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A Study on Anaerobic Treatment and Energy Recovery Technology of Food Waste by Using Hybrid Anaerobic Reactor

Young-Bong Yoon, Jin-Young Park*, Jin-Young Ju, Myung-Ho Kim**

Department of Civil Engineering Graduate School Chonnam National University, South Korea
**Department of Ocean and Civil Engineering. Yosu National University, South Korea*
***Department of Environmental Hygiene Engineering. Dong gang College, South Korea*

Hybrid Anaerobic Reactor를 이용한 음식물쓰레기의 혐기성처리 및 에너지 회수에 관한 연구

윤영봉 · 박진영* · 주진영 · 김명호**

전남대학교 대학원 토목공학과
*여수대학교 해양토목공학과
**동강대학 보건환경과

요 약

2005.1.1부터 직 매립 금지 이후 음식물쓰레기를 처리하는 데 있어 많은 사회적 문제가 대두되고 있다. 그리고 우리나라의 경우 전국 음식물쓰레기 배출량이 11,398ton/day[12]('03)으로 상당히 많은 양이 배출되고 있으며, 주로 음식물쓰레기는 매립, 소각, 사료나 퇴비로 재활용하는 방법으로 처리하고 일부 음식물쓰레기는 혐기성으로 처리 하는 방법이 사용되어 왔다. 이 중 혐기성 처리는 유용한 메탄가스를 발생하여 에너지로 사용가능 하다.

본 연구에서는 pH가 낮고 많은 양의 유기물과 고형물을 함유하고 있어 1단 혐기성 처리시 운전에 영향을 줄 것으로 예상되는 음식물쓰레기의 1단 혐기성처리 가능성 및 혐기성 처리시 메탄가스를 이용하여 에너지로서 사용 가능성에 대해 알아보고자 연구를 실시 하였다.

처리시간과 비용을 절감하기 위해 산형성조를 거치지 않고 반 고형물의 유입시 부유물로 인해 발생될 수 있는 plugging와 channeling 현상을 방지하기 위해 USAB(up flow anaerobic sludge blank)의 장점과 낮은 pH의 음식물 쓰레기의 유입시 미생물에 미칠 수 있는 충격을 최소화 할 수 있는 AF(anaerobic filter)장점을 조합하여 환형유공 지지막속에 그래뉼을 충진시킨 Hybrid Anaerobic Reactor(HAR)를 제작하여 실험을 실시하였다.

본 연구에 앞서 음식물쓰레기의 혐기성 생분해도 실험을 실시하여 혐기성처리가능성을 검토하였으며 실험결과 첨가된 VS량당 총 누적메탄량은 0.471(m^3/kg VS)로 원소 분석하여 얻은 이론 메탄발생량 0.58(m^3/kg VS)의 81.2%를 나타냈으며 유기물 분해속도 상수는 0.18(d^{-1})로 혐기성 처리가 가능하다는 사전 연구 결론을 도출하였다.

연구 결과, 낮은 pH인 음식물 쓰레기를 처리시 산발효조를 거치지 않고도 혐기성 처리가 가능

하였으며, 높은 농도로 존재하는 유기물 및 고형물의 처리효율은 매우 양호했고 또한 인의 제거율도 높게 나타났다. 연구결과를 토대로 전국 음식물쓰레기(11,398ton/d)를 대상으로 에너지를 산출하면 Braun[19]에너지 환산계수 5.97kwh/m3(60% CH_4)를 적용할 때 우리나라의 1일 음식물에서 발생되는 에너지 총량은 6,727MWh로 환산될 수 있으며 이는 유기물(COD)당 발생되는 메탄 가스량을 에너지원으로 사용하기에 충분히 가능하다는 것을 확인할 수 있었다.

이상의 결과에 의하면 고농도의 유기물이 함유된 음식물쓰레기는 Hybrid Anaerobic Reactor (HAR)를 이용하여 HRT 30일 정도에서 충분히 직접 혐기성처리가 가능하며, 이때 발생된 CH_4를 회수하여 이용하면 대체에너지원으로 활용 가치가 높은 것으로 판단된다.

Keywords : Biochemical Methane Potential (BMP), Christensen Oil Equivalents, Food Waste, Hybrid Anaerobic Reactor (HAR), Organic Removal Constant (K), Ton Oil Equivalent (TOE)

Ⅰ. INTRODUCTION

The amount of domestic waste generated in Korea was 42,918ton/day ('03) and the total production of food waste was about 11,398ton /day('03), over 30% of domestic waste. The storage, transportation and landfill of food waste caused the problems of secondary pollution by odor and harmful insects. Also, the ground water was polluted by leachate, because the food waste had high water content and easily decayed. In addition, the method of landfill causing social problems was prevented to treat food waste in the first of January 2005.

So, anaerobic digestion is an important method to treat food waste because of possibility of energy recovery as methane gas.

In this study, the possibility of food waste treatment containing high organic material and low pH in the one stage anaerobic reactor to save cost and time and energy recovery using CH4 gas by the hybrid anaerobic reactor (HAR) was measured.

From other studies, operation is not easy due to limited factors such as pH and Cl concentrations in anaerobic treatment. Also, it is not easy to treat food waste in anaerobic treatment due to containing organic matter of high concentration without processing both acid fermentation and methane formation

High Cl concentrations and a low pH of food waste, poisonous factors, could be effected in anaerobic treatment.

The HAR was designed by combing the merits of the anaerobic filter (AF) to minimize the microorganism shock when food waste of very low pH was injected and up anaerobic sludge blanket (UASB) to prevent from plugging and channeling phenomena by large suspended solids when semi solids were injected. Granule was packed in the section of HAR.

Ⅱ. EXPERIMENT MATERIALS AND METHODS

1. Generation of food waste and characteristic in Korea

Table 1 shows statistics of food waste generation in Korea. Table 2 shows the physical and chemical characteristics of food waste in Korea, and the results of food waste from the dormitory cafeteria at Chonnam National University. Compared to other studies, the C/N ratio was a little low and S ratio was higher. Table 3 shows the analysis results of heavy metals and trace metals of food waste of the HAR. In analyzing food waste, heavy metals such as As, Cd, Hg and Pb didn't exist in the analysis results, but some metals such as Fe, Zn, Na^+, K^- and Ca^{2+} existed. Above heavy metals were analyzed an automatic absorption spectrometer (model spectr AA 300)

2. Equipment-Hybrid Anaerobic Reactor (HAR)

The HAR, which has the combined merits of AF and UASB, brings high removal efficiencies, can treat various and exchangeable wastewater, and operate in little space at a little cost. This reactor consists of influent parts, a mixer, a packed layer, a reactor and effluent parts. Also, the total volume was 62L and net volume was 30L.

In addition, height was 600mm and outside diameter was 340mm. The material of acryl was used. Granule, the packed layer, was 350mm from bottom to top, 180mm from the outside diameter to the inner diameter. Fig.1 shows a schematic diagram of the HAR. It had many holes whose diameter was 3mm. Food waste also was mixed for 24 hours by a slow mixer in order to mix well, to contact well, and then crush, necessary. Food waste was injected once a day.

Table 1. Generation of food waste by City in Korea

(unit : ton/day)

	City	'03
Food waste	Seoul	2,599.3
	Pusan	934.6
	Taegu	550.0
	Inchon	726.7
	Kwangju	345.9
	Taejon	394.7
	Ulsan	267.9
	Kyonggi	2,314.6
	Kangwon	356.5
	Chungbuk	260.9
	Chungnam	455.3
	Chonbok	402.2
	Chonnam	372.7
	Kyongbuk	563.6
	Kyongnam	719.5
	Cheju	134.0
	Total	11,398.4

Table 2. Characteristics of food waste in Korea

Sample	C/N	Elemental Analysis(%,w/w)				
		C	H	O	N	S
Mixed Food	9.0	48.9	8.0	36.5	5.5	1.2
Grain	15.2	43.3	7.6	45.0	2.9	1.3
Vegetable	11.4	47.1	7.3	40.1	4.2	1.4
Meat	7.5	47.6	7.7	36.8	6.4	1.5

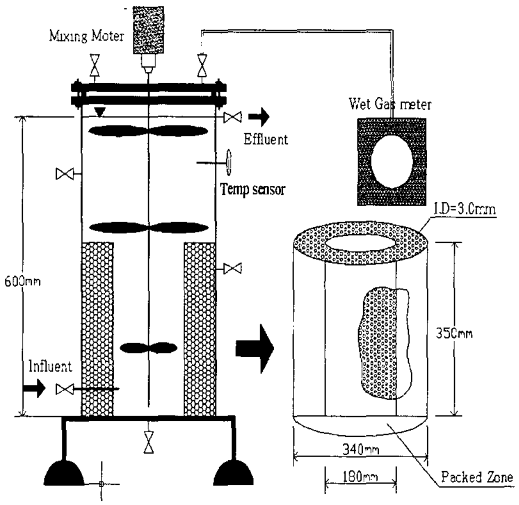

Fig. 1 The structure of the Hybrid Anaerobic Reactor

3. Analysis Methods and Characteristics of Influent.

This experiment was measured on the basis

Table 3. Analysis results of Heavy Metals & Trace Metals in food waste

	Heavy Metals						Trace Metals							
Item	As	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Zn	Mg	Na	Ni	k	Ca
Value(mg/L)	0	0	1.6	2.5	10.9	0	1.5	0	6.7	293	4,853	0.1	2218	1,202

of standard methods and environmental pollution official methods (Korea). The CODcr concentration was ranged from 750,000mg/L to 115,000mg/L. In this experiment, homogeneity of a sample of influent was required and we kept it in 55℃ refrigerator. Table 4 show characteristics of food waste as influent.

4. Biochemical Methane Potential (BMP) Test Using Respirometer

The purpose of the BMP experiment was to measure the amount of methane generated when organic material was resolved under anaerobic conditions, to grasp bio resolution of organic material. This experiment involved controlling temperature, pH and nourishment, in order to promote generation of methane under the good condition of microorganism growth. We also measured the generation rate by the generation of accumulated methane of Chonnam University dormitory. We could measure the total amount of gas by respirometer and gas analysis using GC shimadzu 4C and TCD. 500mL Serum bottles were used for BMP experiment anaerobic microorganisms and nutriments were injected and made good conditions such as temperature and pH.

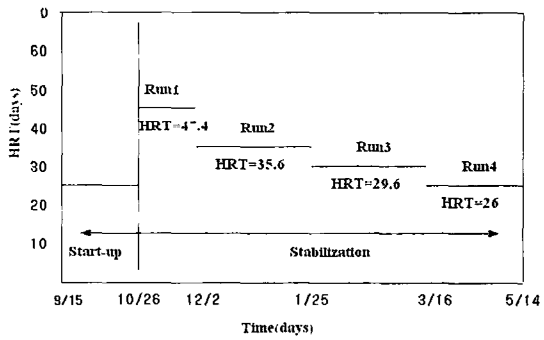

Fig. 2 Changes of HRT

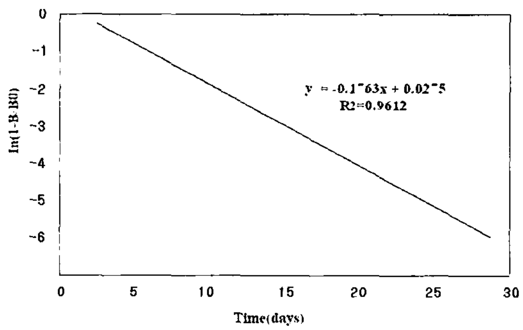

Fig. 3 Results of BMP test with food waste

5. Operating of Hybrid Anaerobic Reactor

In the operating of the HAR, four steps (Run1, Run2, Run3, Run4) for stabilization were conducted according to the HRT (47.4d, 35.6d, 29.6d and 26d). A granule packed layer was brought in anaerobic digestion of OB beer factory. After packing, it adapted to original food waste during 100days and granule could be adapted to food waste after 40 days with HRT (23.7days). Table 5 shows changes of the loading rate according to the HRT. Fig.2 shows changes of Loading Rate according to the HRT.

Ⅲ. RESULTS AND DISCUSION

1. Results of BMP test

From the results of BMP Test about MSW (Municipal Solid Waste), amount of methane gas

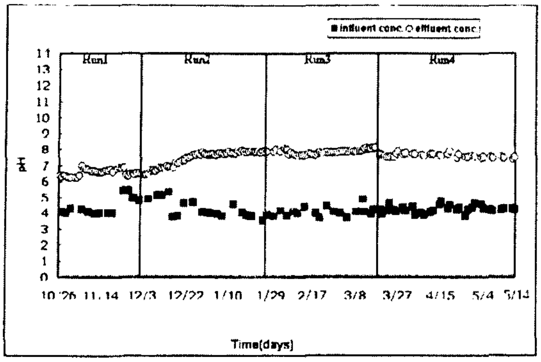

Fig. 4 Changes of pH in HAR

Table 5. Changes of the loading rate according to the HRT

Items	Start up	Step			
		Run1	Run2	Run3	Run4
Operating day	9/15~10/25	10/26~12/1	12/2~1/24	1/25~3/15	3/16~5/14
HRT(day)	23.7	47.4	35.6	29.6	26
Loading rate ($CODg/m^3$ -d)	15.0	14.5	11.4	11.2	11.6
Loading rate (VSg/m^3 -d)	7.3	7.4	4.6	5.6	4.7

was 0.168~0.222(m^3/kg VS) in Owens and Chnoweth's studies and 0.38~0.44(m^3/kg VS) in Chae's study. In this experiment, the total accumulated methane production per VS amount was 0.471(m^3/kg VS).

So the value was 81.2% of theoretical generation of methane, which was 0.58(m^3/kg VS) by the elementary analysis of food waste in the dormitory of Chonnam University. Shin showed that the organic removal constant (K) was 0.29(d^{-1}) in grains, 0.16(d^{-1}) in vegetables and 0.1(d^{-1}) in meats. Choi demonstrated that it was 0.1(d^{-1}) in food waste but it was 0.18(d^{-1}) in this experiment. As the above results show, it was possible to treat of food waste in the dormitory of Chonnam University under anaerobic conditions. Fig. 3 shows the results of BMP test with food waste.

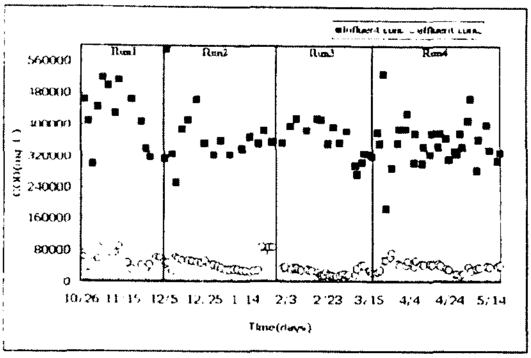

Fig. 5 Changes of CODcr and efficiency in HAR

2. pH

pH maintained 6.5-7.5 without controlling pH, inputting some chemicals to keep the degree of alkalinity. Fig. 4 shows total changes of pH in HAR.

Table 4. Characteristic of food waste as Influent (unit: except pH, all mg/L)

Items	Food waste		
	Max.value	Min.value	Ave.value
pH	5.23	3.54	4.23
CODcr	750,000	115,000	389,698
SCODcr	675,000	65,000	177,978
TS	500,875	95,125	200,113
VS	480,000	72,875	171,253
TSS	181,159	64,500	129,840
VSS	172,860	59,000	122,714
T-N	214,339	296,6	11,024
TKN	213,330	2,171	10,352
NO_2-N	77	11	22
NO_3-N	1,810	368	820
NH_3-N	882	175	444
PO_4-P	4,418	432	800
SO_4^{2-}	19,531	921	9,618
Cl^-	24,644	1,127	6,337

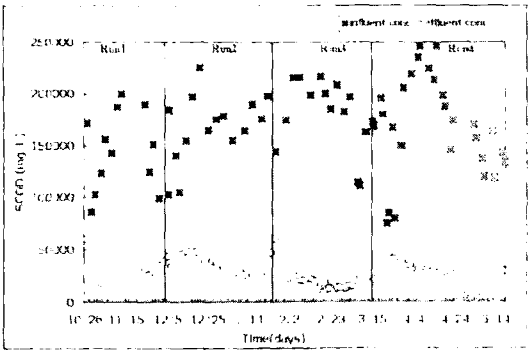

Fig. 6 Changes of SCODcr and efficiency in HAR

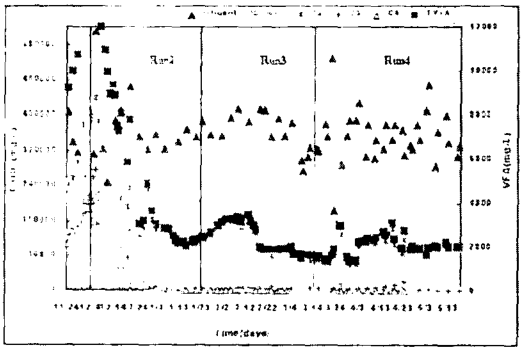

Fig. 7 Relationship between VFA and Influent CODcr

3. Removal of organic materials

While operating this reactor, the removal of organic materials varied according to the influent CODcr concentration and HRT. During the adapting period, we diluted original food waste, operated for 100 days to adapt food waste and the CODcr influent concentration was 8,000~25,000mg/L. The average influent and effluent CODcr concentration and removal efficiency in Run1 were respectively 464,000mg/L, 54,528mg/L and 88%. The influent and effluent SCODcr concentration and removal efficiency in Run1 were 90,507mg/L, 38,983mg/L and 79%. The average influent and effluent CODcr concentration and removal efficiency in Run2 were 363,316mg/L, 40,811mg/L and 88%. Also, the average influent and effluent SCODcr concentration and removal efficiency in Run2 were 180,757mg/L, 34,118mg/L and 81%. The average influent and effluent CODcr concentration and removal efficiency in Run3 were 357,283mg/L, 24,633mg/L and 93%. The average influent and effluent SCODcr concentration and removal efficiency in Run3 were 179,018mg/L, 17,526mg/L and 90%. The average influent and effluent CODcr concentration and removal efficiency in Run4 were 363,316mg/L, 40,811mg/L and 88%. The average influent and effluent CODcr concentration and removal efficiency in Run4 were 364,650mg/L, 39,087mg/L and 89%. The average influent and effluent SCODcr concentration and removal efficiency in Run4 were 173,726mg/L, 29,946mg/L and 28%.

From the above results, the CODcr and SCODcr removal efficiency in Run3 were respectively 93% and 90%. Fig. 5 and 6 show changes and efficiency of CODcr and changes and efficiency of SCODcr in a HAR.

4. Removal efficiency of solid material

The average influent TS concentration in Run1, Run2, Run3 and Run4 was 271,716mg/L, 168,083mg/L, 196,322mg/L and 59,313mg/L. The average effluent TS concentration was 14,357 mg/L, 17,918mg/L, 29,420mg/L and 30,952mg/L. The TS removal efficiencies were 94%, 89%, 85% and 80%. The average influent VS concentration was 222,830mg/L, 146,605mg/L, 178,085 mg/L and 148,691mg/L. The effluent VS average concentration was 9,943mg/L, 11,825mg/L, 18,104mg/L and 25,127mg/L. The VS removal efficiency was 95%, 91%, 89% and 83%.

As HRT decreased, the solid material removal efficiency decreased more and more. Finally, it decreased significantly in Run4. However, the TS and VS removal efficiency was 85% and

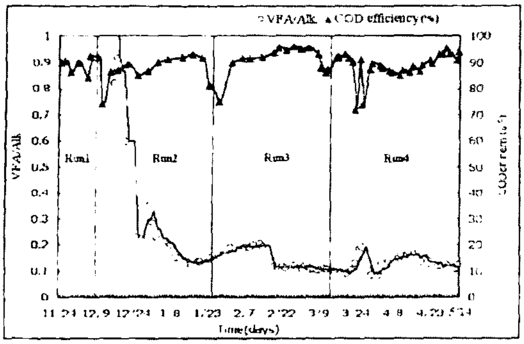

Fig. 8 CODcr efficiencies vs VFA/ALK.

89% in Run3 and a good removal efficiency shown in the HAR.

5. Relationship between VFA, Alkalinity and NH_3

TVA(Total Volatile Acid) can be divided into two parts: IVA(Ionized Volatile Acid) and UVA(Unionized Volatile Acid). The hindrance action of pH in a reactor was decided by UVA. Fig. 7 shows influent CODcr concentration and VFA(Volatile Fatty Acid, C2:acetic, C3:propionic, C4:butytic). Fig. 8 shows CODcr efficiencies vs VFA/ALK. Generally, when the VA/ALK. Ratio was over 0.3~0.4, it has to be controlled because the pH may be decreased[12]. According to Lee's study[8], the VA/ALK, ratio was 0.2~0.7 to remove the organic material effectively. In operating the reactor, the VA/ALK, ratio was the average 1.5 during the first stage and 0.13 in Run3.

NH3 N concentration was 278mg/L, 629 mg/L,637mg/L and 1.341mg/L in Run1, Run2, Run3 and Run4. Because food waste itself has a high protein containment ratio, TA was 5.522mg/L, 14,768mg/L,16,461mg/L and 16,359 mg/L. However, the average CH4 generation per day was 0.14, 0.22, 0.20 and 0.19(m^3 CH_4/kg CODcr). Therefore, there was no effect of gas generation.

6. Gas generation and energy calculation

Table 6 shows the theoretical value and experimental value of CH_4 content and CH_4 generation. The average CH_4 gas generation on Run1, Run2, Run3 and Run4 was 0.14, 0.22, 0.20 and 0.19(m^3 CH_4/kg CODcr d) and CH_4 generation per CODcr removed was 0.18, 0.25, 0.23 and 0.21(m^3 CH_4/kg CODcr rem). So the value was about 53%, 71%, 66% and 66% of theoretical gas production, which was 0.35(m^3 CH_4/kg CODcr rem). Also, CH_4 generation per VS added on Run1, Run2, Run3 and Run4 was respectively 0.35, 0.50, 0.42 and 0.43(m^3 CH4/kg VS added). When results of a chemical ultimate analysis of food waste substitute(C : H : N : S = 48.7 : 8.0 : 36.5 : 5.5 : 1.2), the theoretical CH4 generation is 0.58 m^3 CH_4/kg VS. So, the value was 60.3%, 86.2%, 72.4% and 74.1% of the theoretical value. We could estimate total CH_4 generation from total food waste, which was 1,398 ton/day in Korea and converse to TOE/day and MWh/day. Using a result based on operating the HAR, we could calculate that methane gas generation was 953,221m^3 CH_4/day. By using the oil equivalence conversion factor and energy conversion factor, it is 998TOE(ton oil equivalent/d) and 5.97KWh/m^3 CH_4, 60% of CH_4 gas generation and is 6,727MWh/day according to Braun's study. Table 7 shows the conversion result based on outcome after operating the HAR to estimate food waste generation per day of each city in 2003.

7. PO_4-P removal

The average influent PO_4-P concentration in Run1, Run2, Run3 and Run4 was 1,165mg/L, 565mg/L, 712mg/L and 516mg/L. The average effluent PO_4-P concentration was 163mg/L, 178mg/L, 156mg/L and 273mg/L. The removal

Table 6. Results of HAR operation(all average value)

Items	Step			
	Run1	Run2	Run3	Run4
HRT(day)	47.4	35.6	29.6	26
CODcr removal(%)	88	88	93	89
VS removal(%)	95	91	89	83
CH_4 content(%)	58.5	63.3	62.7	60.9
CH_4 production(L/d)	62.7	80.2	72.6	70.5
CH_4 yield(m^3 CH_4/ kg CODcr .d)	0.14	0.22	0.20	0.19
CH_4 yield(m^3 CH_4/ kg CODcr rem)	0.18	0.25	0.23	0.23
CH_4 yield(m^3 CH_4/ kg VS add)	0.35	0.52	0.42	0.48
Theoretical value / Experimental value(%)	51.4	71.4	65.7	65.7

Table 7. Energy production of food waste in HAR

Province	'03 (Produced food waste)	Energy	
		TOE/day	MWh/day
Seoul	2,599.3	227.3	1,534.3
Pusan	934.6	81.7	551.7
Taegu	550.0	47.8	324.4
Inchon	726.7	64.0	428.9
Kwangju	345.9	30.1	204.4
Taejon	394.7	34.1	233.2
Ulsan	267.9	23.4	157.8
Kyonggi	2,314.6	203.1	1,365.5
Kangwon	356.5	31.0	210.8
Chungbuk	260.9	22.8	154.0
Chungnam	455.3	39.7	268.8
Chonbok	402.2	35.3	236.9
Chonnam	372.7	32.8	220.3
Kyongbuk	563.6	49.7	332.9
Kyongnam	719.5	63.3	424.5
Cheju	134.0	11.5	78.9
Total	11,398.4	998	6,727

(TOE/day : ton oil equivalent/ day, MWh/day: mega watt hour/day)

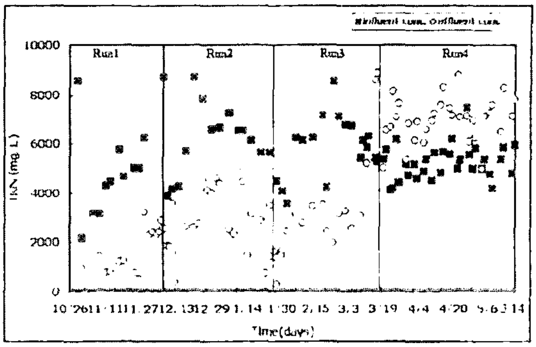

Fig. 9 Changes of TKN and efficiency in HAR

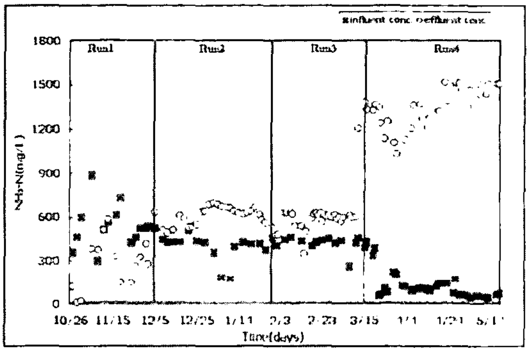

Fig. 10 Changes of NH_3-N and efficiency in HAR

efficiency was 85%, 68%, 78% and 47%. In PO_4-P removal efficiency, it had good removal efficiencies in spite of shorting HRT.

8. Changes of TKN, NH_3-N

The average influent NH3 N concentration in Run1, Run2, Run3 and Run4 was 533mg/L, 373mg/L, 417mg/L and 122mg/L. The average effluent NH_3-N concentration was 278mg/L, 628mg/L, 636mg/L and 1,034mg/L. The NH_3-N removal efficiency in Run1 was 47% but effluent concentration was high in Run2, Run3 and Run4. Fig. 9 and Fig. 10 show changes of TKN and NH_3-N Concentration in HAR.

9. Changes of SO_4^{2-} & Cl^-

According to Shin's study[17], on the stage of

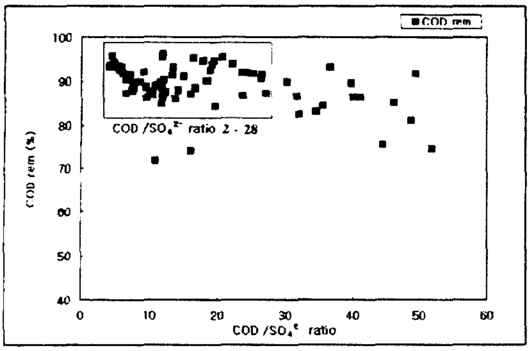

Fig. 11 Relationship between CODcr/SO_4^{2-} Ratio CODcr removal efficiency

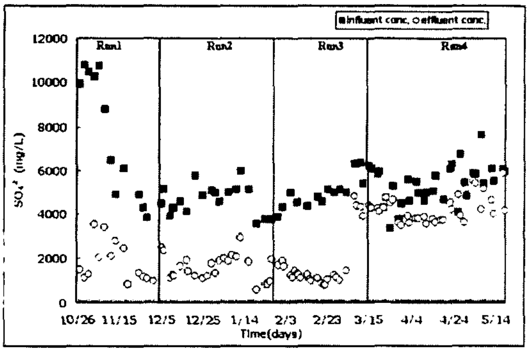

Fig. 12 Changes of SO_4^{2-} and Efficiency in HAR

acid generation, the utility rate of glucose showed the first reaction. Gas generation and a stroma utility speed were not effected below 6,000mg/L sulfate concentration. In Shin's study[16], when sulfate and sulfide were injected at the same time, methane generation bacteria were more affected than acid generation bacteria. Even when SO_4^{2-} was 6g/L, methane generation bacteria were not affected. In the case of sulfide, it almost was not be affected by 200mg/L. But when SO_4^{2} was over 400mg/L, it was affected. According to Isa's study, when SO_4^{2-} was 5 to 20g/L, generally SO_4^{2-} was nearly no affected in the methane generation stage. However, over 2-4g SO_4^{2-}/L was affected in the acid generation stage.

As shown by the results, it was determined that sulfate in food waste was not a high enough concentration to disturb anaerobic operating. The removal efficiency in Run3 was about 57% and removal efficiency in Run4 was decreased in relation to decreasing HRT.

The average influent SO_4^{2-} concentration in R1, R2, R3 and R4 was 9,089mg/L, 4,900mg/L, 5,316mg/L and 5,157mg/L and the average effluent concentration was 1,838mg/L, 1,650mg/L, 1,905mg/L and 4,264mg/L. The removal efficiency was 79%, 66%, 64% and 17%.

Harade's got good results when the influent SO_4^{2-} concentration was 2,000 4,000mg/L and CODcr/SO_4^{2-} ratio was over 7.5-10 in neutral pH. As each sulfate concentration was 30, 150 and 600mg/L, CODcr was reduced as a result of 5, 30 and 40-75% each. Rintala showed that a reactor, which had a high CODcr/SO_4^{2-} ratio of influent water, could remove over 80% of sulfate. It can also remove 20 50% of sulfate under the low CODcr/SO_4^{2-} ratio. Also, a hindrance of S happened when the CODcr/SO_4^{2-} ratio was over 10.

Choi's and Rim showed that the influent acetate CODcr concentration of SGCS (suspended growth contact system) about studying of CODcr/SO_4^{2-} ratio was 2,000mg/L through an anaerobic process. The concentration of SO_4^{2-} was 1.0-13.3. The maximum sulfate removal efficiency was shown when the CODcr/SO_4^{2-} ratio was 1.7 and the maxim CODcr removal efficiency was 2.7. When CODcr/SO_4^{2-} ratio was 1, CH_4 was not generated. As the ratio was gradual, CH_4 increased.

As shown by the above data, the CODcr/SO_4^{2-} ratio was regarded as an important influence coefficient. But in this experiment, the CODcr/SO_4^{2-} ratio ranged 2 to 50. A good removal efficiency of CH_4 was shown in all stages because the influent CODcr concentration was very high. Fig. 12 shows the relationship between CODcr/SO_4^{2-} ratio and CODcr removal

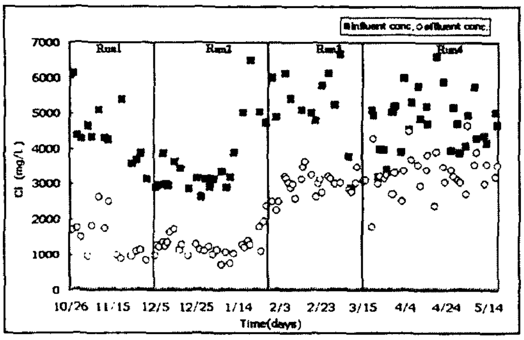

Fig. 13 Changes of Cl Concentration in HAR

efficiency.

Shin's study[17] showed some disturbing trends in inorganic material in the acid formation stage. It was possible to treat the inorganic material under an anaerobic condition when Cl was blow 5,000mg/L.

The maximum Cl^- concentration of food waste was about 9,000mg/L, which didn't disturb the anaerobic operating. In this study, the average concentration of influent Cl in R1, R2, R3 and R4 was 5328mg/L, 3668mg/L, 9157mg/L and 5355mg/L. The average concentration of influent Cl was 1,467mg/L, 1,156mg/L, 3,049mg/L and 3,525mg/L. The removal efficiency was 72%, 68%, 66% and 39%. From the above results, the removal efficiency of Cl decreased according to decreased amounts of HRT. Fig. 12 and Fig. 13 show changes of SO_4^{2-} and Cl^- Concentration in HRT.

Ⅳ. CONCLUSION

In this study, we explored that the possibility of food waste treatment containing high organic material and measured the possibility of energy recovery using CH_4 gas by the hybrid anaerobic reactor.

The results of the study are as follows;

1. Prior to this experiment, we checked the proprieties of treating food waste as an influent under anaerobic conditions, through the bio-resolution of an anaerobic treatment. As a result, the total accumulated methane volume of VS volume ratio was 0.471(m^3/kg VS); theoretical methane generation through elementary analysis was 81.2% of 0.58(m^3/kg VS). Since removal velocity of organic material(k) was 0.18(d^{-1}), it was possible to treat food waste using anaerobic treatment.
2. pH maintained 6.5-7.5 in Run1, Run2, Run3 and Run4 under the anaerobic treatment, without controlling pH and inputting some chemicals to maintain the degree of alkalinity.
3. The concentration of influent and effluent in Run3 were 357,283mg/L, 24,633mg/L and removal efficiency of COD was 93%. The concentration of influent and effluent SCODcr were 179,018mg/L, 17,526mg/L and removal efficiency of SCOD was 90%. In Run3, CODcr removal efficiency had good results.
4. The average CH_4 gas generation in Run4 was 0.19(m^3 CH_4/kg CODcr rem) and CH_4 generation per CODcr removed was 0.21(m^3 CH_4/kg CODcr rem). The value was about 66% of theoretical gas production, which was 0.35(m^3 CH_4/kg CODcr rem). Using a result based on operating the HAR, we could calculate that methane gas generation was 953,221 m^3 CH_4/day.
5. The influent and effluent concentration and removal efficiency of PO4 P in Run3 were 712mg/L, 156mg/L and removal efficiency was 78%.
6. The influent and effluent concentration of NH3 H in Run3 was 417mg/L and 636mg/L and high effluent concentration was showed.
7. The influent and effluent concentration and removal efficiency of SO_4^{2-} in Run3 were 5,316mg/L, 1,905mg/L and 64%. There was no

disturbing effect of SO_4^{2-} and Cl^- in this experiment.

As a result, it is possible to treat food waste, with a high concentration of organic matter, using the HAR for HRT 30 days under an anaerobic condition.

V. Abstract

The total production of food waste was about 11,398ton/day('03) in Korea. Also, food waste was treated by landfill, incineration, reuse and anaerobic digestion. The method of food waste treatment depended primarily on landfill. However, the method of landfill causing social problems was prevented to treat food waste in the first of January 2005.12)
Thus, anaerobic digestion is an important method to treat food waste because of possibility of energy recovery as methane gas.

In this study, the possibility of food waste treatment containing high organic material and low pH in the one stage anaerobic reactor to save cost and time and energy recovery using CH_4 gas by the hybrid anaerobic reactor (HAR) was measured.

The HAR was designed by combing the merits of the anaerobic filter (AF) to minimize the microorganism shock when food waste of very low pH was injected and up-flow anaerobic sludge blanket (UASB) to prevent from plugging and channeling phenomena by large suspended solids when semi solids were injected. Granule was packed in the section of HAR.

The purpose of the BMP experiment was to measure the amount of methane generated when organic material was resolved under anaerobic conditions, to grasp bio resolution of organic material. Total accumulated methane production per VS amount was 0.471(m^3/kg VS). So, the value was about 81.2% of theoretical methane production which was 0.58(m^3/kg VS) by elementary analysis and organic matter removal velocity (K) was 0.18(d^{-1}). From these results, food waste was treated by anaerobic treatment.

From this study, CH_4 generation from food waste (11,398 ton/day) could be estimated. By using an energy conversion factor of Braun's study, 5.97KWh/㎥ CH4, 60% of CH_4 gas generation, the amount of total energy producing food waste is to 6,727MWh/day. It could be confirmed that energy recovery using CH_4 gas was possible.

Above these results, food waste containing organic matters of high concentration could be treated in HRT 30 days under an anaerobic condition, using the hybrid anaerobic reactor and reuse of CH_4 gas was possible.

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