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RESEARCH ARTICLE

DESIGNING, FABRICATION AND PERFORMANCE EVALUATION OF AGRICULTURAL COMPOSTER FOR ECONOMICAL BIOWASTE MANAGEMENT

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ABSTRACT

In the last few years, the rapid increase of human population are creating many environmental problems because of intensification of human activities. A huge amount of wastes are generated from industries including food and agriculture industries. It is essential to protect the natural resources. It can be done with best management practices of agriculture waste in future Composting is the best method to handle the food, agricultural and industrial waste. The main objective of this research is the design and fabrication of an indigenous composter to conserve the agriculture waste. Composter structure is based on two shells. One is inner shells which is having diameter of 48 inches and outer shell having diameter of 52 inches. Between these two shells heat in the form of steam is circulated to give high temperature for pasteurization of compost. Raw material is added in the inner shell. Two gears are attached with this composter structure. One is driving gear which is also small gear attached with motor. Other one is larger gear which is adjusted according to our desire RPM requirement. Larger gear further rotates the shaft present in the inner shell of composter. Gear motor is used having the power of 3355 Watt Watt. Material used for this composter was mild steel. A boiler was attached to this composter to flow the steam in outer shell of composter. Agriculture waste considered for this research corn straw waste. The analysis have been done in a composter for compost effecting parameters. The effect of three independent parameters pressure, RPM and feeding rate was analyzed on the composting time of waste. Results indicated that increase in the RPM the time of composting also increase because of oxygen cannot consumed fully at higher RPM. Whereas the increase in feeding rate decrease the time of composting because the greater number of microbial activities generated in the composting process and compost prepared in less time. In case of pressure, higher the pressure the time of composting decreases because at higher pressure the time rise quickly and thermophilic conditions occurs quickly. At RPM 12 and feeding rate 15kg in 62.89± 2.26 time compost was prepared it was the least time as compare to others. At 10 RPM and 1 bar pressure composting time notice was 65.33±2.60. In combination of feeding rate and pressure, at feeding rate 15kg and pressure 0.5 bar least time noticed 63.00± 2.35.

KEYWORDS

Composter, corn straw, composting time, RPM

1. INTRODUCTION

In the last few years, the rapid increase of human population are creating many environmental problems because of intensification of human activities (Shilev et al., 2007). According to Census, current population of Pakistan is 207 million. Economy of Pakistan is greatly influenced by the agricultural sector and a huge amount of waste generated per year which still have no economic use (Saeed et al., 2015). Agricultural biomass is able to generate leftover with every passing year that causes disposal difficulties (Chaudhry et al., 2009). The climate of Pakistan is very favorable for the growth of various types of crops every year. In Pakistan, 70% people live in the rural areas and most of them are farmers (Ghaffar, 1995). In urban areas of Pakistan solid wastes are generating approximately 20 MT/yr. and crop residue is approximately 82.12 MT/yr and animal manure above 365 MT/yr (Saeed et al., 2015).

In Pakistan Punjab province wheat, rice and cotton include nearly 8.3 million hectare of land. Mostly Pakistan land area lies in a semi-arid zone with average annual precipitation 151 mm. Municipal solid waste has become a serious problem of Pakistan. MSW currently deposited into open landfills. Disposal of MSW is raising public health concern such as spoilage of both air and drinking water quality (Qazi et al., 2009).

Agricultural waste defined by United Nations as production of waste due to various agricultural operations. Agricultural waste comprises of run-off fertilizer from fields, harvest waste, mixing of pesticides with water, manure, pesticides mixed in air, pesticides mixed with soil, salt drained from fields, poultry houses, slaughter houses and other wastes from farms (United, 1997).

A huge amount of wastes are generated from industries including food and agriculture industries. It is essential to protect the natural resources. It can be done with best management practices of agriculture waste in future (Shilev et al., 2007).

Composting methods are most suitable technology for water, soil and air. Biological organic wastes are considered in composting because this is an appropriate practice to convert organic waste into useful products (Argun

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et al., 2017). Composting is a procedure which decomposition of biological raw material is mainly occur because of aerobic microorganisms, whereas some although some anaerobic microorganisms also occurs (Cooperband, 2002).

A lot of work has been done on the composting of agriculture waste in developing and developed countries. Different studies have been conducted in China firstly, mature compost was prepared using distilled grain waste in a lab scale reactor (Wang et al., 2017), secondly compost was prepared using chicken manure by inoculated cold-adapted.

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India also using composting method. India also conducted different studies on the composting of agriculture wastes. The composting of vegetable wastes was done using carton as a additive in a composter (Rawoteea et al., 2017). Compost was prepared using different additive during the composting process of green waste in thermocol boxes (Gabhane et al., 2012). In Spain, a research was conducted to quantify the release of ammonia while running composting process of different useless material into a lab scale reactor (Pagans et al., 2006). In Tunisia, the management aspect and final product for agriculture waste co-composting was adopted for sewage sludge with organic waste (Asses et al., 2018).

Composting is an extensively used technology to convert organic waste into useful organic manure called compost. This technology recycles mineral nutrients including nitrogen, potassium and phosphorus which can be used for agricultural purposes (Wang et al., 2015). Because of these quality nutrients are the part of this compost which mean it a serious competitor with other market fertilizer (Proietti et al., 2016). In composting process, thermophilic conditions are associated which destroy the pathogenic organisms and hygienic compost obtained (Pandey et al., 2016).

Pakistan is an agricultural country. A huge amount of waste is generated every year. To manage the agricultural waste is a big issue. Agricultural waste is a biomass which can be used for many purposes. In this study, the composting process will use to manage the agricultural waste specially corn straw waste. An organic compost will be made by using composting process. It can be used as fertilizers which will be more beneficial for the growth of crops rather than synthetic fertilizer.

The general target of this study is to convert organic waste into organic compost using the specially design composter machine. To design and fabricate an indigenous composting machine and performance evaluation of designed composting machine on the basis of pressure, feeding rate and RPM are the main objectives of the current study.

2. Materials and Methods

The composter was designed and fabricated to converse the agriculture waste in term of fertilizer which can be used in the agriculture fields. The composter is made using the mild steel material. The composter was designed considering following specifications: 1) inner and outer diameter of shells 2) drive and driven gears 3) gear motor 4) base frame 5) insulation 6) main shaft and bearing with brackets and 7) software use for designing. Table 1 provides the features and specification of composter material used in the composter design and fabrication.

Table 1: Features and specifications of composter

Features	Specifications
Material	Mild steel
Diameter of inner shell	48”
Thickness of inner shell	6mm
Diameter of outer shells	52”
Thickness of outer shell	3mm
Length	60”
Shaft pipe	3”
Gear Motor (hp)	5
Insulation	Glass wool 2”
Zinc sheet thickness	0.4mm

2.1 Main parts of Composter

Main parts in the composter are discussed below one by one. Which gives the complete detail and function of each part.

Composter structure is based on two shells. One is inner shells which is having diameter of 48 inches and outer shell having diameter of 52 inches. Between these two shells heat in the form of steam is circulated to give high temperature for pasteurization of compost. Raw material is added in the inner shell. Two gears are attached with this composter structure. One is driving gear which is also small gear attached with motor. Other one is larger gear which is adjusted according to our desire RPM requirement. Larger gear further rotates the shaft present in the inner shell of composter. Gear motor is used having the power of 3355 W. Which is designed according to our load carrying capacity. Gear motor is attached with small gear. Base frame is consisted on four feet which are adjusted in a concrete. Insulation is provided over the outer shell of composter using glass wool to prevent the heat losses. Glass wool is of thickness 0.0762 m and the glass wool is covered with zinc sheet of 0.4mm. Main shaft is of 3 inches in diameter and three rotators are attached with this shaft. Shaft is rotated by the larger gear. Hopper is used to enter the raw material from the top. Back gate is fixed. Front gate can be open to draw out prepared compost. Opener is attached at front side through which gate can open. Two gauges are attached at upper side which is used to measure the temperature compost material and pressure of steam inside the jacket. Composter is supported with the help of four supports which are attached in a concrete. Chain drive is used for the purpose of transmitting the mechanical power from one smaller wheel to another larger wheel. The whole composter was designed using AutoCAD 2007 software.

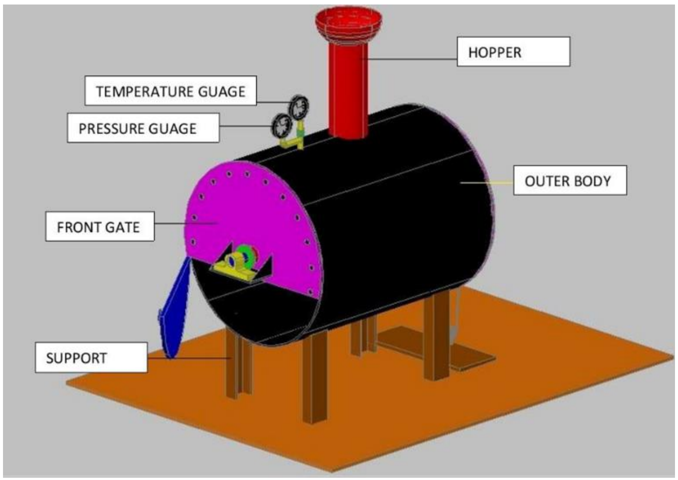


Figure 1: 3D Left side view of composter

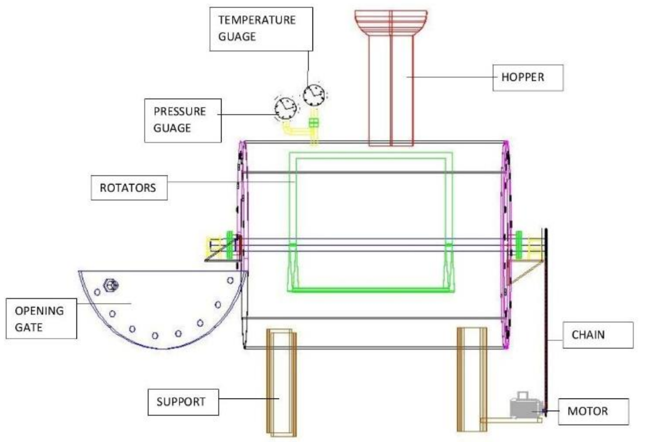
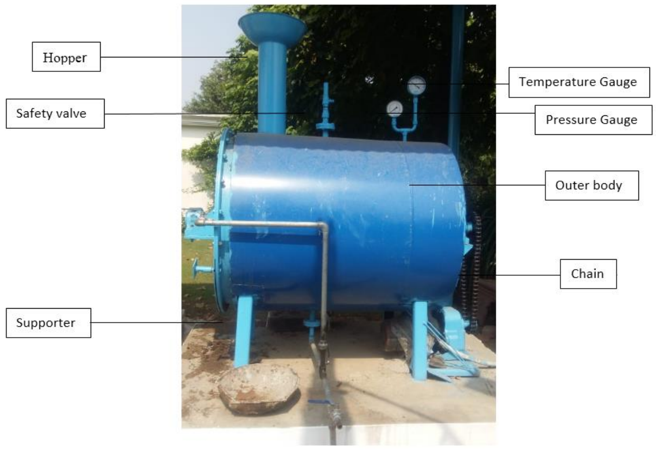


Figure 2: 2D wireframe front view of composter



2.2 Design and fabrication

In this part, the calculation is done for the 1) motor power calculations 2) Number of teeth on larger gear.

Design power calculation

Power rated = 1491.4 Watt

design power = Rated power × Service factor (K S)

The service factor (KS) is the product of various factors K1, K2 and K3. The values of these factors are taken as follows:

Load factor (K1) for variable load with heavy shock = 1.5 (1)
Lubrication factor (K2) for drop lubrication = 1.5 (2)
Rating factor (K3) for 8 hours per day = 1 (3)
KS = K1.K2.K3 = 1.5 × 1.5 × 1 = 2.25 (4)
Rated power = 2hp = 1.4914 kW (5)

Design power= 1.4914 × 2.25 = 3.355 kW=3355 Watt

Calculation for number of teeth on large gear

When:

RPM on smaller gear= N1 = 24

Number of teeth on smaller gear = T1 = 13

RPM on larger gear =N2 = 12

Number of teeth on larger gear =N2 = ?

$\frac{N1}{N2} = \frac{T2}{T1}$

T2= $\frac{N1}{N2}$ x T1 = $\frac{24}{12}$ x 13 = 26

When:

RPM on smaller gear= N1 = 24

Number of teeth on smaller gear = T1 = 13

RPM on larger gear =N2 = 10

Number of teeth on larger gear =N2 = ?

$\frac{N1}{N2} = \frac{T2}{T1}$

T2= $\frac{N1}{N2}$ x T1 = $\frac{24}{10}$ x 13 = 31.2 say 31

When:

RPM on smaller gear= N1 = 24

Number of teeth on smaller gear = T1 = 13

RPM on larger gear =N2 = 14

Number of teeth on larger Sprocket =N2 = ?

$\frac{N1}{N2} = \frac{T2}{T1}$

T2= $\frac{N1}{N2}$ x T1 = $\frac{24}{14}$ x 13 = 22.28 Approximately 22

3. RESULTS AND DISCUSSION

Experimental results are analyzed with the help of graphs and tables. Experiments results obtained by the composter which is design and fabricated in the University of Agriculture, Faisalabad. Necessary statistical analysis applied in this present work.

Three independent variables were selected to analyze the effect of these on the composting time of corn straw.

Table 2: Analysis of variance (ANOVA) for composting time

Source	Degree of freedom	Adjusted SS	Adjusted MS	P-Value
RPM	2	84.91	42.457	0.001
Feeding rate	2	379.73	189.864	0.000
Pressure	2	432.69	216.346	0.000
RPM*Feeding rate	4	256.86	64.216	0.000
RPM*Pressure	4	317.68	79.420	0.000
Feeding rate*Pressure	4	70.42	17.605	0.016
RPM*Feeding rate*Pressure	8	735.65	91.957	0.000
Error	54	284.67	5.272	
Total	80	2562.62		

Results of analysis of variance (ANOVA) at 5% significant level for time of composting of corn straw waste given in table 2 showed that all p-values are less than alpha value 0.05. So all treatments are significantly different. They all have a significant effect on time of decomposition.

3.1 Effect of RPM verses Time

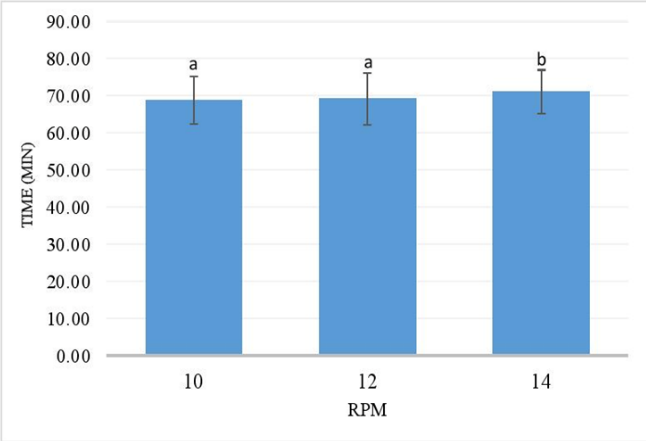


Figure 4: Effect of RPM on Composting Time

Figure 4 shows the effect of RPM on time of composting of corn straw waste in minutes. Three different RPM were selected to see the effect of time in minutes. At 14 RPM the highest mean time was measured as 71 minutes. At higher RPM, the waste material shuffle quickly and more time required for the decomposing of material. There is no significant difference among 10 and 12 RPM whereas 14 RPM is significantly different from others at level $p < 0.05$.

3.2 Effect of feeding rate verses time

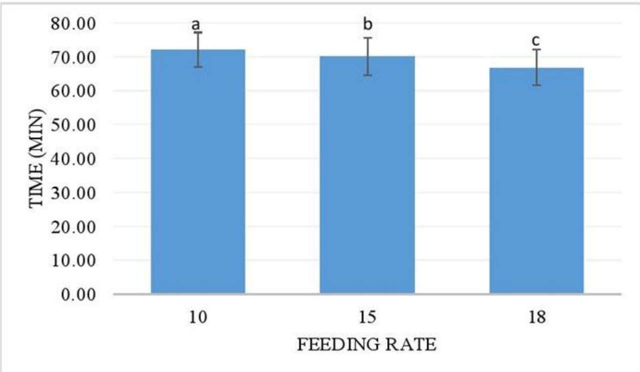


Figure 5: Effect of feeding rate on composting time

Figure 5 shows the effect of feeding rate on time of composting of corn straw waste in minutes. Three different feeding were selected to see the effect of time in minutes. The highest mean temperature was measured as 72.07 minutes at lowest feeding rate of 10kg. Less the feeding rate greater amount of time required for composting. Whereas greater amount of feeding rate less time required because microbial activity more rapidly. All three treatments are significantly different from each other at $p < 0.05$.

3.3 Effect of pressure with respect to time

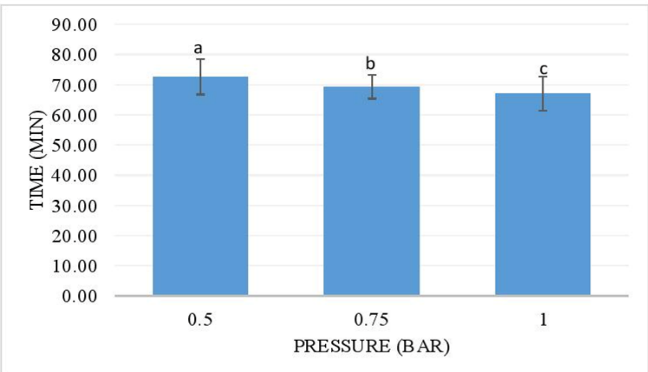


Figure 6: Effect of pressure on composting time

Figure 6 shows the effect of pressure on time of composting of corn straw waste in minutes. Three different pressure were selected to see the effect of time in minutes. The highest mean temperature was measured as 72.63 minutes at lowest pressure of 0.5 bar. At pressure 1 bar the mean time measured 67 minutes. Because at greater pressure the temperature will raise rapidly and decomposing occurred quickly in less time. All three pressure values are significantly different from each other at $p < 0.05$.

3.4 Effect of RPM * Feeding rate on time

Table 3: Combine effect of RPM * Feeding rate on composting time

Treatments	Mean Composting time
RPM*Feeding rate (1*1)	70.22± 3.80 abcd
RPM*Feeding rate (1*2)	67.44± 5.32 d
RPM*Feeding (1*3)	68.56± 4.69 cd
RPM*Feeding rate (2*1)	72.56± 5.32 ab
RPM*Feeding rate (2*2)	62.89± 2.26 e
RPM*Feeding rate (2*3)	71.89± 5.78 abc
RPM*Feeding rate (3*1)	73.44± 6.00 a
RPM*Feeding rate (3*2)	70.11±5.84 abcd
RPM*Feeding rate (3*3)	69.67±5.34 bcd

Means that do not share a letter are significantly different

Table 3 shows the combine effect of RPM and feeding rate (kg) on time of decomposition of corn straw waste material. At RPM * feeding rate (kg) (3*1) highest time 73.44 min required to decompose the waste material. RPM * feeding rate (kg) (1*2), RPM * feeding rate (kg) (2*2) and RPM * feeding rate (kg) (3*1) are significantly different from each other at level $p < 0.05$.

3.5 Effect of RPM * Pressure on time

Table 4: Combine effect of RPM * Pressure on composting time

Treatments	Mean composting time
RPM*Pressure (1*1)	66.56± 6.21 de
RPM*Pressure (1*2)	68.00± 1.66 cde
RPM*Pressure (1*3)	65.33±2.60 e
RPM*Pressure (2*1)	69.11± 7.04 bcd
RPM*Pressure (2*2)	69.11± 5.04 bcd
RPM*Pressure (2*3)	69.11± 7.57 bcd
RPM*Pressure (3*1)	71.67± 3.50 b
RPM*Pressure (3*2)	70.78± 4.24 bc
RPM*Pressure (3*3)	77.11± 2.32 a

Table 4 shows the combine effect of RPM and pressure (bar) on time of decomposition of corn straw waste material. At RPM * pressure (3*3) highest time 77.11 min required to decompose the waste material. RPM * pressure (1*1), RPM * pressure (3*1), RPM * pressure (3*2) and RPM * pressure (3*3) is significantly different from each other at level $p < 0.05$.

3.6 Effect of Feeding rate * Pressure on time

Table 4: Combine effect of feeding rate * pressure on composting time

Treatments	Mean Composting time
Feeding rate*Pressure (1*1)	69.22±4.63 bc
Feeding rate *Pressure (1*2)	72.11± 3.66 ab
Feeding rate *Pressure (1*3)	74.89± 5.67 a
Feeding rate *Pressure (2*1)	63.00± 2.35 d
Feeding rate *Pressure (2*2)	66.11± 2.89 cd
Feeding rate *Pressure (2*3)	71.33± 6.61 b
Feeding rate *Pressure (3*1)	68.78± 7.01 bc
Feeding rate *Pressure (3*2)	69.67± 2.87 b
Feeding rate *Pressure (3*3)	71.67± 5.29 ab

Means that do not share a letter are significantly different

Table 4 shows the combine effect of feeding rate (kg) and pressure (bar) on time of decomposition of corn straw waste material. Highest time needed to decompose the waste material at feeding rate 10kg and pressure 1 Bar. Feeding rate * pressure (1*1), feeding rate * pressure (1*3) and feeding rate * pressure (2*1) are significantly different from each other at level $p < 0.05$. Feeding rate * pressure (1*2), feeding rate * pressure (2*1) and feeding rate * pressure (2*2) are significantly different from each other at level $p < 0.05$.

Results indicated that increase in the RPM the time of composting also increase because of oxygen cannot consumed fully at higher RPM. Whereas the increase in feeding rate decrease the time of composting because the greater number of microbial activities generated in the composting process and compost prepared in less time. In case of pressure, higher the pressure the time of composting decreases because at higher pressure the time rise quickly and thermophilic conditions occurs quickly.

At RPM 12 and feeding rate 15kg in 62.89± 2.26 time compost was prepared it was the least time as compare to others. This was optimum value for RPM * feeding rate combination. In case of RPM * Pressure combination, optimum time was notice at RPM 10 and pressure 1 bar value notice 65.33±2.60. In combination of feeding rate and pressure, at feeding rate 15kg and pressure 0.5 bar least time noticed 63.00± 2.35.

4. Conclusions

Composting is an efficient and environmental friendly method to handle organic waste. In this research an indigenous composter was designed and fabricated for conversion of organic waste into useful compost. Composter structure is consisted on two shells. Inner shells is having diameter of 48 inches and outer shell having diameter of 52 inches. Between shells heat flow in the form of steam to give high temperature for pasteurization of compost. Raw material is added using hopper. A boiler was used to provide steam. Corn straw waste was used in this research to make compost. The effect of three independent parameters pressure, RPM and feeding rate was analyzed on the composting time of waste. Results showed that as RPM increases then the time of composting also increase because of oxygen cannot consumed fully at higher RPM. When feeding rate increased then the time of composting was decreased because the greater number of microbial activities generated and compost prepared in less time. In case of pressure, higher the pressure the time of composting decreases because at higher pressure the time rise quickly and thermophilic conditions occurs quickly. At RPM 12 and feeding rate 15kg, time of composting was notice 62.89± 2.26 and compost was prepared in least time as compare to others. At In case of RPM 10 and pressure 1 bar time of composting was notice 65.33±2.60. At feeding rate 15kg and pressure 0.5 bar least time noticed 63.00± 2.35.

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