium when compared with control

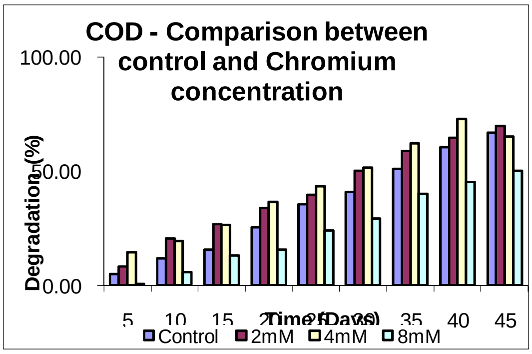

Figure 3: Trends in degradation of Chemical Oxygen Demand with 2mM, 4mM and 8mM Chromium when compared with control

Nitrogen and Phosphorous:

The initial decline in the Nitrogen and Phosphorous was monitored up to 15 days at 2mM, 4mM and 8mM Chromium concentrations. The initial reduction in Nitrogen content in the digester could be explained by the loss in the form of gaseous Nitrogen and its conversion into biomass as was proposed by Beux [19]. A 60.67%, 44.44%, 32.95% of Nitrogen (Figure 4) and 40.96%, 28.92%, 25.3% of Phosphorous (Figure 5) raise than the initial Nitrogen and Phosphorous were observed for 2mM, 4mM and 8mM Chromium respectively. The increase in the Nitrogen and Phosphorous content decreased with increase in the metal concentration. As the retention time increased, there was an increase in Nitrogen and phosphorus content in the feed which can be attributed to mineralization of organic compounds containing organic Nitrogen and phosphorus [20].

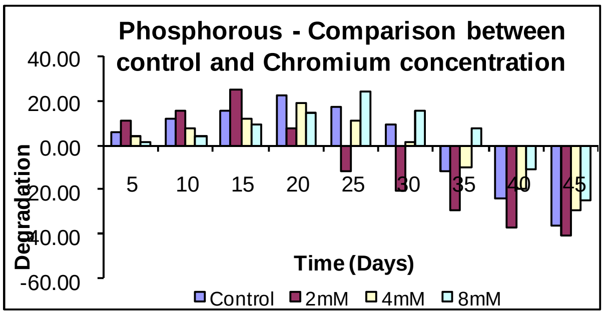

Figure 4: Trends in degradation of Phosphorous with 2mM, 4mM and 8mM Chromium when compared with control

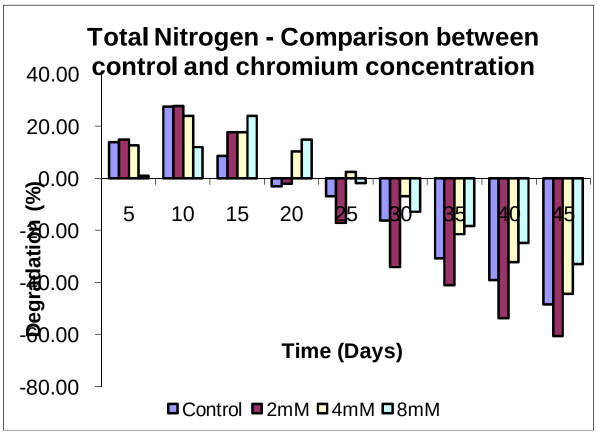

Figure 5: Trends in degradation of total Nitrogen with 2mM, 4mM and 8mM Chromium when compared with control

Effect of Chromium on Digester Performance:

The incorporation of heavy metals has profound effects on microorganisms active in anaerobic digesters [21, 22]. Chromium is a heavy metal with environmental concern. The Chromium in the digester studied was primarily in the soluble form. At low concentration of 2mM, Chromium enhanced the digesters performance slightly and the biogas yield by 1.16 times when compared with control digester. As per Shen and Wang [23] in trace amounts, chromium is considered an essential nutrient for numerous organisms [24]. Studies have indicated that Cr (VI) acts as an electron sink in a membrane bound pathway during anaerobic respiration [25, 26, 27]. As chromium on a minimal amount or in traces is necessary for the activation and activity of many enzymes and co-enzymes, the overall performance of the digester has increased.

But as the concentration of Chromium in the digester increased (4mM and 8mM) the performance of the digester dwindled. Whether heavy metals would be stimulatory or inhibitory to anaerobic microorganisms is determined by the total metal concentration, chemical forms of the metals etc. [5]. When present in large amounts, they cause an inhibitory or toxic effect to micro-organisms. As per Li and Fang [28] and Appels [29], the chemical binding of heavy metals to the enzymes and subsequent disruption of the enzyme structure and function are the main cause of the toxic effect.

Conclusion:

- Chromium in the form of soluble Potassium Chromate addition appears to have some impact on production of biogas based on the consistently stronger production from reactor fed with low concentration of heavy metals over the unfed reactors.
- It was found that Chromium has activated the process of anaerobic digestion and also improved the percentage of biogas formation at 2mM concentration.
- The optimum concentration of Chromium was observed to be 2mM which acted as a good initiator in the process of microbial degradation.
- The increasing order of performance of the digester with Potassium Chromate in the present study was 8mM < 4mM < Control < 2mM. The statistical outcome corroborated with the experimental results with the effect of Selenium on the digester performance (Figure 6).

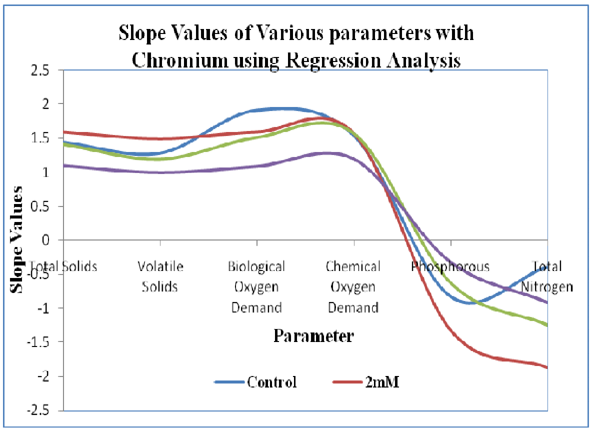

Figure 6: Statistical analysis – slope values of various parameters with 2mM, 4mM and 8mM Chromium when compared with control

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