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액상 돈분 발효조에서 폭기량과 돈분온도가 인의 형태 변환에 미치는 영향

박금주 홍지형 김재영

Influences of Aeration Rate and Manure Temperature on Phosphorus Transformation in Swine Liquid Manure Bioreactor

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Abstract

This study was conducted to investigate the influences of aeration rates and temperatures on phosphorus transformation in the manure during treatment of swine manure in 15.3L batch reactor. The total phosphorus of raw manure was composed of 91.5% of inorganic phosphorus and 8.5% of organic phosphorus. During the experiment, inorganic phosphorus decreased from 91.5% (385.7 mg/L) to 25.8-42.7% (108.8-179.8 mg/L) while organic phosphorus increased from 8.5% (35.6 mg/L) to 57.3-74.2% (241.5-312.5 mg/L). The organic phosphorus was increased by the possible transformation of soluble inorganic phosphorus to poly-phosphate by the microbial uptake. However, soluble inorganic phosphorus was not decreased much during the experiment because the insoluble inorganic phosphorus was transferred to soluble inorganic phosphorus offsetting the microbial uptake. There was no significant difference in soluble inorganic proportion variance during the experiment among treatments for three liquid temperatures and three aeration levels. In terms of phosphorus transformation in the manure and energy consumption required for aeration, lower aeration was desirable for the manure treatment.

Keywords : Swine manure, Aeration, Manure temperature, Sluble inorganic phosphorus

1. INTRODUCTION

As the farm for pig production grows in size recently, manure is excreted intensively in specific place resulting the deficit of application land. Water pollution of river or lake is generated by eutrophication due to nutrient enrichment by phosphorus and nitrogen. Phosphorus is generally considered as the limiting factor for environmental control. Total phosphorus are composed of three kinds of constituents such as soluble inorganic phosphorus (soluble ortho-P), insoluble inorganic phosphorus and organic phosphorus. Among these, soluble inorganic phosphorus is apt to infiltrate and run off resulting in the contamination of ground water and surface water. In raw manure, insoluble inorganic phosphorus constitutes the major part of total phosphorus occupying more than 70%. If the manure is applied to the land without treatment of phosphorus, soil microbes possibly convert insoluble inorganic phosphorus into soluble inorganic phos-

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phorus. Thus, total inorganic phosphorus in manure is likely to contaminate the water receiver if the plant doesn't immediately uptake the phosphorus applied into soil (Luo et al., 2001). Aerobic treatment of manure is generally accepted effective method to reduce the phosphorus. The effects of aeration (Luo et at., 2001) and liquid temperature (Fuhx and Chen, 1975; Jones and Stephenson, 1996; Ndegwa et al., 2001) on the removal of soluble phosphorus were studied by many researchers. However, study on the influences of aeration and liquid temperature variations at the same time on the phosphorus transformation is rare. Actually, as the manure is treated in outside space with variable temperatures, it is desirable to supply optimum airflow in terms of nutrient control and operating cost for the different liquid temperature. This study was intended to investigate the influences of aeration rate for different manure temperatures on phosphorus transformation in the manure during treatment of swine manure.

2. MATERIALS AND METHODS

A. Manure source

The manure for the experiment was collected from the pit of swine finishing barn which was located at the University of Minnesota Southern Research and Outreach Center at Waseca. The raw manure for experiment had total solids of 19.3 g/L, pH of 6.9 and redox potential (E_h) of -166 mV. Physicochemical properties of the raw manure are shown in table 1.

B. Experimental apparatus

The experimental apparatus was composed of nine PVC reactors, each measuring 914 mm in height and 153 mm in internal diameter (Fig. 1). The sampling port for each column was located at the height of 381 mm from the bottom. To control the temperature of the manure, columns were placed in water basin, and a temperature controller with timer

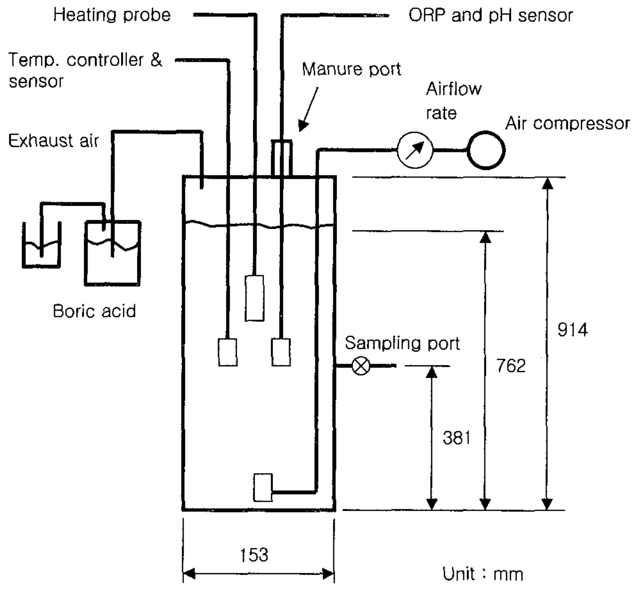

Fig. 1 Schematic diagram of the reactor.

(model A-94460-45, Cole-Parmer Instrument Company, Vermon Hills, Ill.) and a heating probe (Water Heater Screw In Element, John Wood Co., Valley Forge, Pa.) were installed in each of the reactor. The temperature sensor was located in the middle of the manure column and the heating probe was installed at the upper part of column. Airflow to the reactor was supplied by an air compressor (VS401103AJ, 1PH, Campbell Hausfeld), and a airflow rate was controlled by an airflow meter (control range: 0-1 LPM or 0-5 LPM, Fisher Scientific) attached at each column.

C. Experimental procedure

Experiment was done during 21 days in the manure building in which air temperature was controlled to maintain above 7.2℃. Each reactor was filled with raw manure up to 762 mm with a headspace for the scum, making manure volume of 14.0 L. The temperature of the manure in the column was continuously measured every second and used as the parameter to control the temperature by heating probe. The temperatures of the columns were maintained to have 5℃, 15℃ and 25℃, with three aeration level of 0.5 L/M (36 mL/min/L), 1.2 L/M (86 mL/min/L) and 1.9 L/M

Table 1 Physical, chemical, and biological properties of raw manure.

PH	TS	TVS	TKN	BOD_5	VFAs	VFAs/TKN	VFAs/BOD_5	ORP (E_h)	TP	Inorganic P	Ortho-P
-	g/L	g/L	mg N/L	mg/L	mg/L	-	-	mV	mg P/L	mg P/L	mg P/L
6.88	19.3	12.2	3055	11100	6527	2.14	0.59	-166	421.3	385.7	131.1

(136 mL/min/L), respectively. A 3 × 3 factorial analysis with three manure temperatures and three aeration levels was studied. As the ambient temperature went up higher than the desired manure temperature of 5℃ and sometimes 15℃, ice cubes were filled in the water basin to keep the manure temperature from going up over the desired temperature. The pH and redox potential of the manure were measured at the center position of manure of the reactor every day using pH and oxidation-reduction potential electrode meter (DIGI-SENSE pH & ORP meter, Cole-Parmer Instrument Company), respectively. For the physicochemical analysis, 100 mL manure samples were taken from each reactor every day during the first 7 days, and every other day during the remaining period. After sampling, all the samples were kept frozen until they were analyzed afterwards. After sampling, all the samples were kept frozen until they were analyzed afterwards.

After the samples were thawed to the room temperature, total phosphorus (TP), total inorganic phosphorus, soluble inorganic phosphorus, total solids (TS) and total volatile solids (TVS) were determined for the samples. Organic phosphorus was determined indirectly by subtracting total inorganic phosphorus from total phosphorus. Total phosphorus was measured colorimetrically by the ascorbic acid method after digesting for 30 minutes in the autoclave. Prior to analysis for total inorganic P, the samples were diluted 25 times with 1.5 M HCl and centrifuged at 5000 rpm for 30 min, and then analyzed by the ascorbic acid method. Prior to analysis of soluble inorganic phosphorus, the samples were diluted 5 times with DDW and then filtered using fiber filter (G4, 55 mm, Fisher Scientific). After filtration, soluble inorganic phosphorus was determined colorimetrically by the ascorbic acid method. Total organic phosphorus was calculated by the difference between total phosphorus and total inorganic phosphorus. Insoluble inorganic phosphorus was represented as the difference between total inorganic phosphorus and soluble inorganic phosphorus. TS and TVS were determined by the standard laboratory method (APHA, 1998).

3. RESULTS AND DISCUSSION

The pH of the manure with initial value of 6.9 rose up to 8.3-8.6 during first day and gradually increased to 8.7-9.1 for the rest experiment (Fig. 2) showing similar results to former researches (Zhu et al., 2001). The higher values of pH were generally acquired with the higher aeration rates. For the manure of 5 and 15℃, pH values were different due to the aeration rate except from 10th day to 15th day. For the manure of 25℃, there was no difference in pH values between 1.2 L/M and 1.9 L/M of aeration.

A concentration of dissolved oxygen is used to present aeration level of manure. However, redox potential is generally used for the liquid of dissolved oxygen less than 10%. 1 to 10% of dissolved oxygen corresponds to +150 to +400 mV of redox potential (Burton, 1992). Redox potential of the manure rose from the initial value of -166 mV to the minimum value of -72 mV (25℃, 1.2 L/M) and to the maximum value of 216 mV (5℃, 1.9 L/M) during first day and started to decrease gradually due to the microbial activity in the manure (Fig. 3). There was significant difference in

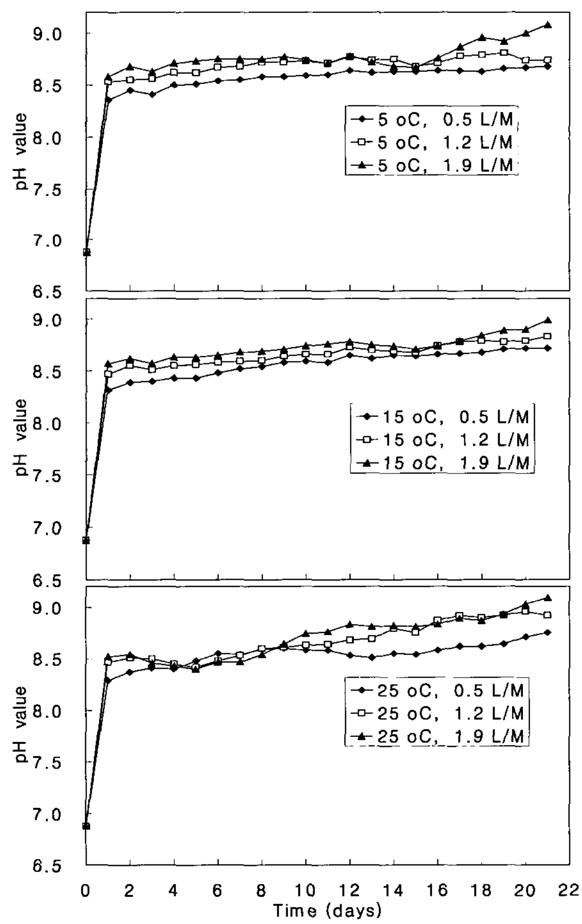

Fig. 2 pH value changes for the different temperatures and aeration rates during the biodegradation of liquid manure.

redox potentials due to manure temperature until 12th day showing lower redox potential for the higher manure temperature. It is because that dissolved oxygen decreases as the liquid temperature increases. Also, as the respiration of microorganism in the manure increased with higher liquid temperature (Hissett et al., 1982), redox potential possibly would have decreased. From the 2nd day, redox potential started to decrease as the oxygen demand by microorganisms probably exceeded the oxygen supply by aeration for all columns. However, from the 13 - 17th day, redox potential with 1.9 L/M of aeration for the all temperatures and with 1.2 L/M of aeration for 15℃ started to increase representing that microorganism in the manure was reduced due to the

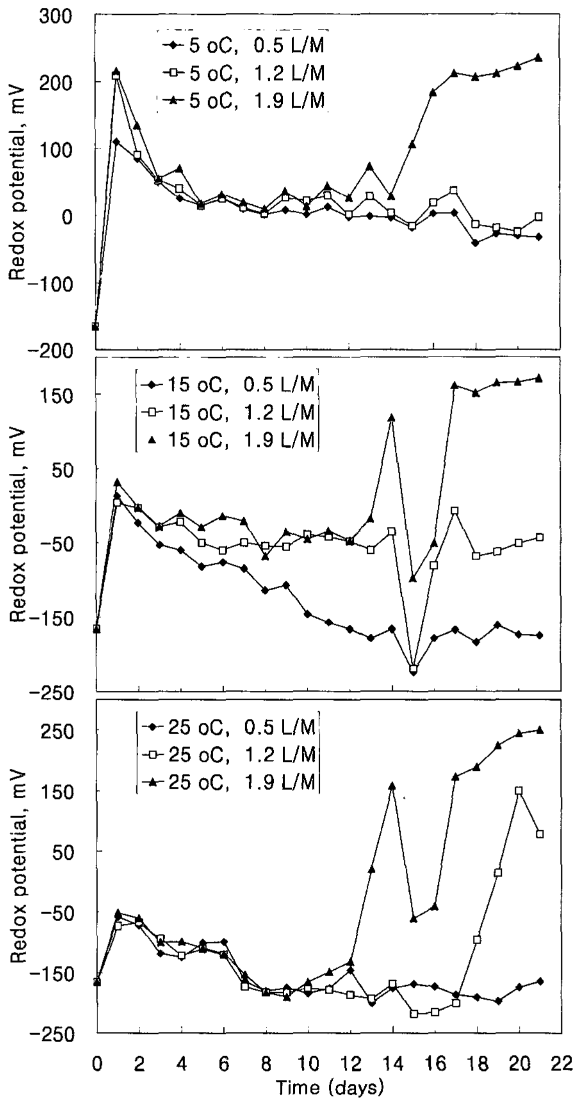

Fig. 3 Redox potential changes in the manure according to aeration rates for the different liquid manure temperature during the biodegradation.

substrate deficit and that the manure was biodegraded to a certain extent.

In raw manure, 421.3 mg/L of total phosphorus was composed of 91.5% (385.7 mg/L) of inorganic phosphorus and 8.5% (35.6 mg/L) of organic phosphorus. Soluble inorganic phosphorus occupied 31.1% (131.1 mg/L) of the total phosphorus.

Inorganic phosphorus decreased gradually with some fluctuations from the initial value of 385.7 mg/L to 113.5-134.8 mg/L for the manure of 5℃ and 132.4-179.8 mg/L for the manure of 15℃ at the end of experiment (Fig. 4). However, for the manure of 25℃, the values decreased abruptly to 96.9-111.1 mg/L at the 7th day and maintained constant values with a little fluctuations to the end of experiment. There was difference in inorganic phosphorus reduction between the manure of 15℃ and 25℃, however, no difference between the manure of 5℃ and 15℃. Inorganic

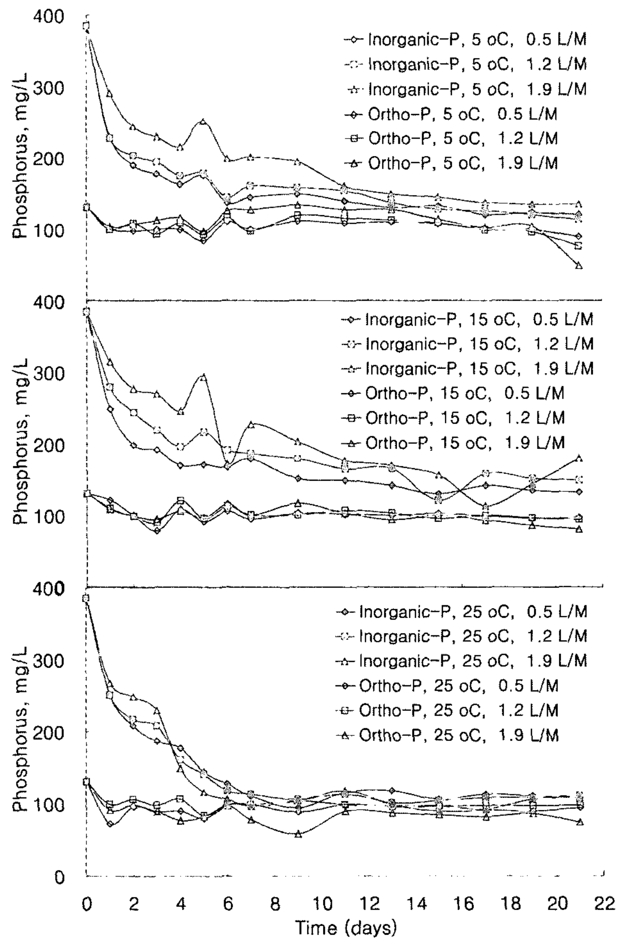

Fig. 4 Changes in total inorganic phosphorus and soluble orthogonal phosphate during biodegradation of swine manure.

phosphorus reduced more quickly during the initial stage to the 11[th] day with the higher aeration for the manure of 5℃ and 15℃, however, there was no difference due to the aeration rate for the manure of 25℃.

Soluble inorganic phosphorus decreased during the first day from 131.1 mg/L to 99.4-104.1 mg/L for the manure of 5℃, 108.9-121.2 mg/L for the manure of 15℃ and 72.4-99.4 mg/L for the manure of 25℃ (Fig. 4). After the first day, soluble inorganic phosphorus remained constant with some fluctuations showing similar tendency to the former research works (Luo et al., 2001). The amount of soluble inorganic phosphorus changed with time without any difference among all treatments with different temperatures and aeration levels. Therefore it could be concluded that soluble phosphorus transformation is not influenced much by liquid temperature and aeration rate.

Phosphorus valance changes during the experiment are shown in Fig. 5, Fig. 6 and Fig. 7. Initial proportion of soluble inorganic phosphorus, insoluble inorganic phosphorus and organic phosphorus to the total phosphorus were 31.1, 60.4 and 8.5%, respectively. Soluble inorganic phosphorus was changed from the initial value of 31.1% to 11.6-21.3% for the manure of 5℃, 19.1-23.0% for the manure of 15℃ and 17.6-23.4% for the manure of 25℃ during the experiment. There was no difference in soluble inorganic proportion variance with aeration time among treatments with three liquid temperatures and three aeration levels. Insoluble inorganic phosphorus changed from the initial value of 60.4% to 7.3-20.4% for the manure of 5℃, 8.4-23.6% for the manure of 15℃ and 3.0-8.2% for the manure of 25℃. Insoluble inorganic phosphorus decreased much for the higher temperatue (25℃) than those for the lower temperatures (5 and 15℃).

Abrupt increase in organic phosphorus proportion occurred from the start to the 4th day and gradual increase thereafter resulted in the final values of 68.0-73.1% for the manure of 5℃, 57.3-68.6% for the manure of 15℃ and 73.6-74.2% for the manure of 25℃. The increase in organic phosphorus is

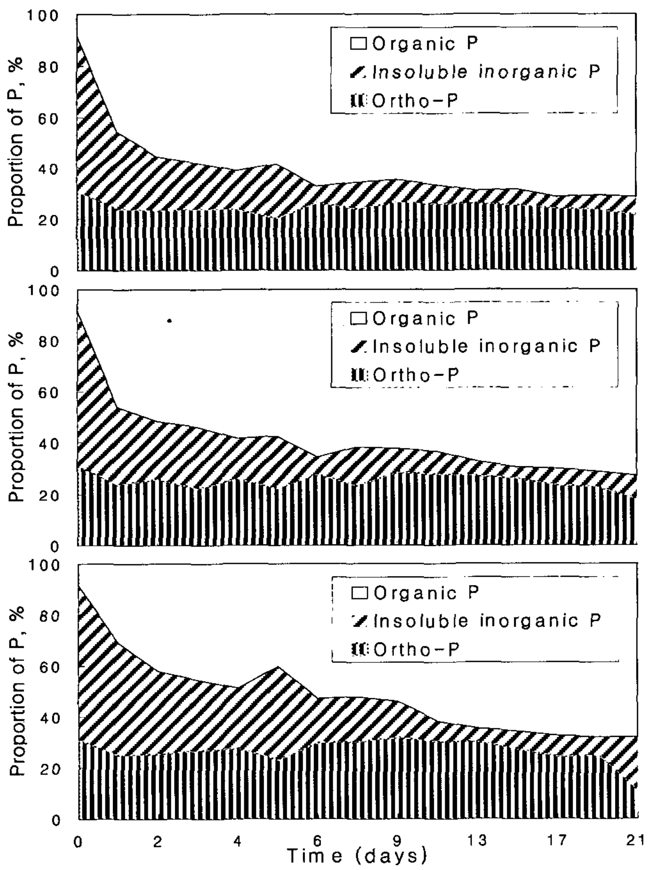

Fig. 5 Constitution of total phosphorus in the manure of 5℃ with aeration of 0.5 (upper), 1.2 (middle) and 1.9 L/M (lower).

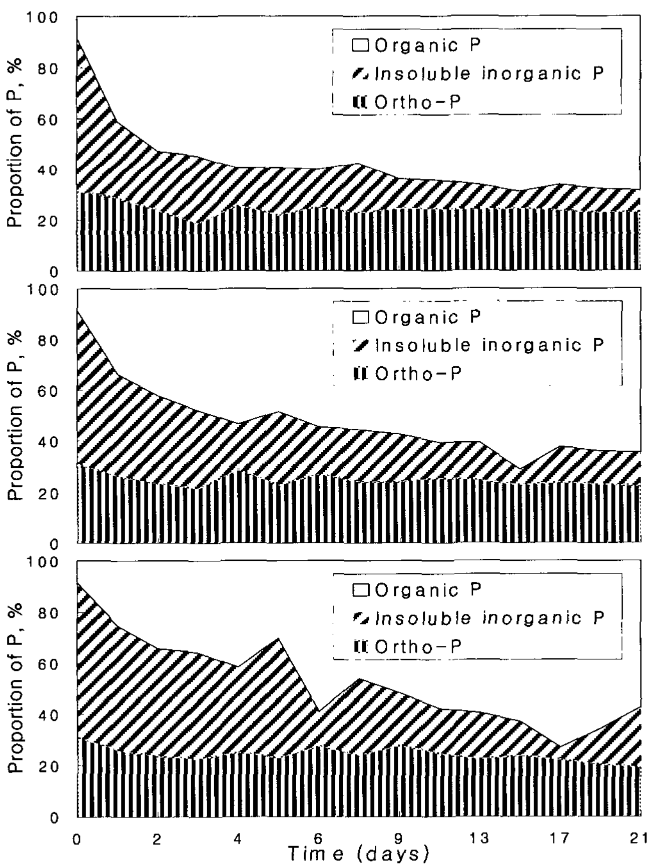

Fig. 6 Constitution of total phosphorus in the manure of 15℃ with aeration of 0.5 (upper), 1.2 (middle) and 1.9 L/M (lower).

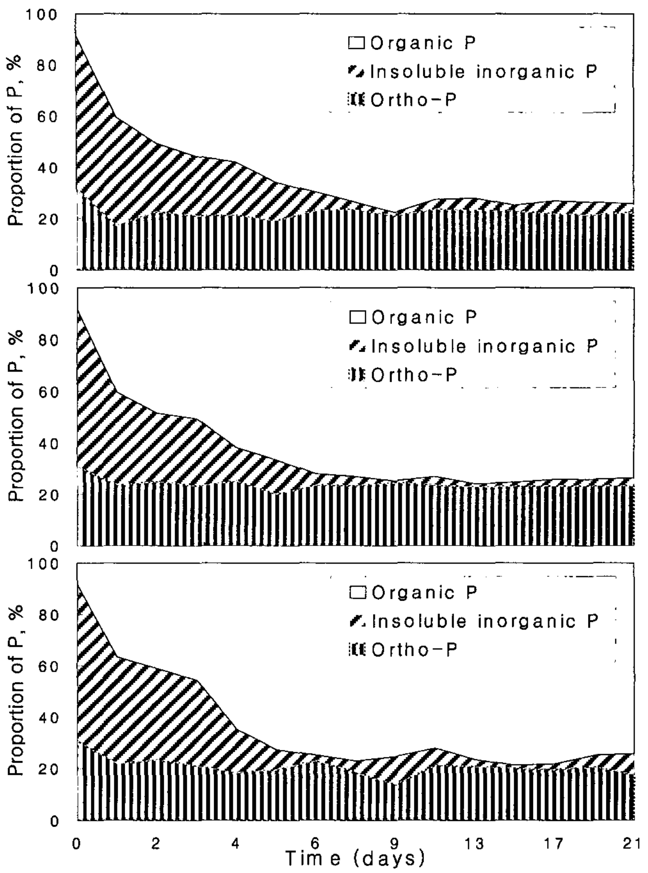

Fig. 7 Constitution of total phosphorus in the manure of 25℃ with aeration of 0.5 (upper), 1.2 (middle) and 1.9 L/M (lower).

due the formation of poly-phosphate by the microbial uptake of soluble inorganic phosphorus. In spite of biological uptake, soluble inorganic phosphorus was not decreased because the insoluble inorganic phosphorus was transferred to soluble state offsetting the microbial uptake (Luo et al, 2001).

An inverse relationships between pH and soluble inorganic phophorus during initial biodegradation of first day were reported by some researchers, when the pH rose up abruptly with the sharp decrease of soluble phosphorus (Ndegwa et al., 2001). In this research, as enough data were not measured during first day, a statistical relationship could not be acquired. Soluble inorganic phosphorus decreased after one day of aeration while pH increasing. However, there was no relationship between pH and soluble inorganic phosphorus during the whole experimental period.

4. COCLUSIONS

PH of the manure rose up from the initial value of 6.9 to 8.3 - 8.6 rapidly on the first day of aeration following a gradual increase to 8.7 - 9.1 during 21 days of experiment. Redox potential value went up rapidly on the first day of aeration. However, from the 2^{nd} day redox potential decreased because oxygen consumption by microbial activity surpassed the oxygen transfer by aeration. After 2 weeks, redox potential increased for the manure for higher aeration treatment indicating a decrease of microbial activity due to a deficit of substrates.

Raw manure was composed of 31.1% (131.1 mg/L) of soluble inorganic phosphorus, 60.4% (254.6 mg/L) of insoluble inorganic phosphorus and 8.5% (35.6 mg/L) of organic phosphorus.

The soluble inorganic phosphorus reduced with some fluctuations from the initial value of 31.1% to 11.6-23.4% according to manure temperatures and aeration rates. There was no significant difference among treatments in reduction of soluble inorganic phosphorus during the experiment. Insoluble inorganic phosphorus reduced greatly from the initial value of 60.4% to 7.3-20.4% for the manure of 5℃, 8.4-23.6% for the manure of 15℃ and 3.0-8.2% for the manure of 25℃.

The organic phosphorus increased from 8.5% to the final values of 68.0-73.1% for the manure of 5℃, 57.3-68.6% for the manure of 15℃ and 73.6-74.2% for the manure of 25℃. The increase in organic phosphorus is due to the transformation of soluble inorganic phosphorus to poly-phosphate by the microbial uptake. In spite of biological uptake, soluble inorganic phosphorus was not decreased much because the insoluble inorganic phosphorus was transferred to soluble state offsetting the microbial uptake.

In terms of removal efficiency of soluble inorganic phosphorus and energy consumption required for aeration, lower aeration is desirable for the manure at the all manure temperature in the experiment.

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