Rotary drum composter as a low cost method for the removal of *Ascaris lumbricoides* and *Trichuris Trichiura* in faecal sludge compost

Eugene Appiah-Effah, Kwabena Biritwum Nyarko, Esi Awuah and Eric Ofosu Antwi

Abstract

The aim of the study was to use of rotary drum composter as a low cost method for the removal of *Ascaris lumbricoides* and *Trichuris Trichiura* in faecal sludge compost. Two runs of compost experiment (Run 1 and Run 2) were carried out consecutively. Each Run of composting was done in four different rotary drums at real scale using a mixture of faecal sludge and shredded maize cobs and monitored for 12 weeks. Concentration of *Ascaris* and *Trichuris* were measured once a week to understand their behaviour. Temperature, Moisture Content and pH were also measured. High concentrations of *Ascaris* and *Trichuris* were present in the initial compost mix of both Runs 1 and 2. The concentration of *Ascaris* and *Trichuris* respectively in Run 1 ranged from 65–77 eggs/gTS and 30–41 eggs/gTS. In Run 2, measured concentrations of *Ascaris* and *Trichuris* ranged from 77–110 eggs/gTS and 46–52 eggs/gTS. After 84 days of composting faecal sludge, *Ascaris* was removed by a minimum of 82% and *Trichuris* by a minimum of 88%. The findings showed that plastic composter with paddles performed better compared with the other experiments. This means that the type of composter have a significant impact on the removal of helminth.

Key words: Ascaris, composter, die off, rotary drum, Trichuris

INTRODUCTION

Faecal sludge contain pathogens that cause health hazards and therefore must be properly treated in any community because, lack of adequate treatment and disposal will lead to high morbidity and mortality. Present in faecal sludge are enteric organisms including bacteria, viruses, protozoa, and helminths which can present a hazard to both human health and the environment (de Bertoldi *et al.* 1988). This means that bad disposal practices poses the danger of pollution of water, soil and air and high potential for epidemic.

Composting method has been recommended as a suitable biotechnology alternative for the effective treatment of faecal sludge into hygienically safe product with minimal impact on the environment. It ensures complete pathogen destruction, while offering the potential to restore the natural nutrient cycle in a way that is both ecologically and socially responsible. The time-temperature combinations lethal to all pathogens excreted in faeces, including the most resistant *Ascaris* according to Feachem *et al.* (1983), have been reported to be: 1 hour at 62°C, 1 day at 50°C and 1 week at 46°C. For effective pathogen destruction, the composting process should be carried out at high temperatures (>55°C) for an extended period of three days (USEPA 1995).

The technology used for composting is a relevant factor (Rodríguez *et al.* 2012) towards achieving a well stabilized and hygienized compost. Generally two main systems of composting can be distinguished...
which are open systems such as windrows and static piles and closed in-vessel or reactor systems. In-vessel or reactor systems can be static or movable closed structures where aeration and moisture is controlled by mechanical (IWMI 2003) or manual means. Reactor composting systems attempt to optimize conditions for the microorganisms thereby giving improved control of the composting process and accelerating the rate of decomposition. That notwithstanding, most studies on sewage and faecal sludge composting have been carried out using open systems such as windrows and static piles.

Rotary drum composters which is a reactor system are considered to be an efficient and promising technology as this type of composter provides agitation, aeration and compost mixing in order to produce a consistent and uniform end product without any odour or leachate related problems (Kalamdhad et al. 2009). Using the rotary drum technique reduces the composting duration whiles rapidly stabilizing the compost (Nayak & Kalamdhad 2014). In several studies, different types of wastes (cattle manure, swine manure, municipal bio-solids, brewery sludge, chicken manure, animal mortalities and food residues) have been effectively composted in rotary drums (Kalamdhad & Kazmi 2008).

Although several studies have addressed faecal sludge composting on larger scale using the conventional methods, very few studies have reported data about the use of rotary drums (Kalamdhad et al. 2009) and their configuration as well as design material in faecal sludge composting. The rotary drum configuration and design material are of critical importance. This is because of their influence on heat generated by micro-organisms through biochemical reactions through effective mixing and transfer of heat from external surface of the design material. This means that there is still a research gap on the effectiveness of rotary drum for composting faecal sludge. The aim of the study was to use of rotary drum composter as a low cost method for the removal of Ascaris lumbricoides and Trichuris Trichiura in faecal sludge compost in Peri-urban areas, Ghana.

MATERIALS AND METHODS

Design and construction of rotary drum composter

This study designed and constructed rotary drums using the discrete element method (DEM). A 3D Model concept of a rotary drum was created using a Computer Aided Design (CAD) software (PTC Creo Parametric 3.0). The 3D model served as a geometric definition which depicted the topology of the design concepts. CD Adapco Star CCM+ (DEM Software) was used to simulate the mixing of the faecal sludge in the rotary drum. The 3D Model of the rotary drum was imported into the DEM software and a mesh was created around the rotary drum for easy analysis. The physical properties of the faecal sludge and shredded maize cobs as well as boundary conditions of the drum were assigned in the software. The model was used to simulate the mixing of faecal sludge and shredded maize cobs (bulking material). The output of the model simulation included the blending time, mixing efficiency, average force required to turn the drum and volumetric efficiency which informed the final design of the rotary drum technology. After the results were obtained from the DEM simulation, the 3D CAD model of the rotary drum was adjusted to generate final manufacturing drawings for fabrication (Figure 1). Four different composters each of volume 130 litres were fabricated with galvanised metal sheet and high density polyethylene plastic of thickness 5 mm (Table 1). The composters operated on a batch mode. The main units of the composter is the drum (metal and plastic) and a mixer (rotating paddle). The drum had dimensions of 60 cm in length and an inner diameter of 40 cm with the mixer spanning the entire length of the drum. The mixer was to provide an effective mixing of the compost feedstock. The rotary drum was coated with black paint and also covered with black polythene material to prevent excessive heat loss from compost. In order to allow for proper aeration of the compost, two openings each of diameter 10 mm was created at the upper part of
the circular sides and another at the longitudinal side. The rotary composter was mounted onto a metal stand and it was manually rotated according to schedule.

With the rotary paddle composters, the paddle blades scoop, lift and tumble compost feedstock in a gentle thorough mixing action. In the case of rotary baffle composters, the baffles act as obstructing vanes or panels which are long flat plates that attach to the sides of the composter to prevent swirling and promote top to bottom movement of compost feedstock (Figure 1).

The composting process

The faecal sludge used in the experiment was collected from three public latrines located in three peri-urban areas in the Ashanti region of Ghana. These latrines have an estimate of between 120–200 visits daily by users. None of the latrines had been emptied for about 2 to 5 months prior to the sampling of faecal sludge. The faecal sludge was a mixture of faeces, urine and anal cleansing materials. Maize cobs

![Figure 1 | Manufacturing drawing of rotary drum composter detailing paddles for mixing.](image)

**Table 1 | Description of rotary drum composting experimental set up labels**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Experiment</th>
<th>Label</th>
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<tbody>
<tr>
<td>1</td>
<td>Metal Rotary Composter with Paddles</td>
<td>Metal Paddle</td>
</tr>
<tr>
<td>2</td>
<td>Metal Rotary Composter with Baffles</td>
<td>Metal Baffle</td>
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<tr>
<td>3</td>
<td>Plastic Rotary Composter with Paddles</td>
<td>Plastic Paddle</td>
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<tr>
<td>4</td>
<td>Plastic Rotary Composter with Baffles</td>
<td>Plastic Baffle</td>
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were shredded using maize milling machine to achieve about 1 to 4 mm particle size for better aeration and moisture control (Kalamdhad & Kazmi 2008). The compost material was prepared by mixing the freshly collected faecal sludge with shredded maize cobs in a ratio of 1:2 (1 part of faecal sludge to 2 parts of shredded maize cobs) on volume by volume basis. Manual turning of up to five complete rotation of drum was done on the first day and subsequently every three days for the first three weeks of the compost process. After the first three weeks, manual turning was done every 10 days till the end of the compost process. Turning was done to ensure that the materials on the top portion moved to the central portion, where it was subjected to higher temperature (Nayak & Kalamdhad 2014). A 12 weeks (84 days) composting period was selected for the proper degradation and hygienization of the compost (Hartz & Giannini 1998) using Temperature, pH and removal of *Ascaris lumbricoides* and *Trichuris Trichiura* as indicative parameters. Temperature of compost was recorded daily insitu at mid mornings at three different locations that is the centre, and the two opposite ends of the compost at varying depths with a long stem mercury in glass thermometer with a temperature range of 0°C to 100°C. The pH was measured using PC 300 Waterproof handheld pH meter.

**Determination of helminth eggs (Ascaris lumbricoides and Trichuris Trichiura)**

The concentration of *Ascaris lumbricoides* and *Trichuris Trichiura* in compost sample was determined using a combination of the floatation and sedimentation method developed by Schwartzbrod (2003). *Ascaris lumbricoides* and *Trichuris Trichiura* were enumerated using a combination of the floatation and sedimentation method (Schwartzbrod et al., 1989). Samples of slurry were diluted into a 2-L container and allowed to stand overnight to enable the eggs to settle completely. As much supernatant as possible was sucked up using a vacuum pump and the sediment placed into tubes and centrifuged for 3 min at 1,500 rpm. The supernatant was poured off and the sediment re-suspended with Zinc Sulphate of 1.3 density and homogenized with a spatula. It was again centrifuged for 3 min at 1,500 rpm. The Zinc Sulphate supernatant was poured into a fresh 2 litre bottle and diluted with 1 litre of water. The container was allowed to stand for 3 hours. As much supernatant was sucked up and the sediment re-suspended by shaking and emptied into centrifuge tubes, the bottle was rinsed twice with deionized water and placed into the tubes with the sediment. The tubes were centrifuged for 3 min at 1,750 rpm. The sediments were regrouped into one tube and centrifuged again for 3 min at 1,750 rpm. The sediment was again re-suspended in about 5 ml acid/alcohol (H₂SO₄ + C₂H₅OH) buffer solution and 2 ml ethyl acetate solution. It was shaken and occasionally opened to let out gas. It was then centrifuged for 3 min at 2,000 rpm. Much of the supernatant was sucked up leaving less than 1 ml of liquid. The deposits were read on a slide using a light microscope. *Ascaris lumbricoides* and *Trichuris Trichiura* were identified on the basis of their shape and size compared with the aid of bench aids for the Diagnosis of Intestinal Parasites (WHO, 1994). The counting was done under a light microscope in both chambers of a haemocytometer at X40 magnification.

**RESULTS AND DISCUSSION**

**Temperature development in compost**

Three significant changes characterised temperature development during the composting process for all the experimental set ups in Runs 1 and 2. These were (i) the low activity stage with relatively low temperatures (mesophilic stage), (ii) the active stage during which there were high temperatures (thermophilic stage) probably resulting from high microbial activity, and (iii) the maturation stage where the compost temperatures stabilised at <10°C above the ambient temperature. As it was indicated by Miller (1996), there is no general definition of the mesophilic and thermophilic range in
temperature interval and it is difficult to determine an immutable border among them. Temperatures between 20°C and 45°C were considered to be within the mesophilic range; whereas 45°C was considered the lower threshold temperature of the thermophilic phase (Ugwuanyi et al. 1999).

At the initial stage of composting, a fast increase in temperature was observed in Runs 1 and 2, which indicated signs of microbial activity. Typical temperature profiles for Runs 1 and 2 are, shown in Figures 2 and 3. The ambient temperature ranged from 25°C to 33°C for Run 1 whiles that of Run 2 ranged from 25°C to 35°C. During Run 1, thermophilic temperatures were obtained few days after starting the compost. Experiment Metal Paddle (MP) attained thermophilic temperatures (>\(\frac{45}{5}\)°C) on the third day whereas it took 4 days for thermophilic temperature to be recorded for experiments MB (Metal Baffle), Plastic Paddle (PP) and Plastic Baffle (PB). Experiment PP had the highest temperature of 62°C recorded on the 8th day. Meanwhile experiments MP, MB and PB recorded highest temperatures of 56°C, 55°C and 58°C on days 9, 8 and 8 respectively. Thermophilic temperatures lasted for 11 to 21 consecutive days for all the experiments with PB having the longest number of days (Figure 2). The Figure 2 shows the temperature increasing rapidly initially to maximum values and then the profile decreased gradually and flattened as time continued in all cases. In Run 2, temperature development were similar to those recorded in Run 1. A maximum temperature

![Figure 2](https://iwaponline.com/wpt/article-pdf/13/2/237/539097/wpt0130237.pdf)

**Figure 2** | Temperature profile for Run 1.

![Figure 3](https://iwaponline.com/wpt/article-pdf/13/2/237/539097/wpt0130237.pdf)

**Figure 3** | Temperature profile for Run 2.
of 54°C was reached after 3 days in experiment PP. Meanwhile maximum temperatures observed for experiments MP, MB and PB were 50°C, 53°C and 52°C respectively. Thermophilic temperature lasted for 12–17 days. It was observed that thermophilic temperatures ended between day 16 and 22 after composting (Figure 3). Similar temperature profiles were recorded in Run 2 as compared to Run 1. The highest temperatures attained in Runs 1 and 2 were indication that the temperature theoretically required to ensure the die off of pathogens including *Ascaris lumbricoides* and *Trichuris Trichiura* were reached in all cases of the experimental set ups. The number of days for which composts could sustain high temperatures in the experimental set-ups might have been influenced by the composter material, the mode of turning, provision of coating and insulation (Figures 2 and 3). The results from this experiment confirmed that sufficient insulation is required to maintain high thermophilic temperatures for a long time to ensure an efficient disinfection of faecal matter during composting Vinnerås (2002). Also it could be presumed that there was a higher population of microorganisms responsible for degradation and that might have speeded up the process resulting in higher temperatures of the compost of all the experimental trials although this parameter was not directly assessed. The mixing regime exposed different parts of the compost for microbial degradation of carbon and this could result in an increase in temperature. That notwithstanding frequent mixing of compost might not be necessary once the organic matter content of the compost has been reduced. The rotary composters with paddles were observed to enhance effective mixing as compared to their respective composter with baffles. Thus thermophilic temperature generated by the composters showed the following trend; PP > PB > MP > MB.

The general trend in temperature development across all the experiments showed a continuous decrease in temperature after about 3 weeks from initial start of the compost. The declining temperatures might be as a result of the reduction in the quantities of available degradable materials (organic matter) upon which microorganisms could feed. Though there were little difference in the highest temperatures recorded for each of the experiments, there existed a potential for heat to be lost in the metal fabricated rotary composters as metal looses temperature easily compared to the plastic fabricated rotary composters. Thus the metal rotary drums sustained temperatures for a relatively shorter time. Based on these experiments, the initial observation suggested certain design parameters and considerations were necessary to achieve thermophilic temperatures.

### Concentration of Ascaris lumbricoides and Trichuris Trichiura in sample

The concentration of *Ascaris lumbricoides* and *Trichuris Trichiura* of Run 1 ranged from 65–77 eggs/gTS and 30–41 eggs/gTS respectively at the beginning of the experiment (Figure 4). In Run 2, *Ascaris* lumbricoides and *Trichuris Trichiura* were not detected.
Ascaris lumbricoides concentration at the beginning of the experiment ranged from 77–110 eggs/gTS whereas Trichuris Trichiura ranged from 46–52 eggs/gTS (Figure 5). This result is an indication that all the samples analyzed were infected with helminth eggs. In each of the experiments, Ascaris lumbricoides eggs were observed to be prevalent as compared to Trichuris Trichiura. However, the variations obtained in each of the experiments showed the degree of infection. This means that in all the experiments the helminth eggs (Ascaris lumbricoides and Trichuris Trichiura) concentration was well above (more than 40–105 times) the recommended value for safe use in agriculture (WHO guideline of Eggs ≤ 1/gTS).

Figure 5 | Profile of Trichuris concentration for Run 1 during composting.

Figure 4 and Figure 5, illustrates the gradual decrease of Ascaris lumbricoides and Trichuris Trichiura concentration over the 12 weeks of composting. In Run 1, Ascaris concentration dropped from initial values at the beginning to final values of 1–13 eggs/gTS for all the experiments (Figure 4). There was a sharp decrease in Ascaris concentration from day 0 to the 14th day. The decline in Ascaris concentration subsequently was fairly consistent for all the experiments except PP experiment. There was an unexpected marginal increase in Ascaris concentration for PP experiment on day 21 before it subsequently dropped till the end of the experiment. This might be attributable to favourable conditions (adequate moisture and aeration) present for their growth. The largest percentage die off (98%) of Ascaris was observed in experiment PP. Percentage die off observed in the other experiments were MP (88%), MB (90%) and PB (92%) (Figure 4). There was significant difference in the mean number of Ascaris eggs among the four experimental set-ups in Run 1 with the highest number of eggs recorded in the MB experiment (50.1 eggs/g) and the least by the PB experiment (16.2 eggs/g, p = 0.0047, (Figure 4). The concentration of Trichuris decreased to 1–4 eggs/gTS at the end of composting (Figure 5). PP experiment had the lowest concentration (1 egg/gTS) compared to MP experiment with the highest concentration (4 eggs/gTS) in the compost at the end of the experiment. Trichuris eggs experienced a significant drop in concentration by the 7–28th day and afterwards decreased steadily till the end of the experiment (Figure 5). However, there was an increase in the concentration of Trichuris in MB experiment on the 77th day. This situation was not expected after the long exposure of compost to adequate sanitizing temperature. The reason could be as a result of sample location as Trichuris appears to survive longer in corner samples than centre samples. However, in all the experiments, Trichuris die off at the end of the experiment was statistically significant (p < 0.0001) when compared with their initial concentrations.

The Figures 6 and 7 shows the results of Ascaris lumbricoides and Trichuris Trichiura concentration in Run 2. At the start of the experiment, the concentration of Ascaris ranged from 95–105 eggs/gTS compared with Trichuris Trichiura which ranged from 40–52 eggs/gTS. The initial concentration of
Ascaris lumbricoides in g/TS were as follows, MP = 103, MB = 95, PP = 105 and PB = 98 (Figure 6). The number of Trichuris Trichiura present in the initial sample was larger in MB experiment (52 eggs/gTS) compared with the least in MP experiment (40 eggs/gTS) (Figure 7). There was a general and consistent decline in Ascaris lumbricoides and Trichuris Trichiura concentrations to a minimum at the end of the experiment (Figures 6 and 7). MP, MB, PP and PB experiments declined to 5, 3, 0 and 2 eggs/gTS for Ascaris lumbricoides at the end of composting. Meanwhile the decline in Trichuris Trichiura concentration was 1, 2, 0 and 2 eggs/gTS for MP, MB, PP and PB experiments respectively at the end of composting. Similar results in decline in Ascaris lumbricoides and Trichuris Trichiura concentrations were reported during co-composting of faecal sludge and other organic waste materials (Gallizzi 2003). The reason for the consistent decrease is attributable to the fact that the thermophilic temperatures obtained were adequate to destroy both Ascaris lumbricoides and Trichuris Trichiura. This thermophilic temperatures increase the rate of die off of Ascaris lumbricoides by increasing the desiccation rate of cells. Eventually the cell can no longer slow down the rate of desiccation and dies (Pecson et al. 2007). It is worthy to note that no Ascaris lumbricoides and Trichuris Trichiura were observed in experiments PP. This might be due to the fact that the material for the composter was able to sustain relatively high temperatures whiles enabling effective mixing regime as a result of the mixing configuration in relation to the other experiments. However, in all

Figure 6 | Profile of Ascaris concentration for Run 2 during composting.

Figure 7 | Profile of Trichuris concentration for Run 2.
the experiments, *Ascaris lumbricoides* and *Trichuris Trichiura* die off at the end of the experiment were statistically significant ($p < 0.0001$) when compared with their initial concentrations.

**CONCLUSION**

The study showed that faecal sludge from public latrines in peri-urban areas of Ashanti region of Ghana was highly contaminated with *Ascaris lumbricoides* and *Trichuris Trichiura*. The heat generated by the composting process exposed the helminth eggs to thermophilic temperatures for a sufficient duration hence high removal rate was achieved at the end of composting. There was a significant impact of different rotary drum materials and mixing configuration on the die off of *Ascaris lumbricoides* and *Trichuris Trichiura*. The *Ascaris lumbricoides* and *Trichuris Trichiura* population decreased significantly in all the experimental set-ups during the composting process. The average die off of *Ascaris lumbricoides* and *Trichuris Trichiura* was similar in both Run 1 and Run 2 but highest in plastic paddle experiment than that of metal baffle, metal paddle and plastic baffle experiments.

The results of all the experiments showed values very close to the WHO guidelines of 1 egg/gTS. The final compost of plastic paddle experiment showed impressive die off in eggs which are within acceptable ranges of no risk of less than 1 egg/gTS. This meant that plastic paddle experiment was favoured over metal baffle, metal paddle and plastic baffle experiments due to the fact that it contained less *Ascaris lumbricoides* and *Trichuris Trichiura* which satisfy the WHO guideline. The findings showed that the type of composter had significant impact on the die off of *Ascaris lumbricoides* and *Trichuris Trichiura* population with plastic drum with rotating paddle mixer performing best.

This research bridges a gap in faecal sludge management as it demonstrates the applicability of the rotary drum technology in faecal sludge composting in peri-urban areas where farming is the main economic activity of majority of the inhabitants.

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