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RESEARCH ARTICLE

A STUDY ON AEROBIC BIODEGRADATION (AT_4) ACCORDING TO MIXING RATIO OF SLUDGE AND SAWDUST

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ABSTRACT

Although the consumption of fossil fuels is rapidly increasing, the development of other energy sources to replace fossil fuels is still insufficient. In this situation, marine reclamation of organic wastes is banned, and research on the fuel conversion using organic wastes is being actively carried out. Among them, fuelization using sewage sludge is progressing, but high water content and biodegradability of sewage sludge are a problem of conversion to fuel. So a method of mixing biomass is used. In this study, the biodegradability was measured according to the mixing ratio of sewage sludge and sawdust using AT_4 test. As the ratio of sewage sludge in the mixture increased, the biodegradability of sewage sludge was increased up to 49.35 g O_2/kg DM considering the biodegradability of sawdust. When the sewage sludge was more than 70%, the biodegradability of the mixture exceeded raw sample (54.67 g O_2/ kg DM).

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INTRODUCTION

Although the consumption of fossil fuels including coal and petroleum is rapidly increasing due to the rapid increase of energy demand due to the economic development and population, the development of other energy sources that can replace fossil fuels is insufficient (Lee *et al*., 2013). Many efforts are being made to develop and disseminate renewable energy around the world because of observing the Climate Change Convention to prevent global warming and increasing the price of fossil fuels. The government has set a target of 5% renewable energy supply by 2020 through the 4th Renewable Energy Basic Plan, and has set about 70% target for waste and biomass (Ministry of Trade, 2016). As a result, interest and demand for biomass is gradually increasing in terms of renewable energy that forms carbon equilibrium (Lim *et al*., 2014). Biomass which has a very high potential as an energy resource means organic matter of living animals, plants and microorganisms. Biomass has been attracting much attention because it can be used in all regions and has the advantage of using existing energy resources. However, biodiesel and bioethanol, which are widely used in many countries, are produced from grain, which are food resources and cause the shortage of food supply (Gwon *et al*., 2011). As a result of the problem, much effort has been devoted to the use of non-edible biomass resources. In recent years, the meaning of biomass has expanded to include organic wastes (such as sawdust, rice straw, agricultural waste, sewage sludge, and livestock manure) from all industrial activities (Kim, 2015). In particular, in the case of organic wastes including sewage sludge, marine dumping is totally prohibited due to '96 Protocol' of the London Convention. Environmental treatment of sewage sludge but also the biomass that can be secured in Korea, the research on the fuelization through the recycling of sewage sludge is being actively carried out. However, sewage sludge is an organic waste with a high water content and high biodegradability, so it has considerable problems in the production and storage of solid fuel, such as the generation of odor by aerobic microorganisms and deterioration of fuel quality. In order to solve the problems of high water content, mixing of low moisture content biomass before drying, can reduce the water content and economically treat wastes requiring treatment simultaneously. In addition, AT_4 analysis of biomass known from previous studies shows that sawdust has relatively low AT_4 as compared to sewage sludge. So, high biodegradability of sewage sludge can be expected to decrease through mixing. In this study, changes in biodegradation will be observed according to the mixing ratio of sewage sludge and sawdust, which were mixed to reduce water content. The changes of biodegradability of sewage sludge in the mixture

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considering the biodegradability of sawdust will be also investigated.

MATERIALS AND METHODS

Material

Sewage sludge used in this study was collected from a dewatering plant at a sewage treatment plant in Incheon. Sawdust used as a mixing material was supplied by a sewage sludge fuel producing company. The samples were collected by the conical quartering method of the waste process test method in Korea and transported to the laboratory within 24 hours. Sewage sludge and sawdust were mixed with 50%: 50% to 90%: 10%, because aim was to produce fuel through treatment of sludge. The biodegradability analysis was performed according to the mixing ratio.

Basic Properties Analysis

Proximate analysis and elemental analysis were conducted to analyze the basic properties of the samples. The proximate analysis analyzed moisture, ash, volatile matter, and fixed carbon content by ‘Methods for analysis of solid refuse fuel product quality test’ in Korea. The contents of C, H, N and S were analyzed by elemental analyzer (FLASH 1112, Thermo Fisher Scientific), and the content of O was calculated by subtracting the content of each component from the total content. The low calorific value conversion was carried out through element composition.

Aerobic biodegradabilit-AT_4

AT_4 (respiration activity) is an assessment of instantaneous oxygen consumption of waste and is being evaluated as a suitable stabilization assessment method as a standardized stabilization indicator in Germany and Austria (Kim *et al.*, 2009). AT_4 was used to evaluate the biodegradability of the biomass mixture. Reduced pressure was measured using a WTW Oxitop controller OC110 analyzer as a principle of absorbing carbon dioxide produced by aerobic microorganisms into soda lime, an absorbent, to estimate the oxygen consumed from the reduced pressure.

To determine the degree of biodegradation, the maximum water holding capacity (WHC) of the dried sample was 50 to 70%. Then, the sample and the absorbent, NaOH, were placed in a 1000 ml analytical bottle, sealed and incubated at 20°C for 4 days (96 hours). The reduced pressure was converted to g O_2 consumption per dry sample weight by following equation (Myszograj *et al.*, 2013; Myszograj *et al.*, 2014; Ryul *et al.*, 2011).

$$AT_4 = \frac{M_R \times V \times \Delta\rho}{R \times T \times DM} \qquad (1)$$

AT_4= Respiration index (mg O_2/g DM)
MR = Molar mass of O_2 (32,000mg/mol)
V = Free gas volume (L)
Δρ = Degrease of pressure in the bottle
R = Ideal gas constant (0.082061 L・atm/mol・K)
T = Temperature of incubator (K)
DM = Dry mass of the sampling (g)

$$\mathrm{DM} = DM_W \times \frac{TS}{100\%} \qquad (2)$$

DM_W = mass of dry substrate (g)
TS = content of dry mass in a sample (%)

Biomass content analysis

Biomass testing methods include manual sorting and selective dissolution method (SDM). The method of analysis is determined by the particle size and component of the waste. When the particle size of the waste is more than 10mm, the biomass content is analyzed by manual sorting method. However, in this study, the selective dissolution method (SDM) was used because the biomass is less than 10mm. The SDM is based on the fact that the biomass is oxidized at a faster rate than the non-biomass by using the dissolution rates of 80% H_2SO_4 and 35% H_2O_2. So the biomass is selectively dissolved, it is a method using the principle that remains (Park *et al.*, 2012)

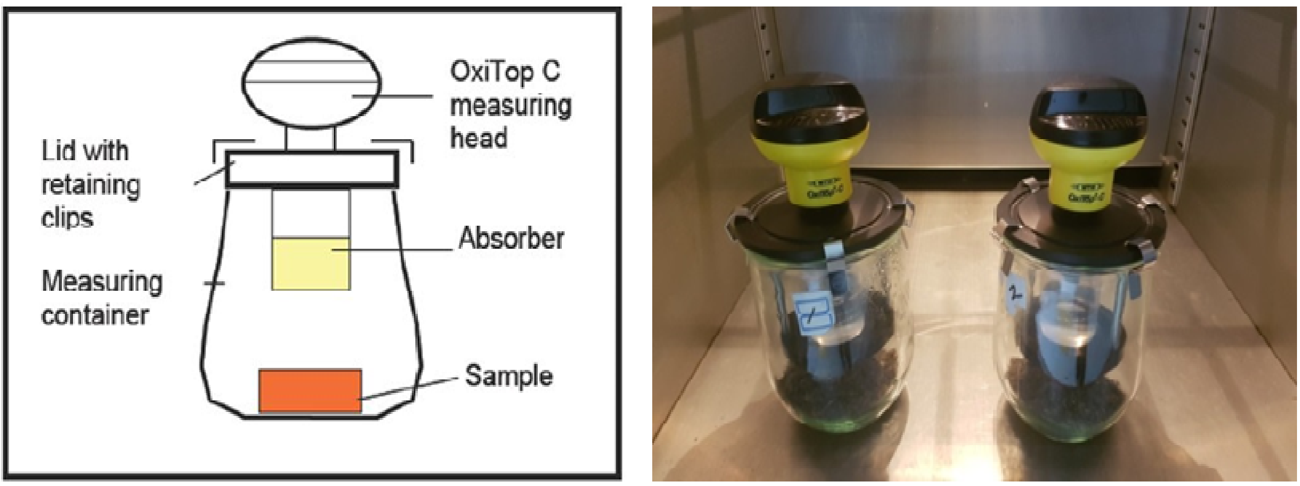

Figure 1. AT_4 schematics (Kim *et al.*, 2009) and measurement device

Sorting solid fuel particle size to 1mm or less and collecting 5g

↓

80% H_2SO_4 reaction(16h±2h)

↓

35% H_2O_2 reaction(5h±1h)

↓

Weigh after drying the residue

↓

Ash measurement

Figure 2. Biomass content analysis procedure

$$x_B = \left[1 - \left(\frac{m_{residue} - m_{residue-ash}}{m_{material}} + \frac{A_{material}}{100}\right)\right] \times 100 \quad (3)$$

X_B= Biomass content (%)
$M_{material}$ = Amount of sample used in selective dissolution test (g)
$A_{material}$ = Ash content of sample (%)
$M_{residue}$ = Dry weight of the residue after the sample has dissolved (g)
$M_{residue-ash}$ = Ash weight of dissolved residue (g)

RESULTS

Basic Properties Analysis

Table 1. Proximate analysis of Sewage Sludge and Sawdust

Material	Moisture(water %)	Ash(water %)	Volatile matter(water %)	Fixed carbon(water %)	LHV(kcal/kg)
Sewage Sludge (n=3)	81.80±0.00	6.38±0.22[35.08]	9.50±1.21 [52.15]	2.32±1.30 [12.77]	3105.39±40.66
Sawdust(n=3)	11.33±1.15	7.91±1.06 [8.98]	57.02±3.34 [64.34]	23.74±4.07 [26.68]	3752.86±548.26

* [] : dry %

Table 2. Elemental analysis

	C (%)	H(%)	N(%)	S(%)	O(%)
Sewage Sludge	33.94	4.97	5.99	2.22	46.51
Sawdust	45.89	5.95	2.23	0.05	45.81

The basic properties of sewage sludge and sawdust were analyzed. Sewage sludge had a water content of about 82% and contained 7 times more water than 11.33% sawdust. As the water content of sawdust was low, sawdust was measured to be about 700kcal higher than sewage and it was measured up to 4200kcal/kg. As a result of measuring the water content according to the sludge mixing ratio, the moisture content of mixture decreased from 82% (sewage sludge 100%) to 51% (sewage sludge: sawdust = 50: 50). As the sawdust ratio increased, the water content decreased.

Analysis of aerobic biodegradation and biomass content by mixing ratio

Table 3. Analysis of aerobic biodegradation and biomass content by mixing ratio

Material			AT_4 (g O_2/kg DM)	Biomass content (%)
Mixture	1	SS 50 % + SD 50 %	37.43	79.30
	2	SS 60 % + SD 40 %	39.40	76.35
	3	SS 70 % + SD 30 %	45.71	74.71
	4	SS 80 % + SD 20 %	49.26	73.99
	5	SS 90 % + SD 10 %	49.35	72.74
SS 100%			54.67	67.68
SD 100%			23.05	79.86

* SS = Sewage Sludge, SD=Sawdust

Analysis of the mixture of sewage sludge and sawdust was conducted according to the AT_4 analysis method and the biomass content analysis method for each mixing ratio. As a result of respiration activity analysis(AT_4) of sewage sludge 100% and sawdust 100%, sewage sludge showed 54.67 g O_2 /kg DM and sawdust 23.67 g O_2/kg DM. The higher the content of sewage sludge in the mixture was, the higher the AT_4 was measured and the difference between 80% and 90% was not significant. The sawdust had the lowest initial pressure drop and the slowest pressure change for 4 day. In the case of the highest AT_4 of sewage sludge, the initial pressure drop was the fastest and the most rapid pressure change was observed. As the sewage sludge content in the mixture increased, the initial pressure decrease was accelerated and the final pressure drop value also increased. The biomass content of each mixture showed that sawdust had the highest biomass content 79% and sewage sludge had 67%. In the case of mixtures, Mixture 1 which had the highest amount of sawdust had the highest biomass content and lower sawdust content decreased the biomass content. The higher the AT_4 of the sample, the lower the biomass content.

Biodegradation change of Sewage Sludge by Sawdust Mixing

The aerobic biodegradability of sewage sludge was 54.67 g O_2/kg DM and the aerobic biodegradability of sawdust was

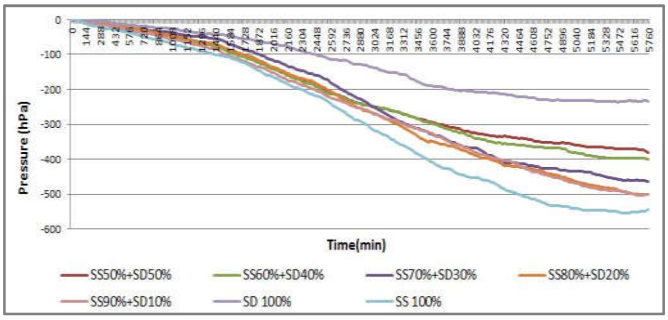

Figure 3. Reduction of pressure by mixing ratio

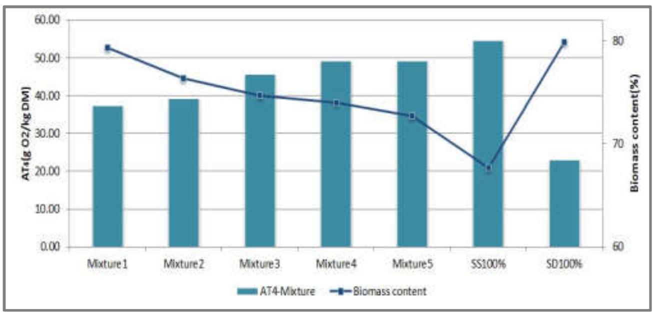

Figure 4. AT_4 values and biomass content according to mixing ratio

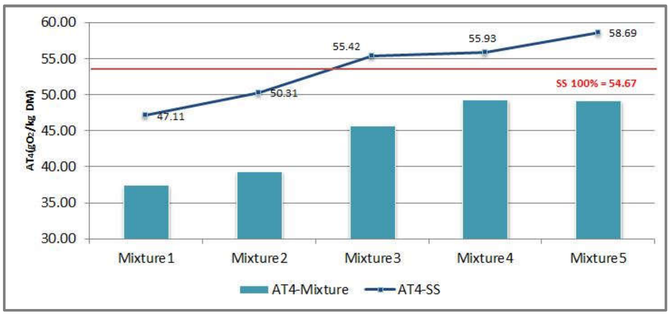

Figure 5. The AT_4 values of the sewage sludge in the mixture considering sawdust and mixture AT_4 by mixing ratio

23.05 g O_2/kg DM. The higher the sawdust content, the lower the AT_4 of whole mixture because AT_4 of sewage sludge was offset by sawdust. Considering the biodegradability of sawdust, the aerobic biodegradability of the sewage sludge in the mixture was found to be lowest in mixture 1 (Sewage Sludge 50%) containing the least amount of sewage sludge. Mixture 5 (Sewage Sludge 90%) showed the highest value and showed 107% biodegradation of the raw sample. As the amount of sawdust increases, the amount of biomass that comes in contact with the sewage sludge increases, and accordingly, the biomass component of sawdust interferes with the decomposition of sewage sludge, resulting in a decrease in AT_4 of the sewage sludge itself. In the case where the sewage sludge content is more than 70%, the value exceeding the biodegradability of the raw sewage. The amount of sawdust was not enough to reduce the degree of degradation of sewage sludge and rather the biodegradability of sewage sludge itself is promoted.

Conclusion

Sewage sludge has difficulties in fuelization due to high moisture content and biodegradation. Mixing method can be used to lower the high water content of sewage sludge, and the use of sawdust with a low water content can be expected to reduce water content. The high biodegradation of sewage sludge should be considered simultaneously with the moisture content because it can cause the problem of odor generation and fuel quality deterioration at the time of storage. Therefore, in this study, biodegradability was measured along with reduction of water content when mixing sewage sludge and sawdust, and biomass content analysis was conducted to analyze biodegradability. In addition, AT_4 of sewage sludge considering sawdust was calculated according to the mixing ratio of sewage sludge and sawdust. The results of analysis are as follows.

(1) As a result of analysis of biodegradability according to mixing ratio, sawdust showed the slowest initial decomposition rate and lowest pressure decrease. Sewage sludge had the fastest initial decomposition rate as opposed to sawdust and the most pressure reduction. The higher the content of sewage sludge, the faster the initial decomposition rate and the higher the pressure drop.

(2) Biomass content of sawdust was about 80% and sewage sludge was the lowest at 67%. Mixture 1 had the highest value of 79.3% and Mixture 5 had the lowest 72.4% biomass content. The higher the AT_4 of the mixture, the lower the biomass content, which seems to follow the properties of relatively large amounts of constituents.

(3) Biodegradation analysis of the mixture showed that AT_4 of mixture was lowered as the amount of sawdust was increased and it was measured from at least 37.43 g O_2/kg DM (Mixture 1) to 49.35 g O_2/kg DM (Mixture 5). Also, as the sawdust ratio decreased, AT_4 of sewage sludge considering sawdust AT_4 increased, and when the sewage sludge was more than 70%, biodegradation exceeded 54.67 g O_2/kg DM, which is degree of the raw sewage sludge.

Through this study, it was confirmed that mixing of sewage sludge with sawdust not only reduces the high water content of sewage sludge but also reduces high biodegradation. In addition, when the sewage sludge is mixed at a certain ratio, biodegradability may be higher than that of the raw material. The higher the content of sawdust, the lower the water content and the biodegradability, but further studies are needed on the fuel properties depending on the mixing ratio and the degree of biodegradation for use as fuel.

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