Anaerobic degradation of high-soild organic wastes to methane and organic fertilizers

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5.SUMMARY AND CONCLUSIONrecent years major efforts have been made to develop anaerobic fermentation processes for high-solid wastes. In the so-called 'dry anaerobic fermentation", the organic wastes are subjected to solid state fermentation at more than 20% total solids.The aim of the present study was to evaluate the processes of dry anaerobic digestion of the organic fraction of municipal solid wastes and farm wastes. The usefulness of aerobic. semi-anaerobic and anaerobic pretreatments of the organic wastes for stimulation the digestion process were also investigated. 5.1. Effect of Partial Compostina on Dry Anaerobic Fermentation of Municipal Solid Wastes.In this experiment. the organic fraction of municipal solid wastes (MSW) were subjected to 1.2 and 3 weeks of aerobic fermentation at ambient temperature t30 +4°C). Next, the aerobic pretreated wastes were subjected to batch anaerobic digestion at 355 total solids for 10 weeks. Inoculum and Ca003 were added to the pretreated wastes at the rate of 10/and 2.5% of total solids. respectively.The pretreated wastes for one week recorded the highest peaks for biogas and methane production (1.56 and 1.16 L/kg fermenting materials/day). The pretreated wastes for two weeks recorded 1.42 L biogas and 1.06 L methane, while the wastes treated for three weeks recorded 1.24 L biogas and 0.900 L methane /kg fermenting material/day. The maximum production was achieved between the 12 and 18 days of digestion for the pretreated wastes. while. 30 days for non-treated wastes.During the pretreatment period. the total bacterial count ranged from 260 to 800 mil./a. The total bacterial count after the anerobic digestion ranged between 370 and 620 mil./a.During the aerobic pretreatment. cellulose decomposingbacteria increased to reach 20x164 cell/a for aerobic and 50:410?- :or anaerobic cellulose decomposers after 2 and 3 weeks of pretreatment. respectively. After anaerobic digestion these numbers were between ;x10 and 24)(105 cell/a for aerobic. and 15x10a and 40x103 for the anerobic cellulose decomposers.The numbers of aerobic and anaerobic acid producing bacteria increased to reach 21x107 for aernbic and 14)(107 for anaerobic acid producers at the first week of pretreatment and then decreased to reach 15x106 ceil/a for aerobic and 6:4106 for anaerobic acid producers, at the 3rd week. These numbers were ranged between 12 x 104 and 40 x 104 ceii/g for aerobic and 14 x 1.0'3 and 38 x 10a for anaerobic acid producers after anaerobic digestion period.iiform aroup and Salmonella & Shigeila bacteria decreased during the pretreatment period to reach 706 cell/a for Coliformaroup and 10 cellia for Salmonella & 8hiaelia. These bacteriawere ol delec ra hit in the digested' wastes. after anaerobicdiaeszic,n.The level of volatile fatty acids concentration was low during the aerobic pretreatment period. It ranged between 22.4 and 25.6 megika, The initial pH was 6.50. decreased to 6.7 during the first week of pretreatment and then increased to 7.72 at the second week and it reached 7.88 at the third week of aerobic pretreatment. After anaerobic digestion the pH values ranged between 8.22 and 8.64.During the first 2 weeks of aerobic pretreatment, there was a gradual increase in ammoniacal nitrogen. The levels ofammoniacal nitrogen ranged between 223 to 604 mg/kg during the pretreatment period and increased to levels ranged between1016 and 1286 ma/ka after anaerobic digestion. There was a slight increase in nitrogen percentage during the pretreatment and after anaerobic di However the losses of nitrogen content was 15.29% after 3 weeks of aerobic pretreatment and this loss was ranged between 16.94 and 18.357;after the anaerobic digestion.The C/N ratio of the endproduct, after anaerobic diaestion has been reduced and reached the values of (17.17 :1) to (15.84 :1). The final percentages of total phosphorus and total potassium were between 0.4649 and 0.4883% for phosphorus and 1.0024 and 1.0754/ofor potassium depending on the period of pretreatment.The losses of both total solids (TS) and volatile solids (VS) occured during the aerobic pretreatment ranged between 10.72 and 21.07% for TS and 17.10 and 33.60% for VS. The losses of in and VS during the following anaerobic fermentation period ranged between 16.69 and 19.45% for TS and 30.01 and 33.44% for VS.The rate of bioaas production was between 35.50 and 48.56 L bioaas tkp fermented material and 205.42 and 221.02 Lika VS added and 682.76 and 756.66 Lika VS consumed. The figures of methane production from treated wastes were 143.45 and 175.56 Lika VS added and 475.62 and 525.00 Lika VS consumed. 5.2. Dry Anaerobic Fermentation of Municipal Solid Wastes Using Two Phase Process:After 1.2 and 3 weeks of semi—anaerobic fermentation period to produce the oraanic acids (acid production phase), the organic fraction of municipal solid wastes (MSW) were fermented under anaerobic conditions to proudce methane (methane production phase). The results can be summarized as follows:The highest biogas and methane peaks were detected for the-198 —wastes taken after 3 weeks of acid phase (2.7 L biocas and 1.96 L methane ika fermenting material/day). The wastes fermented after acid phase. showed also higher methane content an the biocas produced than those wastes fermented directly.The total bacterial counts ranaed between 36x107 and 76x107 ceal/g fresh welch: during the period of acid phase. whale. after the anaerobic digestion (methane phase). these numbers decreased to reach values ranged between 37x106 and 35x106 cell/g.The aerobic and anaerobic cellulose decomposing bacteria:reased during the acid phase fermentation period to reach 34x10’ ceil/g for aerobic and 62:410479for anerobic. After anaerobic digestion (methane phase). these numbers were ranaed between 12:6.0== and 48x10 cell/a for aerobic and 40x’10: and 93x.101, oeli/a fnr anaerobic cellulose decomposers. The numbers of aerobic cellulose decomposers were generally lower than those of the anaerobic ones.The numbers of aerobic and anaerobic acid producing bacteria increased to reach their maximum after one week of acid phase and then decreased to reach 24x10’ cell/a for aerobic and 26x107 cell/a for anaerobic acid producing bacteria, after 3 weeks of acid phase. These numbers decreased after methane phase to values ranged between 12x104 and 18)(105 cell/a for aerobic and 38x10m and 40:4106 cell/a for anaerobic acid producing bacteria.The counts of Coliform group and Salmonella & Shigelia, (S.5) bacteria were increased during the acid phase. After methane phase. the 53 bacteria were not detcted and the Coliform group bacteria were in the ranae of 210 to 360 cell /g only.The highest production of volatile fatty acids (VFAsi was recorded after two weeks of acid phase, reaching 142.15 meq/kg.Accumulation of 7FAs was mainly due to the formation of acetic. or picnic and butyric acids.The pH values during the acid phase confirmed theaccumulation rates of organic acids produced. It was decreased during the first week of acid phase and remain in the range of 6.12 and 6.19 during the 2nd and 3 rd week of acid phase.There was an increase in ammoniacal—nitrogen during the first week of acid phase. then the value had declined. The total nitrogen loss was ranged between 22.63 and 26.63% of the initial total nitrogen content, during both acid and methane phase.The wastes taken after one week of acid phase and fermented an methane phase lost 21.92 of total solids (TSf. while the wastes fermented after 2 and 3 weeks of acid chase lost 21.21 and.6*, of its TS. respectively. The losses of TS during the acid chase aniv were f.9f5. 9.30 and 12.966 after 1.2 and 3 weeks. respectively.The total losses of volatile solids (VS) were much higher in case of the acid phase followed by anaerobic fermentation (methane phase) indicating the following figures: 43.76, 45.26 and 48.3696 for the wastes taken after 1.2 and 3 weeks of acid chase. respectively.The efficiency of the digestion process in producing biogas from the consumed volatile solids (VS) was ranging between 832.14 and 667.0 L bioaas /kg VS consumed during methane phase only. These figures were 581.6i and 738.41 L biogasikg VS consumed during the period of acid and methane phase.The percentage of nitrogen in the final endproduct produced thl_.ugh the two phase fermentation were in the range of 1.3651and 1.3722%. Phosphorus and potassium percentage in the finished manure were in the range of 0.4712 to 0.4920% for phosphorus and 0.9558 to 0.9857;6 for potassium. 5.3. Effect of Total Solids Concentration. Bacterial Inoculum and Application of $CaCO_3$ on Dry Anaerobic Fermentation of Municipal Solid Wastes.The treatment at 35% total solids (TS) and received inocuium and $CaCO_3$ recorded the highest values of biogas and methane production, where it recorded 1.99 L biogas and 1.44 L methane/kg fermenting material/day, after 33 days of digestion. The treatment at 40S T3 produced 1.34 L biogas and 0.98 L methane /kaiday after 35 days and the treatment at 45% TS produced 1.78 L biogas and 1.27 L methane /kg/day but after 53 days of anaerobic digestion.:co considerable aas production was recorded for the wastes moistened with water. but for the wastes mixed with inoculum or CaCC%3. the production started after the first day of digestion and reacned their maximum oroduction after 58 and 60 dave. resoeciveiv.The total solids decreased in the different mixtures by variable percentages. ranging between 8.61 and 21.92% losses of the oriainal values. according to the type of the mixture. The losses of volatile solids (VS) were between 14.43 and 37.43% of the initial VS added. during the digestion period.The rate of biogas and methane production ranaed between 8.97 and 186.06) and 0.00 and 135.20 Lika total solids added. respectively. These figures were in the range of 15.03 and 323.13 L biogas and 0.00 and 234.80 L methane /ka VS added. The amounts of biogas and methane produced related to the amount of V3 consumed ranaed between 498.51 and 867.30 L biogas and 0.00 to630.01 L methane/kg VS consumed during the 70 days of digestion period. depending on the digesting mixture.The wastes mixed with inoculum and CaCO3 at 35.40 and 45% total solids showed the highest nitrogen losses, being 18.65. 20.08 and 16.76%. respectively. The wastes mixed with CaCO3 only. followed and lost 15.42 of total nitorgen (TN), while the wastes mixed with inoculum iOST 14.66 of TN and the wastes with no addition showed losses of 6.07% TN.The concentrations or nitrogen, in the digested mixtures were in the ranae of 1.3526 and 1.4110%. The C/N ratio of the endoroduct has been reduced and reached values ranged between 19.43 and 23.09. The final percentages of total phosphorus and potassium were in the ranae of 0.4743 to 0.4951% and 0.9481 to 0.976%. respectively.The Coliform group and Salmonella • Shigella bacteria were present in all mixtures before digestion. However, after anaerobic digestion, these bacteria were 110t deteCtea • 5.4. Methane Production from High Solid Wastes as Affected by Leachate RecyclingThis experiment was carried out in 20 L anaerobic digester a: a hich solid waste concentration. (2Yo TS), at 3_5c'C and witn a leachate recycling. The results obtained in this study over 7 weeks could be summarized in the following :The production of biogas and methane started from the first day of fermentaion and reached their maximum production after 25 days of fermentation, being 2.300 L biogas and 1.750 L methane/kg fermenting material/day. The biogas and methane produciton rates were 861.39 L biogas and 610.42 L methane/kg volatile solids consumed.After the first 3 weeks of digestion. the pH levels in the ieachate rose to the optimal operating range for methanogenac activity. The volatile fatty acids (VFAs) concentrations raised to 16580 mg/L after 2 weeks of fermentaion and after 6 weeks, the methane bacteria had reduced the VFAs concentration in the recycled leachate to less than 1928 mg/L. Acetic acid was the prime short—chain fatty acid produced in the leachate while propionic and butyric acids occupied the second position.The concentration of ammoniacal nitrogen increased byincreasing fermentation time to reach its maximal values after 4 weeks. being 1119.33 ppm and then decreased to reach 418.00 ppm after 7 weeks of fermentation.Total organic carbon (TOO) at the fourth week ofinvestiaation recorded more than 5 a/L and decreased to value of 0.9i6 giL at the end ofjexperiment. This means that the organic pollution load decreased by a factor of 80% in the form of bioconversion of these oraanic fractions to form the biogas.Data revealed high numbers of bacteria in the ieachate, the peak value was found to be at 2x108 ceiliml after 3 weeks of anaerobic digestion period. The numbers of anaerobic cellulose decomposers were aenerally higher than those of aerobic ones. It also reach the maximum numbers after three weeks of fermentation. The numbers of acid producing bacteria increased to reach their maximum values after 3 weeks of fermentation and then decreased to reach 3.1x10 for aerobic and 7.1x105 for anaerobic at the end of the fermentation period.The numbers of Califon bacteria started at 9x104 ceilimi. then decreased in the leachate to reach 50 cell only per ml at the end of fermentation. Salmonella and Shigella started at 190 cell/mi and decreased to reach 13 cell/mi after 4 weeks offermentation andnIstAetecteci at the fifth week of fermentation.A slight increase in total nitorcen. total phosphorus and total potassium percentages were appeared in the final organic manure. The conversion of biodegradable carbon into biogas resulted in a decrease of the carbon to nitroan ratio in the endproduct to 19.35:1. This indicateted that. the endproduct has been stabilised and is to be considered as a good soilconditioner. 5.5. Dry Anaerobic Fermentation of Farm Wastes :This experiment was conducted to evaluate the effect of different biological pretreatments. namely, aerobic, semi-anaerobic and anaerobic on biogas and organic manure production from rice straw moistened with water or mixed with cow dung at30% total solids.Different oretreatments of rice straw moistened with water or mixed with cow dung led to early production of bioaas than the control treatments. The peak amount of biogas production for the tested pretreatments type followed the order: Semi—anaerobic; anaerobic; aerobic. While. the effect of the period of pretreatment before anaerobic digestion on the biogas production followed the order: pretreated mixtures for one week> two weeksi three weeks. except in the case of rice straw mixed with cow dune under aerobic pretreatment, it followed the order two weeksi one week > three weeks.Rice straw mixed with cow dung was superior in its biogas aeneration when fermented through anaerobic. aerobic and svmi-anaerobic pretreatment for one week. Biogas production from rice straw moistened with water through any pretreatment was lower than control when the time of the pretreatment was more than one week. Rice straw moistened with water generated low concentration of methane in the biodas produced than that mixed with cow duna.Anaerobic pretreatment exhibited the greatest volatile fatty acids kVFAs) formation and followed by semi-anaerobic pretreatment. The lower VFAs formation were recorded during the aerobic pretreatment. Acetic acid is the primal short-chain fatty acid produced in all cases.pH values during the different pretreatments showed similar pattern for all treatments. being high at the beainina6.26i and then decreased within two weeks to reach pH 6.07 to 7.90 according to the type of pretreatment. The pH values were increased after that. durina the third week to reach values ranaina between pH 6.35 and 8.22.Aerobic pretreatment contained the least amount ofammoniacal-N. while anaerobic pretreatment showed the highest concentrations of it. The concentration of ammoniacal nitrogen in the different pretreatments showed more or less the same pattern beim: high or increasing durina the first one to two weeks. then decreasina to the level higher than the initial concentration.The numbers of total bacterial count. aerobic and anaerobic cellulose decomposing bacteria. aerobic and anaerobic acid producina bacteria were aeneraily higher in rice straw mixed with cow dung than in rice straw moistened with water. The numbers increased in most of the cases to reach their maximum values within 2 weeks of pretreatment. The ratio of aerobic to anaerobic cellulose decomposers was >1 during the aerobic pretreatment and <1 during semi-anaerobic or anaerobic pretreatment. There was a aood reflection of the numbers of acid producing bacteria on the concentration of volatile fatty acids in the different mixtures. This verifies the accumulation of acids and explains the decrease of their concentrations by the decrease of the numbers of acid producers.Coliform croup bacteria and Salmonella Shigeila (SS) werepresent in both mixtures of rice straw and cow dung fermented directly or pretreated before fermentation. Aerobic pretreatment reduce the numbers of Califon group and ES bacteria to numbers ranaina between 4.4x10:; and 6.2x162 cell/a for Coliform and. ii and 18 cell/a for SS bacteria. In the case of anaerobic or semi—anaerobic pretreatments. the nubmers of Conform group and 33cteria were much hiaher than those in aerobic pretreatment. After anaerobic dacestion. in the second stage. the Coliform croup and 55 bacteria were almost niorcLatecte(A -The losses of nitroaen durina the aerobic pretreatment was nigher than semi—anaerobic or anaerobic pretreatments. Rice straw moistened with water under aerobic. semi—anaerobic and anaerobic pretreatments lost 23.57. 19.77 and 16.73% of its total nitroaen contents. respectively during the period of pretreatment. The parallel figures were 23.89. 23.30 and 17.70% for rice straw mixed with cow duna at aerobic. send —anaerobic and anaerobic pretreatment. respectively. The losses in total nitrogen durina the 76 days of anaerobic digestion period was lower as compared with the losses durina the pretreatments period.The losses of total solids (Ti) and volatile solids (VS) during the pretreatment period differed very much according to :he tv oif pretreatment and the fermented mixture. The losses of 73 and VS occured during the pretreatment period ranging between 13.67 and 23.62% of TS and 15.56 and 31.80 or VS for rice straw moistened with water The parallel figures were 8.38 and 24.35% of 75 and 10.56 and 30.71% of V3 for rice straw mixed with cow dune. Losses of TS and VS during the 70 days of anaerobic digestion period were ranged between 14.51 and 23.85% of TS and. 18.88 and 31.59% of VS for rice straw moistened with water. while rice straw mixed with cow dung recorded 15.91 and 26.71% losses of Ti and. 22.11 and 32.715 losses of VS during the same period.The rate of biogas production from pretreated mixtures of rice straw and cow dung were between 85.93 and

143.10 L/kg TS added for rice straw moistened with water and. 112.67 and 178.39 L/kg TS added for rice straw mixed with cow dung. The amounts of biogas produced related to the amounts of VS added were between 121.77 and 181.94 L/kg for rice straw moistened with water and. 141.89 and 224.64 L/kg VS added for rice straw mixed with cow dung. On the other hand, the rate of biogas production related to the amounts of VS consumed during the pretreatment period and 70 days of anaerobic digestion were between 244.53 and 557.00 L/kg for rice straw moistened with water and .between 291.95 and 688.86 L/kg for rice straw mixed with cow dung.The carbon to nitroaen ratio (C/N) of the endproduct, after anaerobic digestion has been reduced and reached values ranged between 31.97 and 39 40 for rice straw moistened with water and. 27.85 and 33.10 for rice straw mixed with cow dung. The final percentages of total phosphorus and total potassium were in the range of 0.2881 and 0.3240 and, 1.3258 and 1.3722%, respectively, for biogas manure produced from rice straw moistened with water. These values were 0.3264 and 0.3472 for phosphorus and, 1.3210 and 1.3920% for potassium for the organic manure produced from rice straw mixed with cow dung.from this study, it can be concluded that municipal and agricultural wastes may be converted to biogas as well as organic manure of high value dndery the following conditions:1 - Pretreated under aerobic condition for one week.2 - pretreated under semi-anaerobic condition for three weeks.3 - Mixing them with inoculum and CaCO3.4 - Anaerobic digestion with leachate recycling.