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# Comparative Evaluation of Mechanized and Conventional Composting Process

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**Abstract:** Composting is the decomposition of organic matter in aerobic environment. windrow turner machine is used to turn compost piles. Composting is an excellent method to increase soil organic matter content. This paper will analyze about the comparison between mechanized and the conventional pile turning methods in composting process and the need for windrow turner machines to manage waste effectively and turn it into nutrient-dense material. This put emphasis on the vital role that windrow turner machine plays in managing problems related to agricultural waste, soil degradation and deficient nutrients in soil. This approach not only delivers a practical solution, it also points out the potential for significant increase in soil fertility and agricultural sustainability. The results of our study show that compost turned by machine has more Cation Exchange Capacity (CEC) values than compost turned by hand that is linked to the turning frequency. After the period of 8 weeks the CEC values in pile 2 raised from 21.23 meq/100 g dry weight to 33.28 meq/100 g dry weight, whereas the Cation Exchange Capacity values in pile 1that was turned using a windrow turner machine increased from 21.23 meq/100 g dry weight to 68.87 meq/100 g dry weight. A large rise in Cation Exchange Capacity values in turned compost indicates compost maturity. The value of 60 meq/100 g of CEC of compost is considered mature compost. Moreover, the value of electrical conductivity in pile 1 increased from 1.98 ds/m to 11.34 ds/m, whereas in pile 2 it climbed from 1.98 ds/m to 7.86 ds/m after 8 weeks. The outcomes of this research contribute to a comprehensive understanding of the benefits related with effective composting and their effects on soil health.

**Keywords:** Sustainable; Windrow composting ; Mechanization; Windrow turner.

## 1. Introduction

Agriculture acts as the principal revenue source for a large segment of the worldwide populace, especially in lesser developed and progressive regions. This is predominant global source of sustenance. A significant challenge within this sector pertains to the substantial generation of organic waste. Failure to promptly address this organic waste issue results in environmental pollution and wasting valuable resources like water, agricultural land, and nutrient in soil. This organic waste also posing threats to both human health and the well-being of various organisms. The predominant method employed in agriculture is intensive farming which results in the depletion of essential nutrients in the soil and the degradation of its texture due to continuous tillage and the application of chemical fertilizers [1]. Proper handling of municipal waste is a major problem in both emerging and established countries throughout the world. Multiple investigations have found that trash generation rates are positively connected with household consumption levels [2]. All over the world crop production rose to feed the world's growing population as a result agro-waste production has increased significantly. Recycling these wastes is essential for ecological security and revenue for agriculture. Out of Pakistan's overall physical land area of 80 million hectares (Mha), 22 million hectares are allocated for agricultural purposes. The agricultural land in the country primarily consists of soil from riverbeds and loess. Which have limited organic matter and essential nutrients. The Green Revolution era helped in improved crop production and growth rates. Consequently, there is a growing requirement for soil nutrients, leading to an increase in nutrient deficiencies [3]. So composting is the way to solve this issue. Composting is the process of converting garbage into nutrient-rich material. This action necessitates the use of oxygen for the breakdown of organic waste.

When compared to raw organic ingredients, the organic fertilizer is a safer option. It improves soil fertility and water retention capacity. It also reduces smells, flies, and other vector concerns and successfully eliminating weed seeds and diseases [4]. Composting has the twin benefit of preserving the environment and efficiently recycling necessary nutrients and organic waste. This multimodal process not only reduces the environmental risks connected with organic waste accumulation, but it also speeds up the breakdown of viruses and weed seeds [5]. Because of their high organic content, composts have long been used as soil supplements. Composting has a number of advantages, including the elimination of diseases and weed seeds. Furthermore, it improves manure management by reducing bulk and mass [6]. The lack of organic matter (OM) in Pakistan's soils limits their capacity to offer the nutrients required for maximum agricultural yield. Continuous crop output and insufficient replenishment have resulted in nutrient depletion in a large percentage of Pakistan's soils. Pakistan's soils are deficient in organic matter [7]. Compost serves as a highly effective substitute for enhancing soil organic carbon levels in developed countries. Surprisingly, this valuable resource remains largely untapped in Pakistan. Vast amounts of leaves, grass clippings, plant stems, vines, weeds, branches, and twigs are routinely incinerated. By decomposing and incorporating this organic material into the soil, it has the potential to enhance soil fertility and result in significant increases in crop yields. Composting relies on three key components: browns, greens, and water. Browns include materials such as fallen leaves, branches, and twigs. In order to facilitate the process of composting, a combination of water, greens, and browns is essential. Greens consist of items like grass clippings, vegetable remnants, fruit scraps, and coffee grounds [8].

**2. Materials and Methods**

The area where we did our experiment is the Pakistan's fifth biggest city. It is located between 29'-22' and 30'-45' North latitude, and 71'-4' and 72'-4'55 East longitude. It is made up of four tehsils Multan Cantonment, Multan Sadar, Shujabad, and Jalalpur Pirwala. Multan has a total area of 3721 square kilometers. This city is located in a bend produced by the formation of five rivers. It is divided from District Bahawalpur through the Sutlej River and from District Muzaffargarh via the Chenab River. Multan has a severe climate with average temperatures of 49˚C in summers and 1˚C in winters. The average rainfall is 127 millimeters [9]. The place where we did our experiments had all the things we needed to make compost piles and make sure our machines worked well. This place was the solid waste management (SWM) site of Muhammad Nawaz Shareef University of Agriculture Multan (MNSUAM). Being so close to the department made it easy to manage everything and turn waste into useful compost. This made things quick and easy, so we could fix any problems or make changes as soon as we needed to while making compost. Composting is like making plant nutrients, and we need three main things for it that’s are brown stuff, green stuff, and water. The brown stuff is things like dried leaves, branches, and twigs. The green stuff is grass clippings, veggie scraps, fruit pits, and coffee grounds. We got the green stuff from the university's gardens and fields. Compost windrow heaps can be aerated and rotated using various machinery equipped with revolving drums. Furthermore, double augers are employed in equipment. Former devices cannot be effective in all materials. Compost material requires exposure to high temperatures to kill pathogens [10].

The tractor-operated Windrow turner machine, developed by the agricultural engineering department of MNSUAM was used in this research work. This machine consists on key components, including a transmission system, frame, and rotor. The power source is a four-stroke Diesel engine tractor. The compost windrow turner features a rotor with a diameter of 170mm and a length of 2970mm. Constructed from a mild steel sheet with a thickness of 9mm the rotor is equipped with a total of 38 turning blades each made from MS sheet. Power generated by the engine is then transmitted to the turning rotor through a gearbox with a speed reduction ratio of 2:1. Power transmission to the machine rotor is achieved through the PTO drive and bevel gearbox. Additionally, the machine features a 500-liter water tank for effective water application. These specifications contribute to the machine's efficiency and functionality in composting operations.

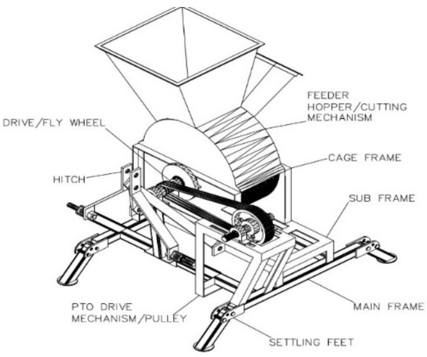


**Figure 1**. Tractor operated wood shredder

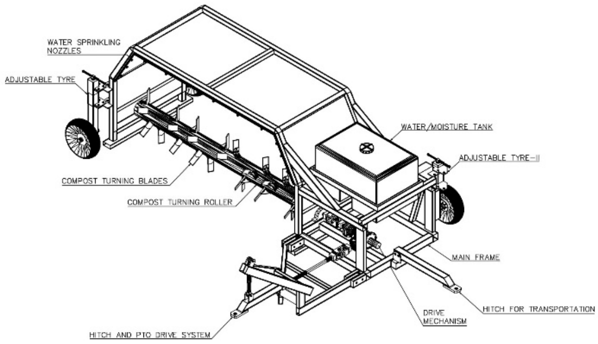


**Figure 2**. windrow turner machine used for pile turning

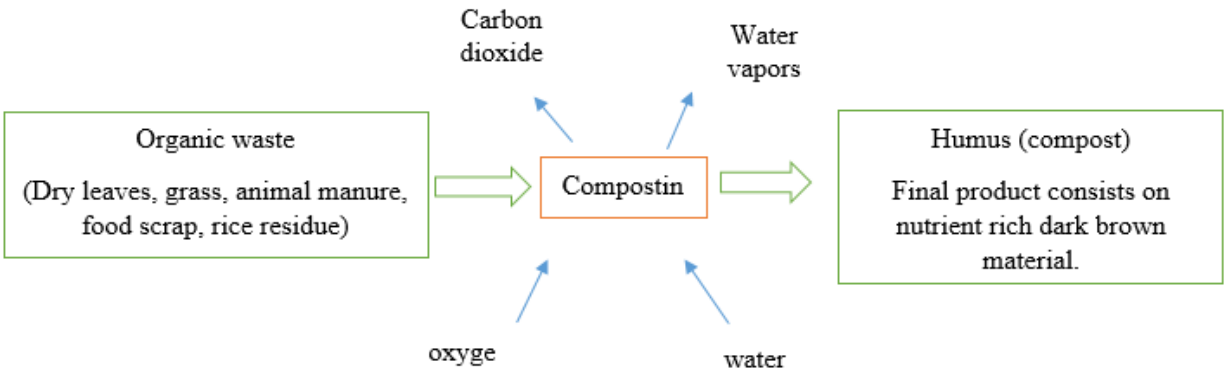


**Figure 3**. Diagram illustrating the process of composting.

Composting is a dynamic process in which microorganisms like bacteria and fungus break down organic waste. This activity produces heat as a byproduct. The heat generated comes from the metabolic activities of microorganisms. Composting releases $CO_2$ and water vapor into the atmosphere. As composting occurs, the volume and mass of the original components decrease. This decline is mostly due to the loss of carbon in the form of $CO_2$ and the release of water vapor. A windrow is formed in the same manner as a static pile is formed but shape of windrow is usually longer [11]. The composting method specifies how this procedure is carried out. Composting process parameters like temperature control and odor control are also affected by the used strategy [12]. Windrow composting is the process of arranging a variety of raw materials in long heaps called windrows that are turned on a regular basis. Windrow composting is the most utilized method on large farms and large-scale composting plants. Several rows of organic material are prepared, twisted in this method. For our research, we chose windrow piles system. We wanted to explore how utilizing a unique equipment known as a windrow turner effect the nutrients, Electrical conductivity (EC), and cation exchange capacity (CEC) in compost. We made two big piles of compost by layering different kinds of materials on top of each other. Each pile was 4 feet tall, 6 feet wide, and 10 feet long. To make compost we used animal manure, dry leaves, shredded wood and fruit scrap. we used tractor operated wood shredder machine to crush the branches of trees. We also added maize stalks and leftover rice to make the compost richer in nutrients like nitrogen, phosphorus, and potassium. If compost piles have an unbalanced ratio of brown to green materials, it can lead to unpleasant odors and hinder the composting process. This balance is vital for creating a successful and effective composting environment. Microbes consume oxygen while digesting organic waste. The decomposition of this organic waste can be accelerated if optimal conditions are maintained, such as PH between 6 and 9, and moisture between 40 and 60, while the optimum range is 65-85% [13]. We utilize a windrow turner machine with 12 nozzles for spraying water on the pile to keep the moisture level at 40-60%. Molasses are also used to boost microbial activity in piles. This helped the crushed materials break down with the help of air. After one week we turned pile 1 with machine and pile 2 manually to see the results variations in machine and manual turned piles and we kept doing that to make the compost better. In windrow composting machines turn the compost piles on a regular basis. Regular turning improves the flow of air through the material. Turning is an extremely helpful for the activity of microorganisms in windrow piles. It speeds up the rate of decomposition [14]. We use a 45 hp tractor and a windrow turner one times per week to turn the pile 1.

**Table 1.** Properties of organic waste used in compost

| Organic waste use | Animal manure | Rice residue | Sewage slug |
|---|---|---|---|
| Total Nitrogen % | 2.21 | 0.87 | 2.43 |
| Total Organic Carbon% | 38.76 | 42.34 | 41.58 |
| C/N Ratio | 17.53 | 48.66 | 17.11 |
| Total Phosphorus % | 6.4 | 0.58 | 0.89 |
| Total Potassium % | 0.97 | 0.35 | 0.68 |
| Bulk Density kg/m3 | 1043.6 | 68.21 | 398.25 |
| Moisture Content % | 78.12 | 4.67 | 3.91 |

Data were gathered from five locations within each compost pile and ensure specified standards like pH levels ranging from 5.5 to 9.0, moisture content maintained between 40% and 65%. The minimum temperature of 62°C was established for pathogen control during the composting process [15]. Throughout the composting period samples were extracted after every two weeks up to the 8th week from a depth of 2 feet in each pile. Each sample weighing 200 grams was collected from both piles, resulting in a total of two samples for each test. The assessment of changes in CEC (cation exchange capacity) and EC (electrical conductivity) levels in each pile was conducted by obtaining two samples at intervals of 2, 4, 6, and 8 weeks.

Compost samples were obtained from the windrows and the cation exchange capacity (CEC) was determined through a series of steps. Initially 200mg of compost sample was placed in a flask followed by a thorough washing with 0.05 N HCL solution. Subsequently the sample underwent an additional wash with distilled water to eliminate any residual traces of HCL.A solution of 1 N Ba(OAc)2 was prepared and its pH was adjusted to 7. This Ba(OAc)2 solution was added to the flask containing the compost sample and the mixture was left to stand overnight. Afterward, the sample was filtered and a small quantity of Ba(OAc)2 was introduced. The prepared sample was subjected to titration with 0.05 N NaOH solution utilizing a potentiometer. The measurement of protons released during the titration process provided the cation exchange capacity of the sample. [16].

Electrical conductivity is measured using a (1:2.5) compost: water suspension with an ICM model 71150 EC meter [17]. A thermocouple thermometer was used to measure the temperature in each compost pile as well as the ambient air.

## 3. Results

### 3.1. Results for Cation exchange capacity (CEC)

Cation exchange capacity (CEC) is a crucial parameter. This indicates a material's ability to regulate nutrient supply for plant growth [18]. The decomposition of organic matter such as plant residues and manures is closely linked to CEC. Consequently measuring CEC is valuable for assessing compost maturity. In Table 2 and Fig 8 we present CEC data for pile 1 and pile 2 in our study. The CEC profiles of all piles exhibited a gradual increase during composting.

**Table 2.** Variation in cation exchange capacity during the process.

| Time period | Cation exchange capacity (meq/100 g) | |
|---|---|---|
| | Pile1(Mechanized turning)* | Pile2(Manual turning) |
| 0 | 21.23 | 21.23 |
| 2 | 38.56 | 23.17 |
| 4 | 49.63 | 28.86 |
| 6 | 57.37 | 31.16 |
| 8 | 68.87 | 33.28 |

* Impact of rotational speed of 300-350 RPM, the forward velocity of 4 km/hr. and the implementation of convex shape turning blades on a turned pile

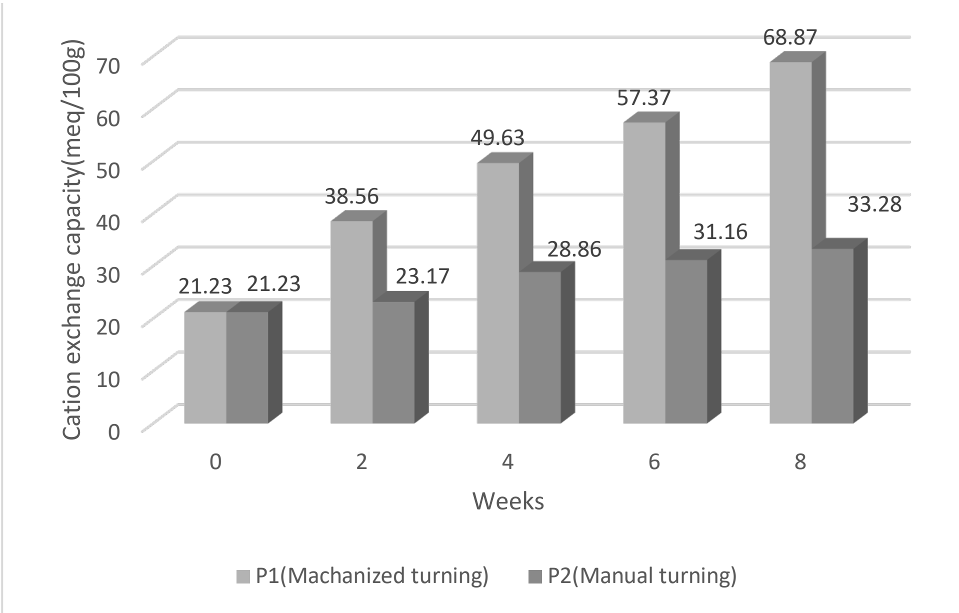


**Figure 4.** Variation in CEC during mechanized and manual turning of composting process.

In the manual turned pile 2 CEC values rose from 21.23 meq/100 g dry weight initially to 33.28 meq/100 g dry weight after 8 weeks. while for the pile 1 where a windrow turner machine was employed CEC values increased from 21.23 meq/100 g dry weight initially to 68.87 meq/100 g dry weight after 8 weeks. The significant increase in CEC values in pile1 compost compared to pile 2 compost attributed to the frequency of turning and use of turner machine. Several researchers have noted that CEC serves as an indicator of compost maturity. They suggest that the minimum CEC value required for acceptable maturity is higher than 60 meq/100 g [19].

3.2. Results for Electrical conductivity

Electrical conductivity (EC) is a measure of a material's capacity to carry electric current. It is typically expressed in S/m or dS/m. EC values indicate the availability of nutrients in compost. larger EC values may suggest larger concentrations of nutrients such as nitrogen, phosphorus, and potassium which are required for plant development. EC is affected by ion concentration in a solution or material. A summary of the windrow turner machine's effect on compost piles electrical conductivity is provided in Figure 9 and Table 3. By comparing mechanical and manual piles turning Table 3 shows results of the influence of using the windrow turner machine. Figure 9 indicating how electrical conductivity changes over time in both circumstances and shows a more comprehensive illustration of the data.

**Table 3.** Variation in Electrical conductivity during the composting process.

| **Time period** | **Electrical conductivity (ds/m)** | |
|---|---|---|
| | **Pile 1(mechanized turning)*** | **Pile 2(Manual turning)** |
| 0 | 1.98 | 1.98 |
| 2 | 3.86 | 2.46 |
| 4 | 5.78 | 4.86 |
| 6 | 8.88 | 5.12 |
| 8 | 11.34 | 7.86 |

* Impacts of the rotational speed of 300-350 rpm of the rotor, 4km/h forward speed of tractor, and convex shapes rotating blades on a pile 1

The increased electrical conductivity (EC) of composted materials might be attributed to the abundance of ammonia and other nutritional ions generated during the fast decomposition of organic waste.

Excessive salt in compost can reduce microbial activity and plant development. EC measurements are useful in determining the salt content of compost.

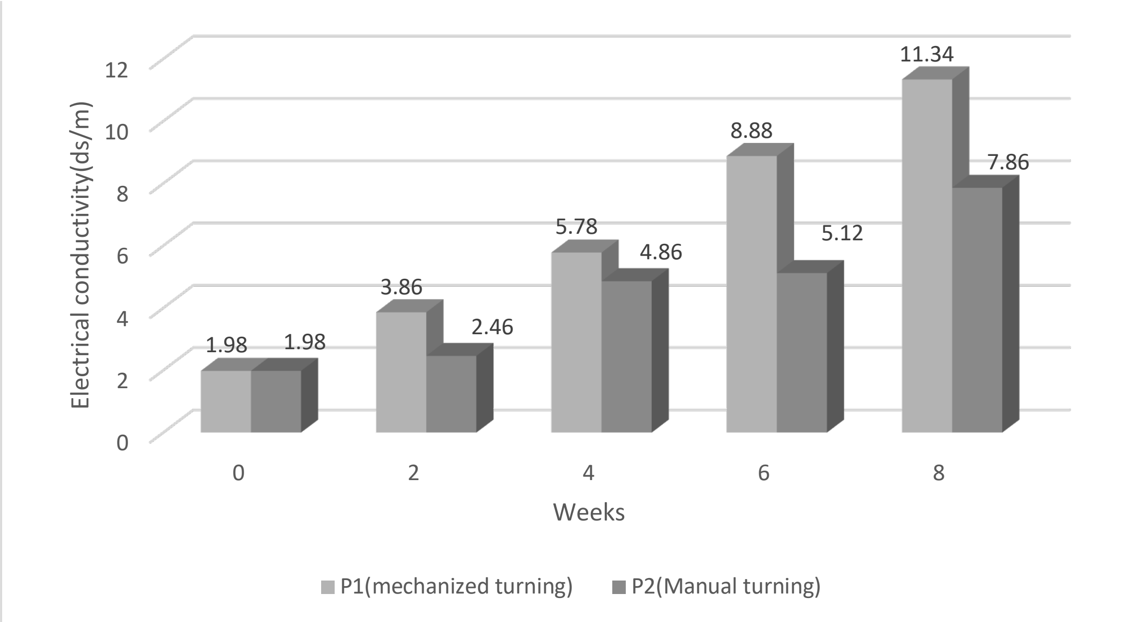


**Figure 5.** Variation in EC during mechanized and manual turning of composting

These findings point out the window turner machine's strong effect on the electrical conductivity (EC) of compost, offering insight on the dynamic changes that occur during the composting process. Due to adoption of the windrow turner machine the electrical conductivity increased for pile 1 significantly. The increase in electrical conductivity from 1.98 to 11.34 ds/m shows the machine's efficiency in enhancing the process of composting. This significant increase suggests that the turner machine significantly supported the acceleration of microbial activity and breakdown of organic materials, ensuing in a more enriched compost production. While the electrical conductivity increased from 1.98 ds/m to 7.86 ds/m in the human turned pile after period of 8 weeks representing that the absence of a turner machine resulted in a minor increase in electrical conductivity as compared to the machine-turned pile. This difference highlights the windrow turner machine significance in promoting more favorable microbial activity and more improving composting conditions.

3.3 Discussion and results of Temperature variation

When microorganism's breakdown the composting elements the temperature of the compost piles increases [20]. The process of composting starts with a mesophilic stage during which the organic ingredients are broken down by microbes. The temperature of pile 1 is 36 degrees Celsius at first but as the decomposition process intensifies it begins to rise. A too-high temperature is detrimental to the action of microbes. The temperature increases to 51 degrees after the fourth day of composting. The temperature of the compost heap rises fast as microbial populations develop and the decomposition of complex organic molecules accelerates. The thermophilic stage defined by temperatures ranging from 55 to 60 °C (131 to 140 °F) is critical for composting success

**Table 4.** Variation in Ambient and compost pile 1 temperature

| Days | 1 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ambient temperature | 35 | 35 | 36 | 35 | 36 | 37 | 37 | 38 | 38 | 39 | 39 | 37 | 38 | 38 | 39 | 37 |
| compost pile 1 temperature | 36 | 51 | 40* | 61 | 48* | 62 | 55* | 65 | 43* | 58 | 52* | 50 | 47* | 46 | 40* | 38 |

*compost pile temperature after turning by machine

Composting material temperatures rise rapidly to reach 55 to 60 °C and then remain at this thermophilic level for several days [21]. The temperature in pile 1 climbs to 62 degrees on the twentieth day of composting and drops to 38 degrees on the sixtieth day. The third phase is the cooling phase, during which temperatures return to normal and the compost stabilizes [22]. In order to sustain the proper temperature for microbial activity we employ a windrow turner machine. The breakdown in the pile is shown by temperature fluctuation.

**Table 5.** Variation in temperature in pile 2

| Days | 1 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ambient temperature | 35 | 35 | 36 | 35 | 36 | 37 | 37 | 38 | 38 | 39 | 39 | 37 | 38 | 38 | 39 | 37 |
| compost pile 2 temperature | 37 | 48 | 52 | 65 | 70 | 72 | 64* | 71 | 74 | 62* | 65 | 67 | 49* | 51 | 54 | 57 |

*Temperature after manual turning in pile 2

While the temperature of pile 2 starts off at 37 degrees Celsius, but as the decomposition process intensifies the temperature starts to rise. A too-high temperature is detrimental to the action of microbes. Temperature management is critical in composting. Temperatures between 45 and 55°C provide the best degradation rates whereas temperatures over 55°C maximize pathogen decrease [23].

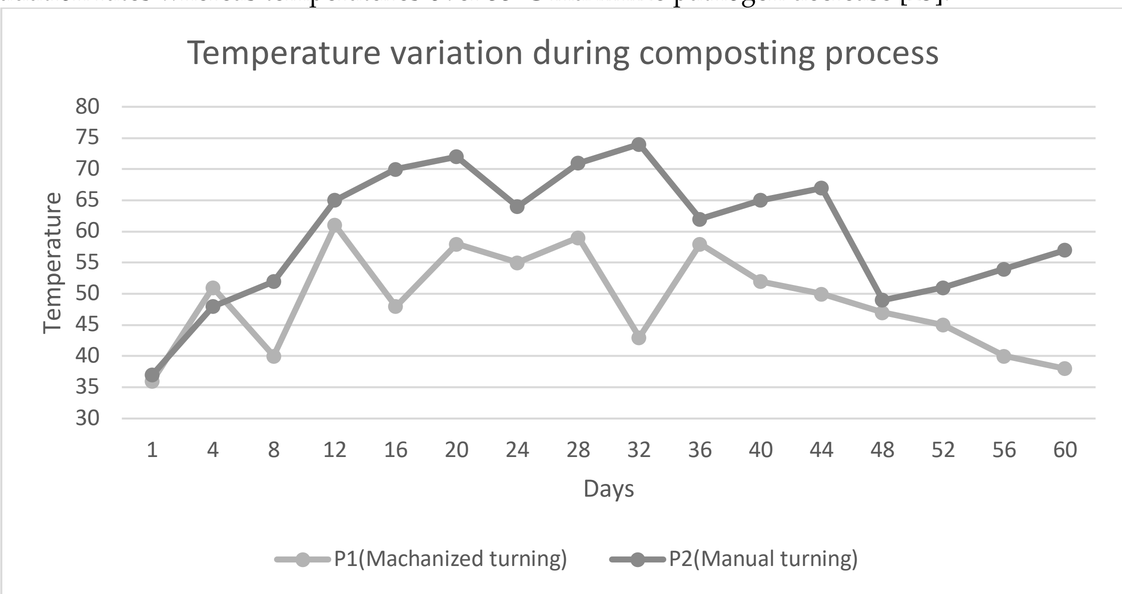


**Figure 6.** Variation in temperature during the composting process in P1 and P2

Excessive temperatures in compost can kill useful microbes particularly those that break down organic materials. Extremely high temperatures can also kill heat-sensitive species and cause nitrogen loss via volatilization. The temperature climbs to 72 on the twentieth day of composting and falls to 57 on the sixtieth day. A temperature rise of 72 degrees indicates poor composting because the temperature is just too high. This demonstrates that the temperature in pile 1 remains at an appropriate level due to the mechanized turning of the pile as opposed to hand turning.

## 4. Conclusion

The mechanized method of composting yields high-quality compost rich in nutrients as compared to traditional composting methods. The size of particles of compost material decreases with turning operations when we use a turner machine on a pile at a turning speed of 300-350 rpm. We employ convex form blades that are tilted at a 45-degree angle which has a substantial influence on compost electrical conductivity and cation exchange capacity with one turning of pile 1 each week. The cation exchange capacity of pile1 increased from 21.23 meq/100g to 68.87 meq/100g and electrical conductivity from 1.98 ds/m to 11.34 ds/m. On the other hand the compost produced without mechanical means is immature since its cation exchange capacity valve is 33.28 meq/100g. which is considered as immature. A 72-degree temperature rise in pile 2 suggests inadequate composting since the temperature is just too high. This illustrates that the temperature in pile 1 remains suitable due to the pile's mechanical turning rather than manual turning. In pile 1 the temperature stays just right because we use machines to turn the compost instead of doing it by hand. This machine turning keeps everything in balance and makes sure the composting process giving us good-quality compost in the end.

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**Conflicts of Interest:** The authors disclose that they have no issues of interest.

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