Corn stalk as matrix in decomposting toilet for treating urine and feces

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Abstract. Bio-Toilet technology (BT) which is appropriate for the habits of Indonesian people has been studied and developed. BT is a dry toilet technology commonly uses ligno-cellulosic waste materials as matrix to facilitate the growth of natural microbes. In aerobic condition, microbes degrade feces and urine. Mineral as the leftover of feces and urine, such as nitrogen (N), phosphorus (P), and potassium (K) remain in the rest of matrix waste. After certain period. matrix can be harvested and used as soil conditioner. BT uses much less water, mobile, and very useful to be applied in areas where water availability is limited. BT type with different capacities, user amounts and mixing systems has been developed using sawdust for matrix. Since corn stalk is categorized as useless and priceless waste, its application in BT is challenging. Performance of BT with corn stalk as matrix to degrade feces and urine of carnivore imitating the human waste was observed. BT M-15 manual mixing type with paddle was filled with chopped corn stalk as much as 45% of total volume. This BT was designed for 15 person as users per day if 80% reactor volume was filled with ligno-cellulosic matrix. It is assumed that 150 g of feces are discharged once per person/day and 1000 mL of urine 6-8 times per day. Start up process was made in the beginning to initialize the needed microbes in the reactor (matrix). The discharge of feces and urine were increased slowly and gradually the users were increased from 1 to 4 users per day. Performance of BT was indicated by the change in the pile that showed by moisture content, temperature and pH. C/N ratio in matrix decreased significantly from 43 to 17. This result showed that the corn stalk could be used as matrix in BT.

1. Introduction

Recently, the population growth rate tends to decrease in the last four decades, but water requirement and waste increase as well as encumber the environment. One of the environmental factors associated with water and waste is the handling of human sewage from sanitation facilities. Inadequate sanitation facilities and the behaviour of people accustomed to open defecation or direct discharge of waste to water body. Lack of clean water and sanitation facilities, such as sewerage pipeline and other sanitation infrastructures decrease the quality life of the community. Considering the economic condition of developing countries, installation of reasonable, deliberate, matching-local and alternative infrastructure is required. To solve the sanitation problem in the slum or rural area through an inexpensive method, recycling the organic waste back to nature on-site with an environmentally sound technology or process are considered. Dry toilet or de-composting toilet using sawdust as media or bio-toilet (BT) technology is one of an example. The technology which is of Onsite Wastewater Differentiable Treatment System (OWDTS) will give direct positive effects. Water reduction for flushing, unnecessary wastewater canal construction, equipment portability, and possible integration with kitchen waste recycling system are examples of OWDTS. Comprehensive research to develop de-composting toilet system using sawdust as matrix has been carried out [1,2]. Application of such dry toilet using sawdust in Indonesia will overcome the common perception on water utilization for body cleansing [3,4].

Wood waste and sawdust is often regarded as worthless material. But with the increasing price of oil or gas, some households or small-medium scale food industries started to use sawdust as fuel to replace gas or timber. Therefore, finding alternatives material for BT matrix is encouraging. Corn stalk as lignocellulosic material is worthless waste and easy to find. Performance of BT with corn stalk as matrix in BT to degrade feces and urine of carnivore imitating the human waste was observed.

2. Experimental

2.1. Materals

Corn stalk which was collected form traditional market di Bandung, chopped to the size of 1-2 cm, sun dried, and put in the decomposting toilet BT type M15. BT box was made from steel with manual paddle screw installed for mixing. Figure 1 (left side) shows the mechanical and inside part of BT type M15. The cycling part and the box/bowl side are separated by a wall. Cycling is needed to mix the dirt and the matrix after using the BT. Figure 1 (right side) In the right side is the illustration when BT is used.

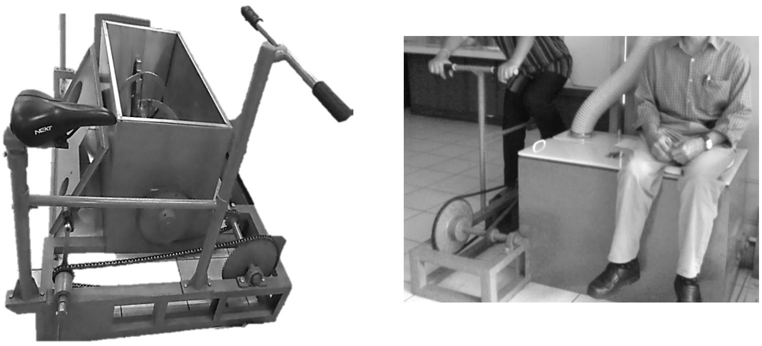

Figure 1. Left : BT type M15 bio-reactor; Right : Illustration when BT is used.

2.2. Method

BT type 15 was designed to treat feces and urine for 15 users per day if 80% volume of mixing reactor was filled with lignocellulose material. In this research, the reactor was filled with 114 L-of chopped corn stalk, equivalent with its 19,4 kg of fresh chopped corn stalk and represented 45% from the total volume. Using an assumption one person discharges of 150 gram feces/day and 1000 mL total volume of urine/day (6-8 times per day), the BT was gradually filled up. In the first 7 days, a discharge of one person per day has been done to initiate the microbes in the BT reactor (as start up process). The discharge was then increased to 2 persons/day for 5 observation days, 3 persons per day in the next 5 observation days, and end up for 4 persons per day in 3 observation's days.

Since the omnivore animals in the nearby zoo have a diet intake similar to humans, the feces was collected, frozen, and used in the research to imitate the human feces. Human urine from one person was collected, frozen, and used in the research.

Pattern on pH, temperature, dry matter and organic content in corn stalk matrix was measured and observed to determine the performance of reactor.

3. Result and discussion

The input of feces and urine was gradually increased as mentioned in the method. It needed total 23 days from start-up to maximal input (Figure 2).

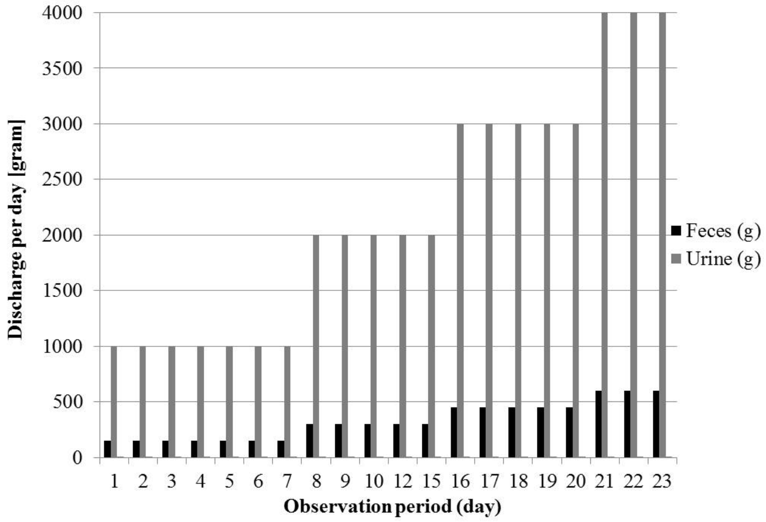

Figure 2. The gradual addition of feces and urine.

During the decomposition, bad odor began slightly detected after days 16. There was no bad odor appeared when 17 users discharged totally 2,550 g feces and 17,000 g urine in 15 days. At this stage odor detected was not too keen to be categorized as a condition rather smelly. This condition lasted for four days, until the observation in day 19. In day 21 the released odor from the reactor increased to be sharp and stinging, but it still got the input of 4 user daily until the day 23 with the total discharged of 6,600 g feces and 44,000 g urine. After 23 days, the input was stopped completely, but the sharp bad smell condition lasted until the day 33.

The bad odor during decomposition process could be generated from the accumulation of un-evaporated liquid from the input materials. In an aerobic decomposting process, moisture content plays a key role together with temperature and aeration. Observation during start-up showed that moisture content in corn stalk increased from 17 to 44, and rapidly to 81% in day 23 (Figure 3).

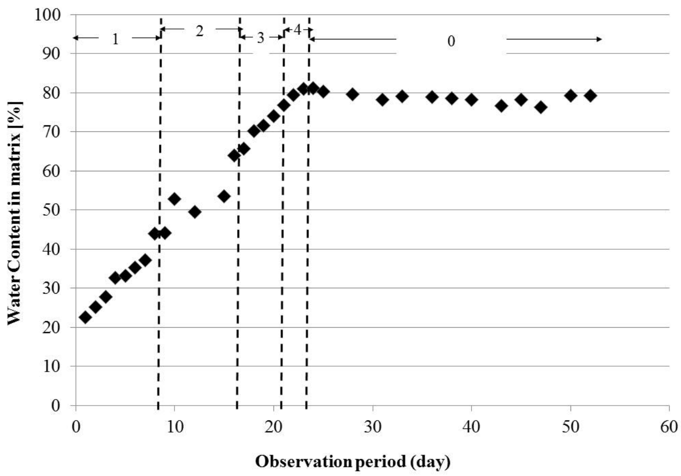

Figure 3.Accumulation of water in the corn stalks matrix in reactor.

Using formula feed for rabbit as model waste in a lab-scale aerobic process, Horisawa et al [4, 5] observed that the degradation rate was nearly constant at moisture content of 30-80%. In our research, after start-up the discharge was increased for 2 users per day until days 15, and the moisture content in corn stalk matrix was stable around 49%. The addition of discharge for 3 users per day and then to 4 users per day linearly increased the moisture content of corn stalk up to 81%. High concentration of water or moisture content in the reactor resulted of the loss of oxygen from the pores of the corn stalk particles and shifted the aerobic condition to anaerobic process. A change of aerobic to anaerobic conditions changed the degradation products. The bad odor could normally produced by anaerobic microorganism in the first step.

The trend of organic matter in the corn stalk during start-up period fluctuated from 97 to 95% dry basis (Figure 4). In the period of day 8 to 23, the decrease of organic matter was linearly from 96 to 93% as the moisture content increased from 20 to 80%. This trend could not convince the degradation of organic material in the discharge or in the corn stalk itself.

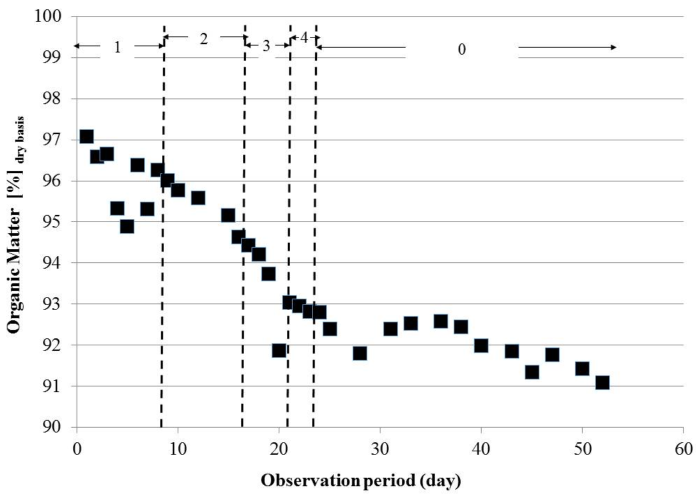

Figure 4. Dry basis organic matter in the matrix during observation's period.

Temperature of corn stalk pile in the reactor showed very interesting trends. By measuring the temperature at the bottom, middle, and top of corn stalk pile in the reactor in 3 different horizontal position (left, middle and right position of the reactor), the changes could be observed in figure 5. With daily ambient temperature during experiment stable in the average of 25^{o}C and 60% relative humidity, the temperature in the reactor (corn stalk pile) increased to 29^{o}C in the first day and the linearly increased to 32^{o}C at the end of start-up period. Addition of a discharge of 2 users per day after start-up increased the temperature in the pile gradually to 41^{o}C in the middle level. The temperature in the middle was not much different with the temperature in the bottom, but much higher in compare with the temperature in the upper level about 4^{o}C. The upper level had more contact with the ambient temperature in compare with the middle or bottom level. The increase of temperature was a desired situation in aerobic decomposting process. A regular discharge could keep the temperature.

As the discharge of feces and urine was increased to 3 users per day, the temperature in the reactor drastically decreased to 32^{o}C in the middle and lower part of the pile, or 30^{o}C on the upper part. The addition to 4 users per day made the temperature in the pile jump to 27^{o}C. The ambient temperature was in average 25^{o}C. Without discharge of feces and urine (after day 23), the temperature in the corn stalk pile increased slowly to 30^{o}C in the middle level. These changes showed the activity of the microbes involved in the process. From organoleptic measurement, the slightly stink smell could be perceived after days 16. It showed a shifting to unfavourable conditions in BT. The comformity of high water content in the pile is shown in Figure 3.

Measurement of the pH in the pile during start-up process showed the increase from 6.2 to 7.3. The addition of 2 users discharge per day decrease the pH in the corn stalk to 6.8 and then slowly back to 7.3 (Figure 6). Further addition of 3 users discharge per day increased the pH in the pile up to 8.5. Further addition of discharge decreased the pH to 8. After discontinuation of the discharge, the pH in the pile slightly fluctuated in the average value of 8. From generated smell it could be presumed that the increase of pH was caused by the ammonia. In anaerobic conditions, the protein from the discharge could be degraded to ammonia.

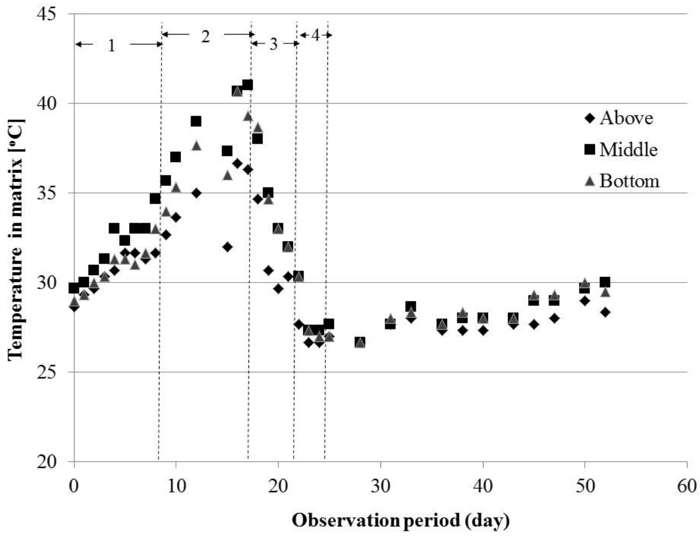

Figure 5.Temperature changes in the corn stalk pile.

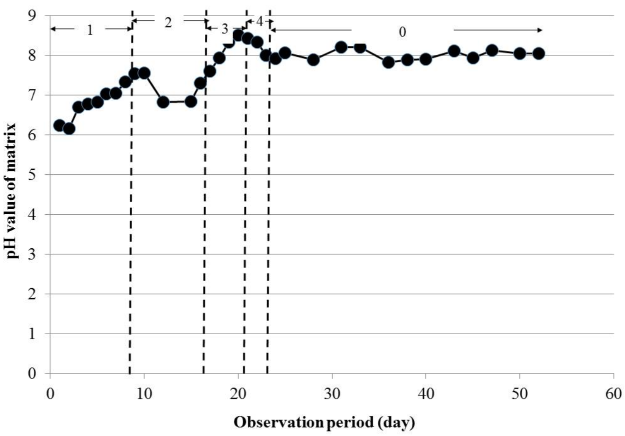

Figure 6. pH value of corn stalk in reactor.

From the day 36 until the last day of observation, the pungent smell inside the reactor was reduced gradually from rather smelly to earthy. After settling for ± 2 months of conditioning, the pungent smell totally disappeared and the material smell resembled soil as well as showed black colour of soil.

During the decomposition process of feces and urine in corn stalk matrix, the C/N ratio decreased gradually, from 43.24 to 24.59 on the day 17 of observation and declined further to 18.74 on the day 23 of observation. The C / N ratio decreased to 16.75 in the final day of observation. The decrease of C/N ratio during the experiment was supposedly due from the process of decomposition by microorganisms in the reactor. The C/N ratio at the end of this research has been approached with the C/N ratio of soil.

4. Conclusion

Corn stalk has been used for matrix in BT. The optimal input to the BT manual type 15 to degrade feces and urine was for 2 users per day, even on the discharge of 3 users per day the performance of BT was slightly reduced. Further addition of discharge to 4 users per day increased the moisture content in the matrix and gave burden to the corn stalk to shift the process to anaerobic condition. The C/N ratio of corn stalk decreased rapidly to soil like condition.

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