The investigation on maturing period of compost from composting toilet

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Abstract

Differed from normal compost such as animal manure or sewer, compost from composting toilet is produced by unique operation, since small amount of organic solid such as feces is continuously input in matrix for long time. Therefore, to know its maturing period for safety plant growth, changes of NH_4^+−N content and germination index (GI) after composting process were monitored in the present study. Sawdust, rice husk and charcoal were prepared as the matrix and 250-400 g-fresh of feces were continuously input in 15 L of the matrixes every weekday for three month. In 0 day after composting process, NH_4^+−N content in charcoal, rice husk and sawdust compost were 1024 mg/kg, 2112 mg/kg and 2365 mg/kg, respectively. The NH_4^+−N content in all compost were moderately decreased from 28 days to 52 days after composting process. GI in all composts were excess 50% at the 0 day and the values during 0-52 days were 62-79% in charcoal compost, 61-85% in rice husk compost, and 53-67% in sawdust compost. These results suggested that all compost was nearly maturated at the beginning of maturing procedure.

Keywords

Composting toilet, maturation, ammonia nitrogen, germination index

INTRODUCTION

Composting toilet, which is able to decompose human excrete and make compost, has some advantages which is low-cost, water-free, saving sewer-pipe network and recovery of fertilizer components (Winblad *et al*., 2004). Taking these advantages, the practical application has been attempted in rural area in Japan (Ito *et al*., 2006), urban slum in Indonesia (Ushijima *et al*., 2007) and rural area in Burkina Faso where is sub-Sahel region (Ushijima *et al*., 2012). Sawdust is mainly used as a composting matrix in the toilet. To expand the availability of the toilet in all over the world, several matrixes as an alternative to sawdust is required due to the limitation of sawdust availability especially in dry area. It has been suggested that several agricultural by-product (chopped corn stalk, rice husk and bio-charcoal from rice husk) were effective for fecal decomposition as the matrix (Hijikata *et al*., 2011a) and their compost promoted vegetable growth (Hijikata *et al*., 2011b). However, information about compost maturation process after removal from composting toilet has been limited.

While it has been reported that several agricultural by-products were applied to bulking agents for municipal solid waste compost (Iqbal *et al*., 2010) and sewage sludge compost (Zhao *et al*., 2011), the maturation process after removal from composting toilet is differ from these maturation process. Because small amount of solid waste such as feces is continuously input in matrix for long time. Therefore, maturation process after removal from composting toilet should be investigated to use the composts as a safety soil conditioner for plants. Considered to practical usage of the composting toilet, short maturation term is better for users, since the composting toilet is set near their house.

In the present study, therefore, the maturation process was investigated by measurement about change of NH_4^+−N content in compost and germination test with Komatsuna (*Brassica rapa* var. perviridis) in order to determine a time required for maturation. In addition, the difference of maturation progress among several matrixes was simultaneously investigated.

MATERIALS AND METHOD

Materials

In the present study, totally 3 types of agricultural by-products, which were charcoal made from rice husk, rice husk and sawdust, were prepared as the matrix. As a substitute for human feces, pig feces were utilized, because the compositions of pig feces are similar to human feces (Lopez *et al*., 2002). Firstly, in this study, composting process was monitored at first. Then, compost maturation was observed.

Composting experiment

Composting procedure Composting monitoring was demonstrated for about 90 days using the 3 type of matrix. 15 litre of charcoal, rice husk and sawdust were used as the initial matrix, and 250-400 g-fresh of the feces was input to the matrixes in composting toilet reactor every day at room temperature. In the previous our study, 40-50 litre of initial matrix was utilized and 700-1000 g-fresh of the feces was input to the matrix every day (Hijikata *et al*., 2011a). The amount of feces was assumed that 5 persons use the toilet (one person excretes about 150 g-fresh of feces per day). In the present study, the proportion of initial matrix and input feces was kept but these amounts were scaled-down to 3/10. Fecal load ratio (total input feces / total input matrix, w/w in dry weight base) of all matrixes at the end of the composting experiment was unified to 3.6. This value was assumed that 5 persons use the toilet in 3 months. Assumed as a low cost composting toilet (Ushijima *et al*., 2011), electric power for heating and ventilation was not used except for mixing. Besides, moisture content in composting matrix was not adjusted during the composting experiment.

Degradation ratio Fresh weight of input feces was monitored every day and total dry weight of input feces was calculated using moisture content (weight of water per weight of fresh matrix) of feces. Dry weight of total compost was calculated using data of total fresh weight of compost and moisture contents of the matrix every week. We assumed that the difference between the dry weight of total input feces with total input matrix and dry weight of compost was degradation amount. And then, fecal degradation ratio was calculated as followed:

$$D_a = (F_t + M_m) – M_t$$
$$D_r = D_a / F_t \times 100$$

Where D_a is degradation amount in dry weight base, F_t is sum of input feces at the time (g-dry), M_m is total input matrix (g-dry), M_t is weight (g-dry) of compost in reactor at the time and D_r is degradation ratio (%, w/w).

Moisture content Moisture content (weight of water per weight of fresh matrix) of matrix was monitored every week. The matrix was picked up from three different parts as three replicates and set to porcelain cups. The cup was kept in oven at 105°C over night. The moisture content was calculated as followed:

$$M_f = W_w / W_m \times 100$$

Where M_f is moisture content (g / g-fresh matrix), W_w is weight of water (g) and W_m is fresh weight of matrix (g).

Compost maturation experiment

Maturing operation After composting experiment, all compost was removed from composting reactor. All compost samples were left in incubator at 28°C and 50% humidity supposed tropical semi-arid climate. Compost was sampled at day 0, day 14, day 28 and day 52. Then, all samples were stocked in freezer at -20°C.

Ammonium measurement 3 g of air dried compost was extracted with 30 ml of 2 M KCl for 60 minutes with shaking. Then extracts were centrifuged at 6000 rpm for 10 minutes and filtered by bunchner funnel with 5C filter paper (ADVANTEC). After adequate dilution, NH_4^+–N in the extract was determined by indophenol blue method (Standard methods, 1989)

Germination test Germination test was carried out with compost extraction using Komatsuna (*Brassica rapa* var. *peruviridis*) (Chikae *et al*., 2006). 5 g-dry compost was extracted with 100 ml of boiled distilled water for 30 min with shaking. Then extracts were centrifuged at 6000 rpm for 10 min and filtered through 0.45 μm membrane filter (ADVANTEC). 30 number of Komatsuna seeds were set on triplicate filter paper in a petri dish. 8 ml of compost extraction was applied in the petri-dish. The petri-dish was wrapped with aluminum foil and left in incubator at 23°C. After 24 h, numbers of the germinated seeds were counted. After further 96h, root length was recorded. To measure the root length, the young plants were scanned as a picture data and the length was measured by Image J software (Wayne Rasband, USA). The germination ratio (G_m/G_c), the root length ratio (L_m/L_c) and the germination index (GI) (Zucconi et al., 1981) were calculated as the followed:

G_m/G_c

= germinated seeds number in compost extraction / germinated seeds number in distilled water

L_m/L_c

= root length in compost extraction / root length in distilled water

$GI(\%) = G_m/G_c \times L_m/L_c \times 100$

RESULT AND DISCUSSION

Monitoring of composting process

The fecal degradation of the charcoal was observed earlier than those of rice husk and sawdust (Fig. 1). It was observed after 20 days and that of rice husk and sawdust were observed after 33 days. This was suggested that the microbial activity in charcoal was higher than those of rice husk and sawdust because charcoal has many micropore for living place microorganism (Fanice and Matthias, 2009). The fecal degradation ratio of charcoal, rice husk and sawdust compost reached 64%, 68%, 65% at the late phase, respectively (Fig. 2A). In the previous study, the degradation ratio of charcoal, rice husk and sawdust compost reached 42%, 46%, and 25%, respectively (Hijikata *et al*., 2011a). The reason of high degradation ratio in the present study might be moisture content of composts. The moisture content increased to 40-50% at 10 days and saturated around 50-60% in the composting process (Fig. 2B). It has been reported that most favorable moisture level for biodegradation in different compost mixture varied from 50% to 70% (Richard *et al*., 2002) and microbial growth in sawdust matrix on small-scale biodegradation system with organic solid waste was found from 30% to 70% (Horisawa *et al*., 2000). Therefore, moisture content, in the present study, was kept in most favorable condition. In contrast, moisture content in the previous study was increased to 30-45% at 20 days and saturated around 40-50% in the late phase (Hijikata *et al*., 2011a). A reason of the different moisture content between the present study and previous study might be composting device. In the present, commercial compost reactor (long: wide: depth = 1: 2: 1.4) was used. In previous, self-made composting toilet reactor (long: wide: depth = 1: 1.3: 1.8) was used. This would affect water evaporation from the composts.

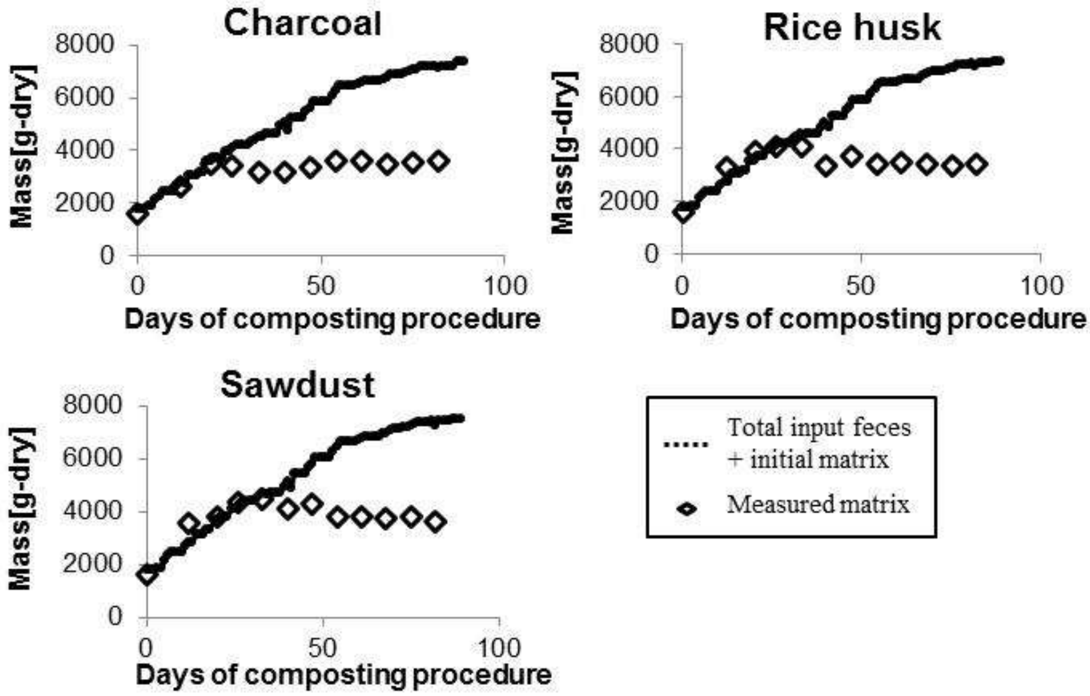

Fig. 1 Change of input feces with initial matrix and composting matrix during composting procedure

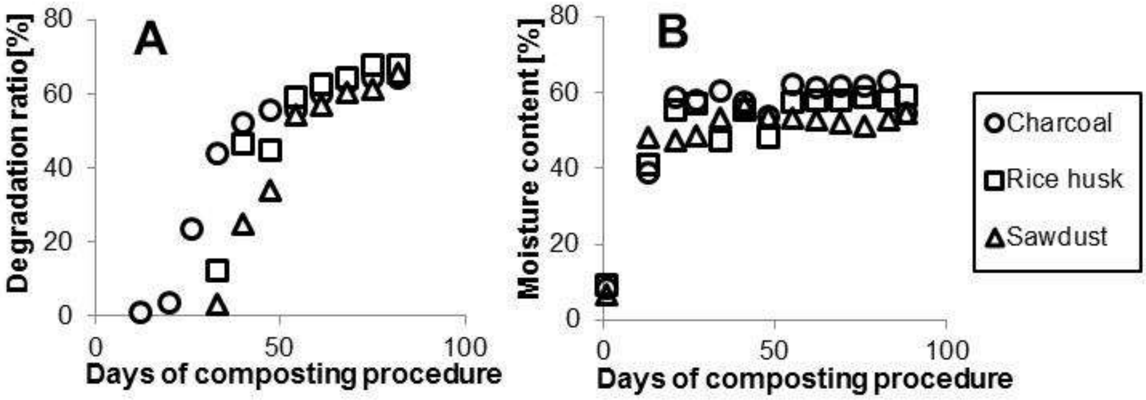

Fig. 2 Dry weight base degradation ratio (A) and moisture content (B) during composting procedure

Maturation process

Change of NH_4^+−N content of compost after composting experiment were showed in Fig. 3. The NH_4^+−N content of charcoal compost 0 day, 14 days, 28 days and 52 days after composting procedure were 1024 mg/kg, 1250 mg/kg, 3241mg/kg and 738 mg/kg, respectively. At day 28, significant increases were observed. The reason of the increase might be addition of water because the charcoal compost was so dried. The water addition might be activate microorganisms in charcoal compost and organic nitrogen in compost might be decomposed to NH_4^+−N. After the drastic increase, NH_4^+−N was decreased at 52 days. Except for this drastic increase and decrease, there was no significant change of NH_4^+–N content during maturation experiment moderate reduction from 28 days to 52 days was observed in other composts in the present study. These tendencies implied that nitrification activity was not high in the maturation process. NH_4^+–N content of charcoal compost was less than that of any other compost. The reason might be same with the cause of high fecal degradation of charcoal. Micropore of charcoal might promote nitrification bacterium.

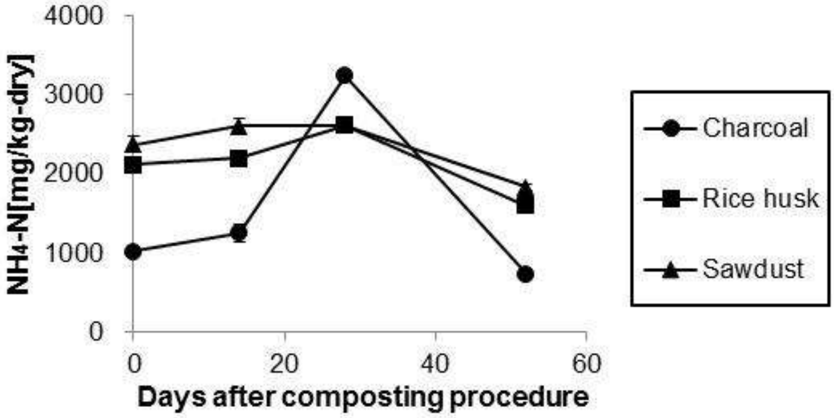

Fig. 3 Changes of NH_4^+–N content of compost after composting procedure

Change of germination ratio (G_m/G_c) in charcoal, rice husk and sawdust compost was 0.92-1.03, 0.87-1.00 and 0.72-0.92, respectively (Fig. 4). Change of root length ratio (L_m/L_c) in charcoal, rice husk and sawdust compost was 0.67-0.85, 0.74-0.88 and 0.73-0.75, respectively. These result suggested that germination was not affected by compost extract but growth of young root was affected by the extract more sensitive. GI is one of the most sensitive parameters for evaluating the toxicity and the degree of compost maturity. Zucconi *et al*. (1981) has proposed 50% of GI as an indicator of phytotoxin-free composts. On the other hands, Tiquia *et al*. (1996) and Sellami *et al*. (2008) have used 80% of GI as an indicator of the disappearance of phytotoxicity and maturity of compost. In the present study, therefore, we defined that 50-80% of GI was nearly maturity and more than 80% was completed maturity. The result showed that GI in charcoal was 62-79% during 0-52 days and reached around 80% at 14 days. In the case of rice husk, the value was 61-85% during 0-52 days and excess 80% at 0 days. In the case of sawdust, the value was 53-67% during 0-52 days and the value did not reach 80%. The GI value in sawdust compost was relatively lower than those of others during the maturing procedure but no less than 50%.

In all compost, surprisingly, GI value was higher than 50% at the beginning of maturation process. This result suggested that all compost was nearly maturated at the time. It has been known that decomposable organic matter can be degraded only 4 days in composting toilet (Narita *et al*., 2005). Therefore, amount of decomposable organic matter would be small portion at the time. Results of moderate change of NH_4^+–N in maturation process also supported this suggestion. On the other hands, it has been known that the degraded lignin fragments are building units for humic substances, which is factor of soil amendments, in compost (Tuomela *et al*., 2000). Change of humic substance content in maturation procedure, therefore, should be investigated.

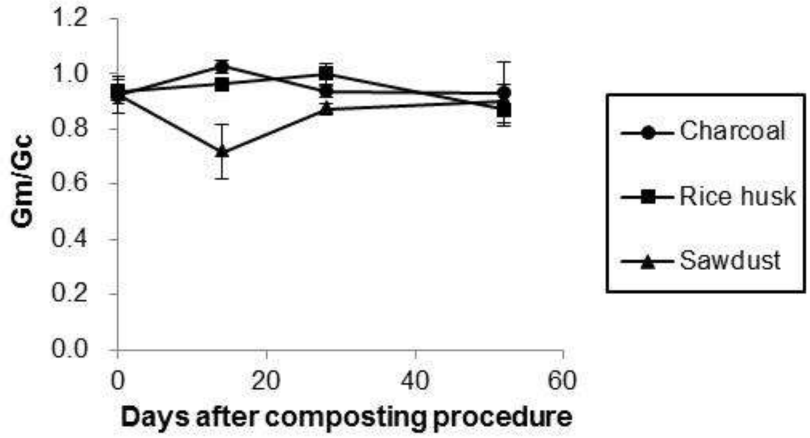

Fig. 4 Change of germination ratio (G_m/G_c) after composting procedure

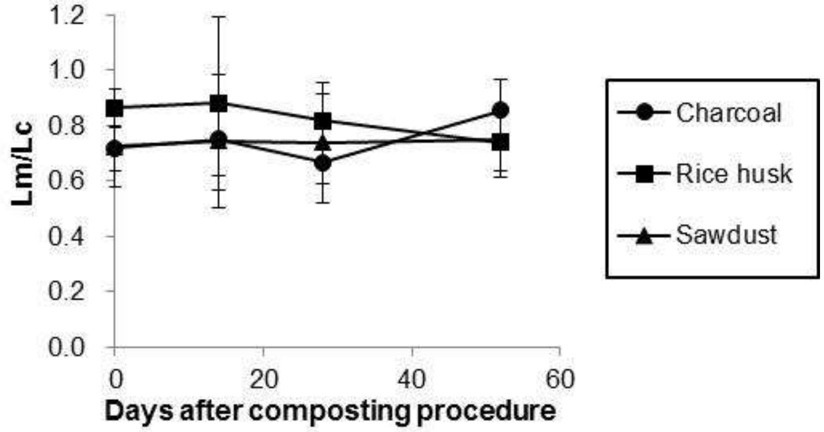

Fig. 5 Change of root length ratio (L_m/L_c) after composting procedure

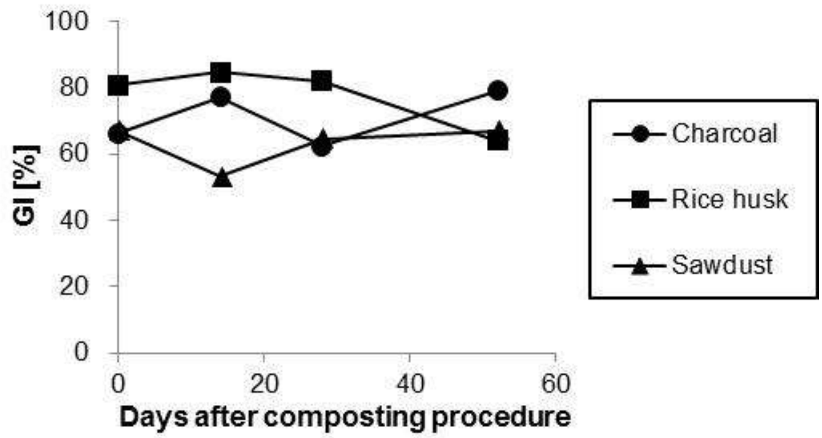

Fig. 6 Change of germination index (GI) after composting procedure

CONCLUSION

In the present study, the maturation process was investigated by measurement about change of NH_4^+–N content in compost and germination test in order to determine a time required for maturation. There were no significant nitrifications at maturation process and GI value of all compost excessed 50% at the beginning of maturing procedure. Our results suggested that all compost was nearly maturated at the beginning of maturing procedure. On the other hands, NH_4^+–N content of charcoal compost at the beginning of maturing procedure was less than that of any other compost. This implies that nitrification of charcoal compost was caused at a good pace at a composting process before maturing procedure. For the future, change of humic substance content in maturation process should be investigated in order to determine effectivity of maturation process.

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