Research Article

Design and Development of In-Vessel Composter for Treating Agricultural Weeds

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Abstract

Most of the agricultural fields in India, weeds are playing a major role to decrease the productivity of the agricultural crops. The weeds are periodically removed by the farmers and are being dumped somewhere or left burnt in the same field, which leads to many environmental pollution problems. Keeping this in view, to eliminate the environmental pollution and to make a useful energy product out of weeds, it has been proposed to use the weeds for composting process to turn into a compost which will in-turn enhance soil fertility and agricultural productivity. Indiscriminate open disposal of weeds may cause many toxic gases and odour to release during the decomposing process. During the past years, cattle waste, organic waste and decomposing materials are only used for composting process in conventional composters or bins, no specific composter is designed for exclusively treating agricultural weeds by composting. This paper describes about the design of an in-vessel composter of capacity 50 kg, exclusively for treating the agricultural weeds by the method of in-vessel (closed) composting. The details of design calculation along with the fabrication of in-vessel composter are discussed.

Keywords: agricultural weeds; bio-energy; composting; design; in-vessel composter

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Introduction

In past years, as per the sources from ministry of urban development and central pollution control board, Municipal Solid Waste (MSW) generated is being 52MT and by 2017, it was 450g per capita daily generation and urban population of 450 million generated MSW of 72MT [1]. In Tamilnadu, generation of MSW is about 67680 tonnes/year and operational capacity to produce energy is about 15.8%.

In India approximately, 65MT of weeds is produced especially, parthenium, amaranthus etc. and operational capacity of about 40% is used for composting [2]. The composting offers several advantages such as modifies and stabilizes soil pH, increases the soil's ability to hold essential nutrients, increases beneficial soil microorganisms, binds contaminants and degrades compounds, helps with wetland restoration and erosion control and suppresses weeds and many pathogens.

Compost can be produced from organic waste such as cattle manure, saw dust and agricultural weeds which is suitable for anaerobic decomposition method. Generally, weeds are cut into small pieces so that it becomes a good source for composting and it consumes less time for composting the materials [3]. Weeds (10%) are added in more quantity for the composting process and saw dust (5%), cattle manure(2-3%) are also added for maintaining carbon and nitogen source to improve the source of micro-organism for better composting. The suitable weeds species of parthenium, phyllanthus, amaranthus are taken for the composting process since these are problematic weeds [4].

In this study, the composting weeds are fed into composting cylinder for composting where decomposition occurs faster when it is in closed condition (in vessel) and the cylinder is placed below 20°C for proper composting.

Among the various microbial process, anaerobic decomposition method is used for treating weeds and the in-vessel composter offers some advantages than other types of composting such as odour will be less, assure pathogen destruction, easy construction and operational maintenance. Reports on further modification reveals to develop an enlarged size of composting cylinder for effective compost production. The methodology adopted for the design of in-vessel composter is detailed in this paper.

Material and Methods

Among the anaerobic decomposition methods used for treating weeds, the in-vessel composter offers a selective way of composting to reduce odour potential, assure pathogen destruction, simple construction and operational

maintenance. As reports say, further modification has to be done to develop an enlarged size of composting cylinder for effective compost production [5].

To design an in-vessel composter, two sections namely plug flow system and agitated bed system was planned.

Plug flow system

Plug flow remains the combination of all composting materials i.e. weeds (10%), cattle manure (2-5%) and sawdust (5%). It maintains proper carbon and nitrogen ratio relationship [6].

Agitated bed system

Agitated bed remains the mixing of all those composting materials during composting. Hence, in the inner side of the composter, the shaft and blade should be incorporated in the composting cylinder for mixing the materials, since the composter should be rotated 2-3 times for every 24 hrs manually and sprinkling of water should be done at the time of every rotation.

The selected composting materials based on the characterization with high moisture and high carbon content especially, saw dust carbon ratio will be 32.5:1. For better compost, C:N ratios ranges from 25-30:1. In view of enhancing the treatment of agricultural weeds in the developed in-vessel composter, the weeds (10%), saw dust (5%) and cattle manure (2-3%) are filled inside the composting cylinder in a layered manner one after another. The first layer is saw dust, second layer is cattle manure, third layer is saw dust, fourth layer is cattle manure and so on till it covers one-half of the volume of composter. After that the top layer which is the final layer is filled with the selected agricultural weeds to cover upto three-fourth of the volume of composter [7].

Figure 1 Agitated bed system

Figure 2 Selected weed (parthenium species)

Composter components

Composting cylinder and cylinder cap:

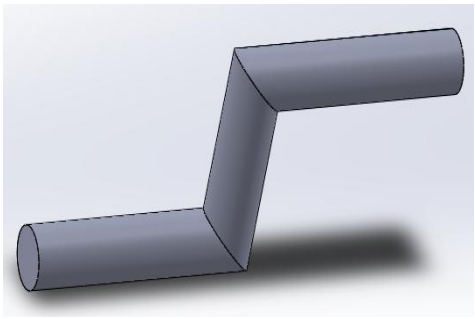
The cylinder of the in-vessel composter is made up of PVC which makes it free from corrosion. The dimension of the composting cylinder of 750 * 350 mm is selected. The cylinder cap is used to open and close, when feeding materials in/out of composter. The height and diameter is based on the size of the composting cylinder.

Bearing and shaft

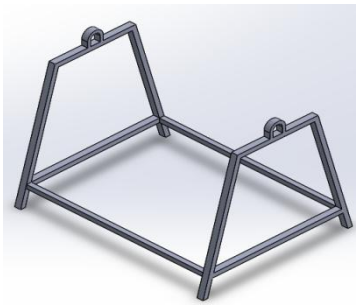
The bearing and shaft is made up of iron and mild steel respectively. The bearing is fixed at both the sides of the composting cylinder. The bearing is used for fixing the shaft to mix the materials. The shaft rotation makes the correct mixing of composting materials of saw dust, cattle manure and weeds.

Handle bar and stand

The handle bar is used for shaft rotation and is fixed along with shaft. Whenever the handle bar is rotated, shaft is also rotated for mixing the composting material. The stand is made up of iron rod which supports composting cylinder. The stand fabrication is shown in **Figure 3**.



Handle bar



Stand

Figure 3 Stand fabrication

Composting materials

Saw dust

Saw dust is a by-product or waste product of wood working operation such as milling, drilling etc. there is a very strong possibility of sawdust getting decomposed quickly because, it composts at a faster rate because it has high amount of carbon [8]. In this composter, 5% of sawdust is used for better decomposition.

Cattle manure

Cattle manure is made up of digested residues of plants and grains. The organic fraction of manure plays an important role in increasing soil organic matter, improving soil structure and water infiltration rate. It contains about 3% of Nitrogen, 2% of Phosphorus and 1% of Potassium [9]. Cattle manure may be used for compost piles. In this composter, 2-5% of cattle manure is used for good composting.

Agricultural weeds

The unwanted plants growing naturally with the main crops are called weeds. Once the weeds are harvested, it might be placed somewhere in the same field which will create some environmental effects [10]. So, several species of harmful weeds (Amaranthus, Parthenium species etc.) are used for compost piles for better composting. It has high organic matter and rich in nutrients especially in both carbon and nitrogen.

Design calculation for dimension of in-vessel composter

The design of composter and input feeding is based on diameter and height of the cylinder. In view of enhancing the treatment of agricultural weeds in the developed in-vessel composter, composting material are filled inside the composting cylinder which is layered one after another. Diameter and height ratio was fixed at 1:2 [11]. Based on the height and diameter, the amount of composting material allowed for filling in the composting cylinder was calculated

The diameter (D) and height (H) ratio of 1:2 for cylinder is fixed by assumption based on input feeds of composting materials in the composter, and is given by following formula,

$$H= 2D; D=H/2;$$

On the basis of input feed of weeds, the volume of composter was found by using the following formula,

$$\text{Volume of composting cylinder} = \pi.D^2.H / 4, \text{ cm}^3$$

where,
D = Diameter of composting cylinder, cm. H = height of composting cylinder, cm (Volume of cylinder, cm^3 is converted to amount of material, kg)

$$\text{Amount of mass} = \text{volume of composting cylinder} * 0.001, \text{ kg}$$

The mixture is filled $3/4^{th}$ of the composting cylinder for better compost [12],

$$\text{Amount of } 3/4^{th} \text{ filling of mass in the cylinder} = \text{amount of mass} * 0.75 \text{ kg}$$

From the calculation, the composting cylinder, stand and handle bar was designed according to the composting materials.

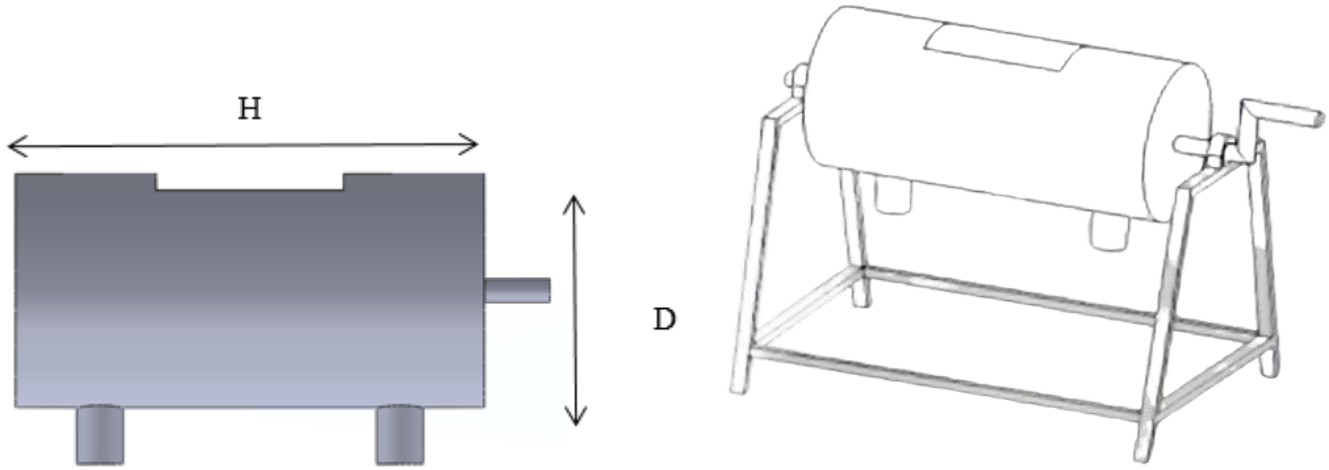


Figure 4 Solid work design of in-vessel composter

Results and Discussion

Design of composting cylinder:

The design of composter and input feeding is based on diameter and height of the cylinder. The design of in-vessel composter was done by solid works software. For the treatment of agricultural weeds to compost, the weeds (10%), saw dust (5%) and cattle manure (2-3%) are filled inside the composting cylinder by layering one after another. The D/H ratio was calculated based on the amount of composting material to be allowed for filling in the composting cylinder [13].

The diameter (D) and height (H) based on input feeds of composting materials in the composter, was found to be H=70 cm and D=35 cm

After calculating the diameter and height, the volume of composter was obtained to be

$$\text{Volume of composting cylinder} = 3.14*35*35*70/4 = 67313.75 \text{ cm}^3$$

Amount of mass = volume of composting cylinder * 0.001, kg = 67313.75*0.001

Thus, Amount of mass = 67.313 kg.

The composting material is filled to 3/4th space of the composting cylinder for better compost = 67.313*0.75 = 50.48 kg.

The mass of in-feed material will be approximately, 50kg filled in the composting cylinder, to become better compost.

Development of in-vessel composter:

After completing the design, the in-vessel composter was fabricated according to the dimensions and was ready for feeding. The composting materials are filled by layering one above another. The first layer is saw dust, second layer is cattle manure, third layer is saw dust, and fourth layer is cattle manure and so on, till it covers ½ of the volume of composter. After that the top layer which is the final layer is filled by selected agricultural weeds to cover 3/4th of volume of the composter.

After filling the composting material, the composting starts. This composter are designed to minimize odor and process time by controlling environmental conditions such as airflow, temperature, and oxygen concentration. The detention time in-vessel varies from 3-4 weeks [14].

The composter was rotated 2-3 times for every 24hrs manually and sprinkling of water was done at the time of every rotation [15]. The process of feeding materials in fabricated composter is shown in **Figure 5**.

Sawdust filling (5%)

Cattle manure filling (2-5%)

Agricultural weeds filling (10%)

Fabricated in-vessel composter

Figure 5 Feeding of composting materials and fabricated in-vessel composter

Conclusion

In-vessel composter was designed for a capacity of 50 kg feed of agricultural weeds for composting into better compost in 2 to 3 weeks of retention time. The composter was designed in a cylindrical shape with height being 70 cm and diameter being 35 cm. It can hold feed upto 3/4th of its volume and is also fixed with suitable agitator assembly to turn the compost at periodic intervals of time. Due to this design, the in-vessel composter receives better compost which has high nutrient content, better carbon and nitrogen ratio, good colour and odour. The compost produced from this composter when applied to soil, gives better results of improved water holding capacity, provides good plant growth which in turn helps in greater yield.

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