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ANAEROBIC CO-DIGESTION PROCESS AND PRETREATMENTS OF ORGANIC WASTE: A REVIEW

J. SANTHOSH[a1], R. JAYANTHI[b] AND N. RAMACHANDRAN[c]

[a]Research Scholar, Department of Civil Engineering, Periyar Maniammai University, Thanjavur, India
[b]Professor, Department of Civil Engineering, Periyar Maniammai University, Thanjavur, India
[c]Vice Chancellor, Periyar Maniammai University, Thanjavur, India

ABSTRACT

Anaerobic digestion is the most feasible technology to dispose the organic waste, owing to its biodegradability and high energy recovery. Generally, the utilization of single substrate like manure which has low C/N ratio and buffering capacity will be balanced by the addition of minor amount of single or a variety of different substrates. In order to achieve waste upgrading, energy production and improvement fertilizer quality, it is essential to practice this type of co digestion. Suitable operating conditions and incessant monitoring will prevent the collapse in the system. Over and above the Co-digestion technology added other actions like Diluting the probable toxic compounds in due course, fine tuning of moisture content and pH and also aids to expand the range of bacterial strains involving in the process. In recent years, the utilization of different organic wastes justifies the implementation of codigestion technology. However, some of the substrates will be very slow to break down for producing biogas, occurrence of any physical problems like floating or foaming and also if the molecular structure of the substrate is poorly accessible to the microbes and their enzymes. The intricacy happened may be cracked through pretreatment technologies. This paper reveals the experiences of various co digestion and pretreatment processes.

KEYWORDS: Co-digestion, Pretreatment, operating conditions and monitoring component

It is necessary to treat the organic wastes in order to maintain clean and green environment. Anaerobic digestion is a process where the organic wastes are completely degraded to form biogas which has the composition of Methane, Carbon di oxide and traces of Hydrogen sulphide, Ammonia, Hydrogen and Nitrogen, Water vapour, etc. Generally, the utilization of single substrate like manure which has low C/N ratio and buffering capacity will be balanced by the addition of minor amount of single or a variety of different substrates. In order to achieve waste upgrading, energy production and improvement fertilizer quality, it is essential to practice this type of co digestion. Suitable operating conditions and incessant monitoring will prevent the collapse in the system. Over and above the Co-digestion technology added other actions like Diluting the probable toxic compounds in due course, fine tuning of moisture content and pH and also aids to expand the range of bacterial strains involving in the process. However, the anaerobic digestion technology, a biological process which constantly have reliance on the following environmental conditions like temperature, pH, nutrients content, C/N ratio, presence of inhibitors, substrate nature, presence of micro elements and particle size.

ANAEROBIC CO-DIGESTION TECHNOLOGY

Anaerobic Digestion of Manure with Various Co Substrates

The experiment deals with the co digestion of manure with other substrates such as energy crops, industrial wastes or food industry wastes in order to enhance the biogas production. Biochemical methane potential assays were performed for optimizing biogas and methane production. Cumulative biogas and methane were measured. Similarly, bench scale semi continuous digesters using 30l plexi glass reactors were used. 100% of dairy manure and various combinations of dairy manure and corn silage, dairy manure and whey, Dairy manure and waste grease and dairy manure and corn silage were the substrates for the experiment. The addition of only 30% co substrates enhanced methane yields by anywhere from 1.2 to 1.6 folds when compared to digestion of dairy manure alone. The experiment proves highly effective process for producing sustainable alternative energy adding co substrates to the digestion process increased methane production.

Anaerobic Co digestion with various mixing conditions- I.Digester performance

Various mixing conditions with codigestion process were evaluated through the arrangement of laboratory scale anaerobic digesters in 2litre pyrex bottles with a working volume of 1 litre. For Experiment 1, non thickened primary sludge was fed and for the experiment 2 and 3 the digesters were supplied with non thickened primary sludge and Waste Activated Sludge for digester A, Thickened waste activated sludge were added in the digester B and for Digester C combination of Primary sludge and Thickened waste activated sludge were added. Target time for retention for all the 4 digesters is 20 days. The study justified the Vigorous and continuous mixing may put off the good performance of the high solids anaerobic digesters and also proved the adequate feed distribution and the formation of new spatial associations. The experimental work demonstrated that it is possible to stabilize unstable digesters within three weeks by minimizing the mixing level.

Co digestion of Sewage sludge and Organic Fraction of Municipal Solid Wastes

About five experiments were executed in two types of experiment arrangements of 40 dm^3 bioreactor in thermophilic batch mode and two stage quasi continuous acidogenic digestion under thermophilic (56°C) and mesophilic methane fermentation (36°C). For Experiment I, Primary sludge and thickened excess activated sludge with the ratio 1:1 were added. 75% of

[1]Corresponding author

sewage sludge and 25% of Organic Fraction of Municipal solid Waste (OFMSW) were taken for experiment II. Experiment III was carried out with quasi continuous two stage arrangement with Organic Fraction of Municipal solid Waste(OFMSW) and for Experiment IV, both primary sludge and activated sludge were added in equal proportion. Experiment V handled with 75% sewage sludge and 25% OFMSW. Finally it is observed that the cumulative biogas production in the combination of sewage sludge and the OFMSW. It also gave a good reason that increasing proportion of OFMSW increased the gas production. The study results that the biological efficiency of methane production in the quasi continuous experiment IV furnished 82%,similarly experiment V offered 62.7% which was much higher than the batch experiment II of 49.3%.

Co digestion of industrial sludge with Municipal Solid wastes in anaerobic simulated landfilling reactors

Three reactors were operated for anaerobic co digestion. Reactor 1 was considered as Control reactor and fed with Organic Fraction of Municipal Solid Waste (OFMSW). Mixtures of Industrial Sludge and Organic Fraction of Municipal solid Waste (OFMSW) with equal proportions were fed in Reactor 2. One portion of Industrial Sludge and Two portions of Organic Fraction of Municipal solid Waste (OFMSW) were added in the reactor 3. All the reactors were operated with leachate recirculation at the rate of 300 ml/day in all the reactors. It was investigated that the addition of industrial sludge decreased the percentage of methane in the anaerobic simulated reactors. COD removal achieved about 93% in control reactor, 67% in run 1 and 58% in run 2.

Co digestion of potato tuber and its industrial by products with pig manure

The experiment was performed with the use of potato tuber and its industrial by products like potato stillage and potato peels in a continuously stirred tank reactors at 35° C for a codigestion with pig manure at a loading rate of $2KgVSm^3$/day. About 15-20% of potato waste occupies the feed Volatile Solids. The study also revealed that the digested materials still contained some degradable material and also liberated some appreciable amount of methane during post storage.

Anaerobic Codigestion of simulated organic fraction of Municipal Solid wastes and fats of animal and vegetable origin

The research was conducted with simulated organic fraction of municipal solid wastes in the form of diluted dry pet food, fats of animal and vegetable origin. Semi continuous flow was followed in a pilot plant, at a temperature of 37°C and the Hydraulic Retention Time (HRT) was 17 days. No significant differences in the performance of the anaerobic codigestion were observed when a fat from animal origin was suddenly changed by a fat of vegetable origin with a completely different Long Chain Fatty Acid profile. During steady state, treating a simulated Organic Fraction Municipal Solid Waste, high percentage of Total Volatile Solids removal as 73%, 0.8 m^3 biogas per kg Total Volatile Solids degraded and yielded 58% methane. Inclusion of fat of vegetable and animal origin results slight increase in methane content.

Semi continuous co digestion of solid slaughter house waste, manure and fruit and vegetable waste.

The investigation focused on the co digestion process through semi continuous and mesophilic wet digestion system processing a mixture of manure, solid slaughter house and fruit and vegetable waste. The substrate was evaluated separately through a laboratory scale using four 2L reactors under semi continuous mode at 35°C. Methane yield of 54-56% was achieved in the $0.3m^3$/KgVS added. Further increased loading showed the decreased biogas production and reduction in methane yield. Similarly, another examination was carried out with 10 different feed compositions. The digestion of mixed substrates was in all cases than that of pure substrates, with the exception of mixture of equal amounts of substrates. For all other mixtures, methane content of 50-57% after 60 days of operation were observed.

Biogas production from different substrates in an experimental continuously stirred tank reactor anaerobic digester

The study executed the anaerobic digestion by means of two combinations of substrates. First combination with chicken, pig and bovine manure, the second on animal and vegetable biomasses such as chicken, cow manure and olive husk. After carrying out physical and chemical characteristics of the substrate, two experimental campaigns have been carried out. First experimental campaign was with poultry litter(diluted in water), bovine manure(diluted in water) and a mixture of poultry litter and pig manure. For the second experimental campaign, the following mixtures were considered.M1: cow manure with piggery manure anaerobically digested as inoculum, M2:Chicken manure with piggery manure anaerobically digested as inoculum, P1: Olive husk with piggery manure anaerobically digested as inoculums and P2: Olive husk with rumen fluid as inoculum.It was observed that a good productivity for pig manure was found as 0.13 Nm^3/kgVS. Similarly, the influence of inoculums was evaluated. Combination of pig manure anaerobically digested and chicken manure, the highest methane production was found $0.11Nm^3$/kgVS whereas the rumen fluid on olive husk yielded $0.03Nm^3$/kgVS.

The study of cowdung as co substrate with rice husk in biogas production

An experimental analysis was conducted with cow dung and rice husk. The temperature 26-29°C for a period of 52 days with TS concentration of 8%. Three different combinations of sample A with 50%weight cow dung and 50% weight rice husk and B with 25%

weight cow dung and 75% weight rice husk and C with 0% weight cowdung and 100% weight rice husk. The experiments resulted that 50% cow dung and 50% rice husk showed a cumulative biogas production of 161.5ml at the end of 38th day. Rice husk does not show any significant contribution in biogas production.

Anaerobic mesophilic co-digestion of sugar beet processing waste water and beet-pulp in batch reactors

Waste water and beet pulp were fed in the batch reactor for anaerobic co digestion study where the waste water was allowed for settlement and suspended particles from the waste water were removed. Similarly, the beet pulp was dried and grinded with the pestle. Both Separate and co digestion studies were carried out with the above substrates. Basal medium was also added into the reactors to provide sufficient macro and micro nutrients. Continual mixing was applied at 175rpm by using a mechanical shaker for 38 days of operation. About 63.7%-83.7%of COD removed and 69.6%-89.3% VS were reduced which indicates high biodegradability. The biodegradability gets diminished with raised F/M ratio.

A comparative study on anaerobic co-digestion of water hyacinth with poultry litter and cow dung

The study was experimented through the addition of water hyacinth with poultry litter was conducted in series A digesters. In the same way, water hyacinth with cow dung also carried in the series B digesters. For both the experimental works, co digestion was carried out in mesophilic range of 30 to 37°C with a TS concentration of 8%.The combination of water hyacinth and poultry litter generated more biogas when compared with the mixture of water hyacinth and cow dung.

Experimental study on biogas production in batch type digester with different feed stocks

The water hyacinth, paddy chaff, bagasse were combined with cow dung to produce biogas. The paddy chaff was preheated to 90° C with mixing water 1:5 ratio with TS 7% by mixing fermented cow dung to instigate the anaerobic co digestion process. Maximum gas production was found in water hyacinth compared to paddy chaff. Presence of higher carbon content which contains a lot of cellulose, hemicelluloses, pectin, lignin and plant wax generate twice more than that of paddy chaff.

Biogas recovery from anaerobic digestion process of mixed fruit-vegetable wastes

With the intention of studying the performance of mixed fruit and vegetable wastes in a single stage fed batch anaerobic reactor for biogas production was performed. A single stage fed batch anaerobic digester with total volume of 200 litres was used. Vegetable wastes of ± 80% and Fruit wastes of ± 20% were taken on grab sampling. The codigestion experiment of the study proved the significance of utilization of mixed solid wastes of fruit and vegetables. It showed the composition of methane about 65% volume/10.4%TS with a flow rate of 20-40ml/min.

Anaerobic co-digestion of food waste and straw for biogas production

The study was carried out as codigesion experiment in 1 litre capacity anaerobic bottles at 35°C with different composition of Food waste and straw. Mixing was done by shaking at 50r/min. the total organic load of FW and straw in each group was 5gVS/L. The optimum mixing ratio of FW to straw appears to be on the point of 5:1 and the methane production yield was reached about $0.392m^3$/kgVS. The next experiment campaign was about the optimization of the straw particle sizes under the above same conditions. Five groups were organized with total organic load of 6gVS/L of which the straw sizes were 0.3mm,0.3-0.45mm,0.45-0.6mm,0.6-1mm and >1mm. The experimental study proved that the combination digestion was more than single substrate digestion. The optimal mixing ratio for the codigestion of Food Waste and Straw was found to be 5:1 and the recommended size range of straw was 0.3-1mm.

ENHANCEMENT OF CO DIGESTION THROUGH PRETREATMENTS

Anaerobic digestion has the facility to utilize different substrates for converting them into biogas and beneficial material. However, some substrates will be very slow to break down for producing biogas. It is may be due to the presence of any chemicals that inhibit the growth and activity of the microorganisms, occurrence of any physical problems like floating or foaming and also if the molecular structure of the substrate is poorly accessible to the microbes and their enzymes. Any of the above said problems may take place or all may crop up together. In order to overcome these complexity, pretreatment will be the best opportunity to crack these problems. A variety of pretreatment skills have been developed in modern existence to increase the availability for anaerobic digestion of sugars and other small molecules in lingo cellulosic substrates. The technology offers the way to create anaerobic digestion sooner, intense increase in biogas yield, exploitation of new and/or locally available substrates and put off processing tribulations such as high electricity requirements foe mixing or the development of floating layers. A single pretreatment technology will not compromise all the anaerobic digestion systems and substrates. The different pretreatment technologies stated here may be better well- matched to a particular reactor design or size of the reactor or economic situation of the region. The selection of pretreatment method is robustly reliant on substrate composition. The utmost challenge for pretreatment of biogas substrates is combining the right substrate composition with the right pretreatment technology to increase the bioavailability of the substrate. The most vital aspect for selecting a pretreatment technology are the energy balance and costs. In most cases, pretreatments with a low energy demand have a lower impact on the rate of degradation and corresponding biogas yield compared to pretreatments with high energy input. The pretreatment technologies persuade on anaerobic digestion has only been examined in recent years and there is still a need to optimize these technologies for the biogas sector. These pretreatment technologies not only endow with increased rate of anaerobic digestion and improved biogas yields but also depict lesser quantities of digestate and lower methane emissions from the digestate leading to reduced greenhouse gas emissions.

Performance Enhancement of Batch Anaerobic Digestion of Napier Grass By Alkali Pre-Treatment

Alkali pretreatment was done in order to enhance the biodegradability of lignocellulosic biomass and improved biogas production for a substrate like Napier grass (Pennisetum purpureum) which is primarily grown for grazing. Sodium hydroxide solutions of three different concentrations of 0.3%, 0.6% and 0.9% were prepared and the dried napier grass were added with solids of 5%. The dosage added in the alkaline solution in the order of 5.6g,11.2g and 16.8g NaoH/ 100g of TS Napier grass. The soaking was performed at different temperatures of 60°C, 70°C and 80°C. The duration of alkaline treatment ranges from 1-3 hours. The optimal concentration of sodium hydroxide in the form of 0.6%(w/v), the dosage of about 11.2g of NaoH/100 g TS of Napier grass, treated at a temperature of 80°C for the duration of two hours yield the gas of 0.158m^3 CH_4/kg TS under the period of 8 days of anaerobic digestion. The SCOD of the hydrolysate was about 5417 mg/l and this is due to the solubilisation of lignocellulosic biomass under alkaline conditions which subsequently increased the biodegradability and hence VFA and biogas production. It is put forward that the increased alkaline concentration may inhibit the propagation of acetogenic bacteria by rendering a toxic medium. Hence, mild alkali concentration can be an effective alternative for enhancement of biogas production for lignocellulosic biomass.

Alkaline pretreatment for enhancement of biogas production from banana stem and swine manure by anaerobic codigestion

Alkaline pretreatment was conducted for the banana stem and swine manure which was further utilized in codigestion process.The banana stems and swine manure were pretreated with 2%, 6%, and 10% (by weight)at 55 °C for 54 h using a wet-state NaOH pretreatment[17]. Batch tests were performed with codigestion of banana stem and swine manure in the digester volume was 1000 mL, with an effective volume of 500 mL. A control digester was fed with untreated banana stem and swine manure. the daily and cumulative biogas production, total biogas and methane production, overall methane content, and biogas and methane yields based on the VS loading were measured and calculated to investigate the effect of NaOH pretreatment on codigestion performance. The best biogas fermentation performance was obtained with a 6% NaOH (by weight) pretreatment as it depict the 90% of total biogas production in shortest digestion time. The TS and VS reductions were 48.5% and 70.4%, and the biogas and methane yields were 357.9 and 232.4 mL/g VS, respectively, after anaerobic digestion, which showed that the process possessed good production potential in this application.

Anaerobic digestion of poplar processing residues for methane production after alkaline treatment

Poplar, an ideal energy crop which is richer in cellulose and hemicelluloses was taken as substrate for the study. It was used as sole feedstock for anaerobic digestion and allowed for alkaline treatment. the viability of the substrate daily and total methane production, the optimal condition of pretreatment and anaerobic digestion after alkaline pretreatment and also the structure changes of the poplar processing residues were analysed during the treatment. Three NaOH doses of 3.0%, 5.0% and 7.0% based on dry matter of poplar processing residues and residues without the addition of NaoH were used in the study. After alkaline pretreatment it was followed with anaerobic digestion. The highest methane production of 271.9 L/kg VS was obtained at conditions of 35 g/L after 5.0% NaOH treatment, which was 113.8% higher than untreated one. However, methane production of 3.0% NaOH at the same concentration was 256.6 L/kg VS and only 12.1% less than that of the 5.0% NaOH. Considering the costs efficiency, the 3.0% NaOH might the optimal dose for practical applications. Changes of chemical component and structures were beneficial for the improvement of biodegradability and enhancement of methane production.

Improvement in anaerobic degradation of olive mill effluent (OME) by chemical pretreatment using batch systems

Industrial effluents containing high concentrations of phenolic compounds were used as substrate for anaerobic digestion. A chemical pretreatment was adopted to anaerobic biological degradation. This paper examined the viability of waste water generated from Oil Mill Effluent(OME). Here acid cracking was followed by coagulation –flocculation process with the aid of Alum and Iron salts. Nearly, 25-50% of the initial COD were removed from raw OME. After chemical pretreatment, for evaluating the increase in biogas production and improvement in anaerobic biological degradation, Biochemical methane potential (BMP) assay was carried out for both crude OME and chemically pretreated OME samples. During anaerobic digestion, the pretreated sample yielded more than 80% of biogas when compared with untreated sample. Not only enhancing the gas production, the chemicals also removed the colour. Similarly, iron sulphate removed the total phenol from raw OME. It was demonstrated that the biodegradability of OME could be significantly enhanced by chemical pretreatment and therefore anaerobic degradation after a suitable pretreatment could be considered as a safe disposal method for OME.

Thermal and Chemical Pre-Treatments of Cow Dung and Poultry Litter enhance biogas production in Batch Fermentation

Lignocellulosic biomasses like cowdung(CD) and poultry manure (PM) were taken as substrates and were mixed in a 4:1 ratio(CD:PM). The mixture was fed to a 0.5 litre flask for thermal pretreatment. Thermal pretreatment was carried out in two temperatures of 60°C and 80°C for 3 hours. The pretreated slurries were kept at 4°C for 24 hours. The samples which were not subjected to pretreatment treated as control. 100ml of inoculum and some quantity of distilled water were added to the Chemically pretreated slurries to obtain total solid concentration of 8%. For chemical pre-treatments, 0.45 g, 1.35 g, and 2.25 g of 6N NaOH were added into substrates in 0.5L digesters. These solutions were allowed to mixing in a rotary shaker for 1 hour to facilitate the solutions with pH levels of 9,11and 13 respectively. The samples which undergone thermal treatment for 80°C attained the Cumulative biogas production and volatile solid reduction 46.3% and 26.1% higher than that of control, respectively. Similarly the samples with chemically pretreated with 0.45 g, 1.35 g, and 2.25 g of NaOH increased cumulative biogas yield by 0.03, 21 and 56% over that of control, respectively. This study revealed that thermal and NaOH pre-treatments of the substrate mix obtained from cow dung and poultry manure in 4:1 ratio enhance VS reduction and biogas production.

Improving methane production during the anaerobic digestion of waste activated sludge: CaO-Ultrasonic pretreatment and using different seed sludges

This study was executed with three individual seed sludges, which domesticated by filter paper (SS1), food waste (SS2) and grease (SS3) for conducting anaerobic digestion of waste activated sludge (WAS) initially mixed evenly with CaO with a dose of 40mg/ g TS in a 5.0 L beaker. Then the mixed sample was splitted in an ultrasonic reactor with a working volume of 2 L. The reactor operated with two 75 W ultrasonic probes at its bottom which can produce a 20 kHz ultrasound and the samples were treated with 30 minutes. CaO-ultrasonic pretreatment for WAS was finished. After 25days, through batch experiments it was identified the CaO-ultrasound pretreatment with acdification and optimum seed sludge addition of SS3, which had a stronger ability of degrading WAS and producing methane than SS1 and SS2, can increase 68.92% of methane yield and 69.2% of VS reduction. The effective of WAS AD by SS3 a stronger. This study paved a new way for industrial application of dealing with WAS.

Study on effect of pretreatment methods on Biomethanation of water hyacinth

The study determined the effect of different pre-treatment methods on the biogas yield from water hyacinth (WH) of various forms like chopped, dried and ground water hyacinth (WH-CDG), treating water hyacinth with NaOH, dried and ground (WH-NaOH), ground WH and combining with cow dung (WH-C), ground WH and combining with poultry waste (WH-PW),ground WH combining with primary sludge(WH-PS).The different combinations of water hyacinth were added in anaerobic digesters of 250 ml capacity and the temperature was maintained at 35°C. The alkali(NaOH) treatment was effected by soaking chopped water hyacinth in 1% NaOH (by volume) solution for 2 days followed by sun drying and grinding. The resulting powder was used to prepare digester WH-NaOH. Each biodigester was given 5 gm of inoculum from an anaerobic poultry waste digester as seed. Biomethanation of these digesters were carriedout in duplication. Daily biogas production, slurry temperatures were monitored throughout the period of study. The treatment with NaOH may have aided the breakdown of the lignin and cell wall of water hyacinth with an improved pH for the methanogens to gain access to nutrients trapped in the plant. However, alkali treatment did not bring about a significant increase in biogas yield when compared with WH-CDG. The result of the study has shown that dried and chopped Water hyacinth combined with poultry waste (WH-PW) had the highest cumulative biogas yield followed by dried and chopped water hyacinth combined with primary sludge (WHPS),while the alkali treatment did not affect the biogas yield significantly. These results indicate that water hyacinth does not require chemical treatment. It also shows that drying and grinding to fine powder is a more effective pre-treatment method along with blending with poultry or primary sludge.

Effect of ultrasonic, thermal and ozone pre-treatments on waste activated sludge solubilisation and anaerobic biodegradability

In order to enhance the efficiency of anaerobic digestion, the effects of ultrasounds, ozonation and thermal pre-treatment have been studied on waste activated sludge. The feature of this study was to carry out the comparison of the three pre-treatments in the same conditions and on the same sludge sample. Each treatment was tested in two conditions close to optimum conditions to maximise batch anaerobic sludge biodegradability. All treatments were led to chemical oxygen demand and matter solubilisation and had little influence on mineral matter. It is identified that in terms of solubilisation thermal pre-treatment was better than sonication or ozonation. But, in terms of batch anaerobic biodegradability, best results were obtained with ultrasounds with an energy of 6250 or 9350 kJ/kg TS and a thermal treatment at 170° or 190°C.

CONCLUSION

This paper reviews the efficiency of co digestion and pretreatment which aids to enhance the gas production. It is believed that the exploitation of variety of different substrates will balance the substrates which has low C/N ratio. In order to accomplish waste upgrading, energy production and improvement fertilizer quality, it is vital to follow this type of co digestion.

Moreover this type of co digestion dilutes the substrate toxicity. Similarly, the other technique the pretreatment proves the viability of enhancement in biogas production. The combination of the pretreatment technologies illustrated and justified the enhancement. The utilization of the substrates with minor quantity of lignin and high carbonaceous content will prove the co digestion technology as a most feasible technology through which the wastes dumped in the society may be explored and energy recovered.

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