EFFECTS OF CO-DIGESTATE APPLICATION ON THE SOIL PROPERTIES, LEACHATE AND GROWTH RESPONSES OF PADDY RICE

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1 INTRODUCTION

Climate change resulting from global warming eventually became a global issue. The Korean government pronounced "Low Carbon Green Growth", a new paradigm, as driving force for future development in 2008. Livestock manures have a potential to be a valuable resource if efficiently treated. Recently recycling of livestock manures for biogas production through anaerobic digestion is increasing and to enhance the biogas yield organic resource such as food waste or agricultural residue are added. In Korea, 42 million tons of livestock manures were generated in 2008 and 84 % of them were used for compost and liquid fertilizer production (MIFAFF, 2009). About 5 million tons per year of food wastes were generated in 2007(MOE, 2008).

Generally speaking, food wastes in Korea have a high content of salt because of salty soup and sauce. When applied to the soil, some negative affects to the crops occur: inhibition of water absorption by osmosis, direct toxicity of sodium or chlorine ion, growth retardation or necrosis resulting from nutritional imbalance by antagonism, restraint of root elongation by impeding moisture movement and aeration in soil due to the deterioration of soil physical properties by dispersion effect of sodium ion in soil (Bernstein, 1975; Shannon, 1997). In Korea, all the compost and liquid fertilizer must meet the guideline which is maximum 1% and 0.3% of salt content, respectively as sodium chloride according to the "Korean quality standard for fertilizer".

Pig manure and food wastes were usually co-digested in Korea. After anaerobic digestion, it has quantities of plant nutrients, such as nitrogen, phosphorous, potassium and other micro nutrients. It has, however, potential risks to plant and soil. In this study, we monitor the contents of co-digestate for seasonal variation to assess the safety of co-digestate and investigated the soil properties and crop responses by applying it to the paddy rice cultivation based on N supplement.

2 MATERIALS AND METHODS

2.1 Monitoring the seasonal variations of co-digestate

We sampled co-digestate fermented with pig manure slurry and food waste slurry by 70:30 in its volumetric basis in biogas plant in Korea. HRT was 20 days at high temperature (52℃). Chemical properties of co-digestate were analyzed according to standard method (APHA, 1998).

2.2 Paddy rice cultivation

Pot test: Paddy rice was cultivated in 1/2000 a Wagner pot packed with paddy soil. Soil was sampled before transplantation of paddy rice and after harvesting. After fertilizing with chemical fertilizer and co-digestate, leachate was sampled every two weeks for two months. Crop responses to fertilizer were investigated at harvesting stage.

Chemical analysis: Paddy soil was analyzed according to soil and plant analysis methods (NIAST, 2000). Soil was dried at room temperature and sieved with 2 mm. The pH and EC of compost was measured using pH meter (Orion 720A+) and EC meter (Orion 145A+), respectively, on 1:5 water extracts. Organic matter content was determined by Turin method, available phosphorus by Lancaster method, and total nitrogen content by Kjeldahl digestion, respectively. Soil was extract by 1N-NH_4OAc solution (pH 7) and then its exchangeable cation was determined by ICP (GBC Integra XMP). Nitrate nitrogen of infiltrated water was determined by Ion chromatography (DIONEX).

3 RESULTS AND DISCUSSION

3.1 Seasonal chemical variations of co-digestate

The chemical composition of livestock manure varies by livestock species, dietary and maturity etc. To secure the co-digestate as an alternative fertilizer, variations of nutritional contents should be within the guideline. In case of applying organic waste including food waste to arable land, salt content becomes the limiting factor for utilizing. In Korea, people seedle paddy rice in March and transplant in the middle of May to early June. For this reason, there were monitored the chemical variations of co-digestate from March to July. According to the fertilizer standard quality in Korea, liquid fertilizer including digestate should contain minimum 0.3% of total nitrogen (T-N). As shown in Figure 1, T-N content was higher than 0.3%, which met the Korean guideline except in June and at the same time the content of sodium chloride was under 0.3%. Other quality standard such as heavy metals was within the permission. This means that the co-digestate used in this experiment are suitable fertilizers.

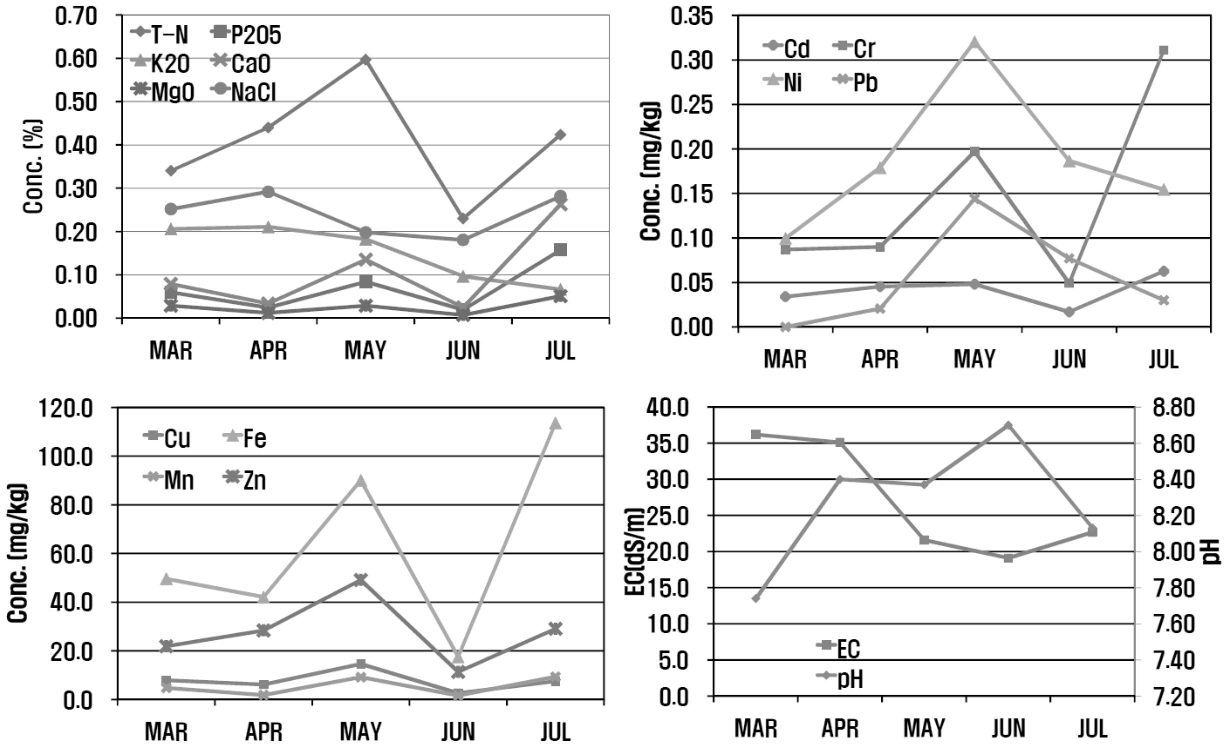

FIGURE 1 **Seasonal variations of pig manure slurry co-digestated with food wastes from March to July in Korea.**

3.2 Cultivation of paddy rice in pot

Paddy rice treated with chemical fertilizer and several levels of co-digestate were cultivated in 1/2,000 a Wagner pot. The properties of paddy soil before fertilization and after harvesting are shown in Table 1. There was no significant difference in pH, OM and T-N content during the sampling periods. In case of exchangeable potassium, its content in soil after harvesting increased with the amount of co-digestate applied. For feeding stock of additive included copper and zinc which is essential element for co-enzyme, it was considered that the high application rate of co-digestate combined with pig manure resulted in the accumulation of copper and zinc in soil. Other heavy metals, however, were not related with the rate of co-digestate application.

TABLE 1 **Physico-chemical properties of paddy soil before fertilization and after harvesting**

	Treatment	pH	EC	OM	T-N	P2O5	Ex. Ca	Ex. Mg	Ex. K	Ex. Na
			(dS/m)	(g/kg)	(%)	(mg/kg)	---------------- (cmol+/kg) ----------------			
Before Exp.		**5.01**	**0.81**	**32.8**	**0.15**	**89.36**	**6.43**	**1.07**	**0.23**	**0.54**
After Exp.	**None**	**5.68**	**0.55**	**33.7**	**0.17**	**73.15**	**4.35**	**0.80**	**0.25**	**0.39**
	CF	**5.61**	**0.81**	**33.9**	**0.15**	**72.68**	**4.50**	**0.90**	**0.28**	**0.44**
	CD75	**5.63**	**0.82**	**33.6**	**0.15**	**63.23**	**4.46**	**0.85**	**0.27**	**0.44**
	CD100	**5.64**	**0.60**	**32.1**	**0.14**	**69.08**	**4.50**	**0.84**	**0.27**	**0.44**
	CD150	**5.52**	**0.95**	**34.1**	**0.15**	**82.96**	**4.98**	**0.97**	**0.30**	**0.53**
	CD200	**5.61**	**1.07**	**34.0**	**0.16**	**96.09**	**5.07**	**1.04**	**0.32**	**0.54**

		Cd	Cu	Zn	Pb	Ni	Cr	Mn
		-- (mg/kg) --						
Before Exp.		**0.11**	**4.95**	**5.59**	**4.15**	**0.65**	**0.16**	**41.17**
After Exp.	**None**	**0.20**	**6.42**	**6.34**	**5.79**	**0.55**	**0.23**	**62.86**
	CF	**0.21**	**6.45**	**6.05**	**5.60**	**0.73**	**0.33**	**67.64**
	CD75	**0.20**	**6.60**	**6.51**	**5.76**	**0.53**	**0.25**	**73.61**
	CD100	**0.21**	**6.91**	**6.42**	**6.02**	**0.55**	**nd**	**71.77**
	CD150	**0.19**	**7.38**	**8.30**	**5.59**	**0.56**	**nd**	**77.08**
	CD200	**0.20**	**8.05**	**10.01**	**5.73**	**0.58**	**nd**	**71.93**

*0.1 N HCl extractable

**CF means chemical fertilizer and CD represents co-digestate.

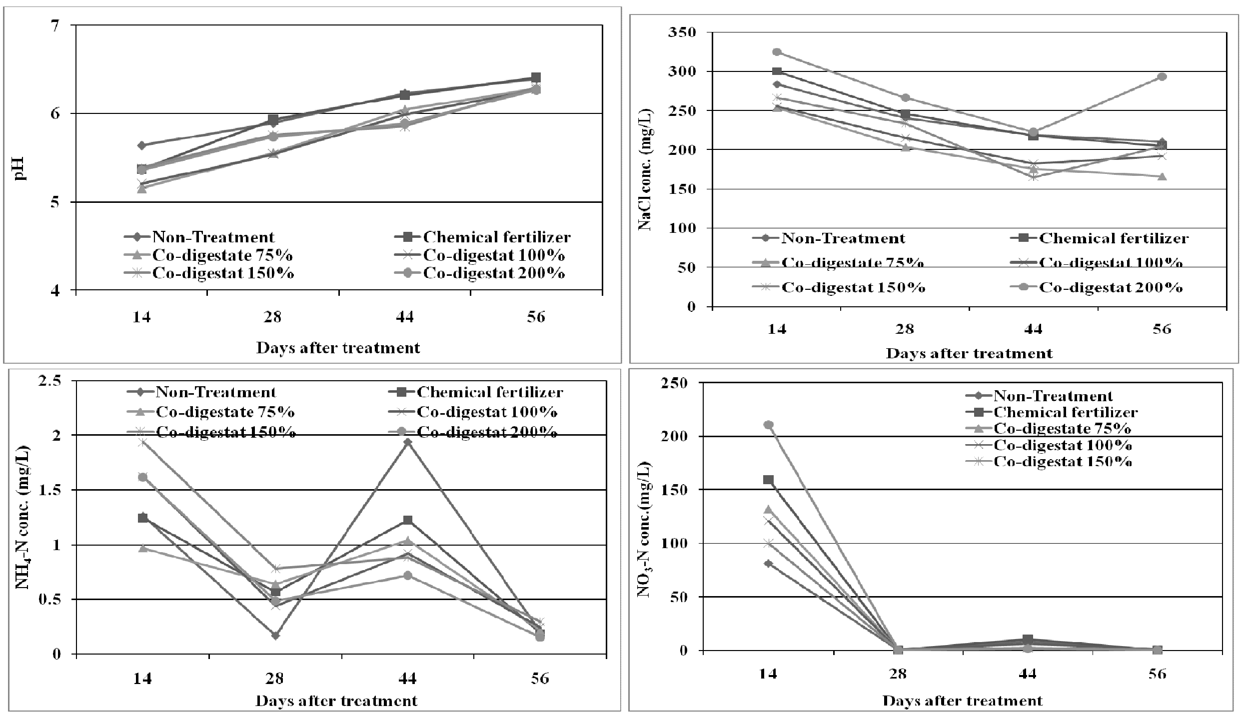

FIGURE 2 **Changes of some chemical properties of leachate with the time after fertilizing.**

As shown in Figure 2, the pH increased with the days after treatment of chemical fertilizer and co-digestate. However, pH in the untreated pot increased with a similar tendency, indicating that the pH increases did not result from the fertilizing. However, concentrations of sodium chloride decreased with time.

In case of nitrogen, concentration of ammonium nitrogen fluctuated with time, while that of nitrate nitrogen which charged negatively like soil particle was washed out within two weeks. The ratio of NH_4^+-N/ NO_3^--N was above 50:50 in two weeks after treatment and then drew back. Smiciklas and Below (1992) reported that rice grew better in most situations when NH_4^+-N/ NO_3^--N ratio was above 50:50.

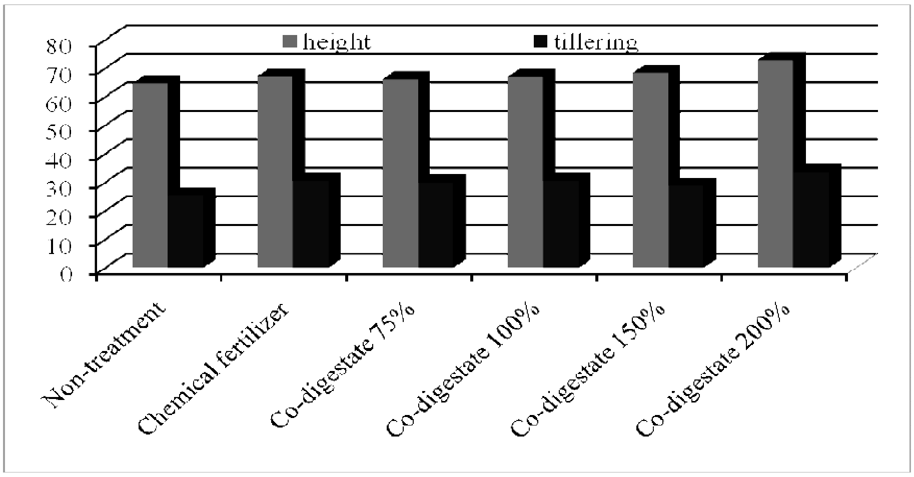

FIGURE 3 **Growth responses of paddy rice with different fertilizer.**

Considering the growth responses of paddy rice (Fig. 3), there was no significant difference between the treatments (DMRT at 95% level). However, limited to the co-digestate treated pot only, the more co-digestate applied the taller the plant height was. In case of paddy rice, optimal application rate should be established for co-digestate to prevent the loss by lodging.

4 CONCLUSIONS

The study for investigating the soil properties and crop responses by applying co-digestate to the paddy rice cultivation based on N supplement showed that soil applied with co-digestate was increased in exchangeable potassium, copper and zinc mainly due to the high rate of pig manure in co-digestate applied. Considering high salt content due to the combination with food waste, strict quality assurances are needed for safe application to arable land though it has valuable fertilizer nutrient. Leachate after treatment showed that the concentration of nitrate nitrogen washed out within two weeks. Considering the salt accumulation results in soil, it is highly recommended that the application rate of co-digestate should not exceed the crop fertilization rate based on N supplement. With these results, we concluded that co-digestate could be used as an alternative fertilizer for chemical fertilizer. More studies are needed for the long-term effects of co-digestate application on the soil and water environment.

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