Composting: A Better Alternative of Chemical Fertilizer

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Abstract. Increases in the different types of pollution and their harmful impacts divert the concern of humans toward the environment and also the measures to control these pollutions. Research proved that there is a strong connection between human activities and pollutions. Steps should be taken to minimize these pollutions. Already lots of study is done in this area but much more is needed to be done. As chemical fertilizers can increase the plant growth rapidly but this growth does not develop good characters in plants. The chemicals of these plants assemble in human body when used. One of the ways of improvement is to use the natural material in agriculture instead of synthesized chemicals because these chemicals show long term negative impact on the environment as well as on human health. By doing the traditional composting practice we can minimize pollution and provide the natural bio-fertilizers to the plants which are safer for the environment and the human. This paper is the overview of composting discussing its process, different types and the physical and chemical properties of product “compost”. It also focused on the types of organic wastes that can be used for composting. The process of composting depends on different parameters for its maturity and stability.

1. Introduction

While choosing an eco-friendly way or moving towards organic food as an alternative to synthesized chemical rich products it is necessary to enhance the methods that can be used in organic farming. The use of chemical fertilizers is increased because of its strong and rapid effect on plant growth. But the plants grown by these chemicals are less in nutrition quality and the chemicals of fertilizers assemble in human body which are toxic in nature and are very dangerous [1]. In 90s fertilizers includes very less amount of nutrients required for plants growth because most of the nutrients were provide by naturally fertile soil and by adding some manure [2]. But today, about 70% the crop production has to depend on fertilizers. So, to reduce the harmful effect of chemical fertilizers on environment and human health there is a new agriculture practice called ‘organic farming’. The organic fertilizer is cost effective, and are easily available [3]. Composting is one of best and traditionally used methods in agriculture in which waste organic matter is used to produce useful compost. It is a natural process of generating nutrient full useful products. The compost produced is not only beneficial to improve the quality of soil but also enriches the soil with all the essential nutrients of plant [4]. Firstly, research on the composting method was done by Albert Howard in India [5]. It is a most promising technology for recycling the waste biomass into highly valued product. The product compost contains minerals for
plants growth and microorganisms for soil health [6]. Recent research on composting is to improve the food waste composting as to properly manage the waste, addition of different organic or inorganic additives, how to mitigate the gaseous emission during composting and variation in the microbiological activity.

Food waste which is one of the major reasons for waste management problem is the most plentiful bio-waste in the world which can be reuse by composting [7]. In developing countries generally food waste is disposed in open landfill [8] which contain large part of carbohydrates, protein and lipids which can be used as raw material [9]. The whole process of composting is depended on microbial activity. By controlling the microorganism in different stage of composting can regulate and boost the process which can give desired product. So, microbiology of composting can help in adjust the rate of process, compost quality and efficacy [10]. By the development in biological tools new research provide a complete knowledge of microbial action that take place during every specific stage of biodegradation process in composting. We can measure the kinetics of composting by finding the activity with the relation with the microbial activity [11]. The culture based and culture independent methods are used to measure the microbial activities during the degradation in composting. Culture based methods were based on the adenosine triphosphate (ATP) content and microorganism activities and metabolites measurements [12]. However, some microorganism is not cultivable which limits this method and culture independent method makes the process simpler to understand the activity. Composting is measured by identifying microbial inoculum. But by adding some substances the whole process can be speed up, quality can be improving and the product can be more economical. These substances are called additives which can directly affect the rate of biodegradation [13]. Research suggest that reducing in time and higher temperature in composting can influence the microbial community. A new study shows that use of acid utilizing yeast (pichiaudriavzevii) as an inoculum can reduce the time and induce the activity [14].

Another reason which restricts the use of compost is the gaseous emission during the process. Gases like \( CH_4, N_2O, NH_3 \) etc. are the main greenhouse gases emitted during composting which are reason of environment pollution. For this study was done by evaluating the microbial population as tool to relate the variation in different parameter with the microorganism population and its consequences on gaseous emission [15]. Research showed that blending of phosphogypsum and superphosphate can mitigate the \( CH_4 \) emission by 85.8% to 80.5% and \( NH_3 \) emission by 23.5% to 18.9%. The emission of \( NH_3 \) was reduced because of the reduction in aeration. It should be noted that decrease in aeration is completely independent of the quality of compost [16]. It was observed that mixing phosphogypsum with dicyandiamide could reduce \( CH_4 \) by 75.6% and \( N_2O \) by 84.5% while \( NH_3 \) by 22% [17].

Research shows that after 12 months of the application of compost on land there is a decrease in amount of \( NH_4NO_3 \) and EDTA also bioavailable copper and zinc [18]. A case study reveals that using compost as fertilizer gives both high yield and increased soil C and N content, where synthetic fertilizer produces only high yield but it did not improve the soil C and N contents. It resulted that synthetic chemical fertilizers could stimulate the high yield but it will not give sustainable crop production, crop health, or soil health over the long period. By the environmental point of view, the chemical fertilizers are very effective in stimulating the yield but it leaches the nitrate which pollute the groundwater. There is no requirement of liming when compost is used on soil, while chemical fertilizers acidify the soil because of which it is necessary to use lime in chemical fertilizers. The process of liming impact the atmosphere because break-down of acid in soil liberate \( CO_2 \) from the applied calcium carbonate [19]. So all the studies done clearly suggest that composting technology is a
sustainable recycling and reusable method which overall can control the environment pollution and also reduce the risk of human health.

2. Methodology
Composting is a process in which the organic matter is degraded into simpler chemical composition by the microorganisms. The product obtained from this process is called ‘compost’. Compost is a bio-product which contains all the natural contents or nutrients which a plant requires for growth[20]. For the process of composting the organic waste is put into a pile under the favourable condition which includes proper availability of oxygen, sufficient moisture and proper temperature. There will be release of $\text{CO}_2$ as a by-product from this process [21]. The quality of a compost depends on the chemical content and their ratio present in it [22]. The compost produced is also called soil’s “black gold”[23]. The chemical process take place during composting is as:

Microbial Degradation process of composting

$$\text{Complex organic compound (waste)} + \text{H}_2\text{O} + \text{O}_2 \rightarrow \text{simpler organic compounds} + \text{CO}_2$$

3. Physical properties of Compost
For a well maturity of compost, the following physical property range should be observed

Table 1. Showing physical properties ranges for compost [24].

| Physical property          | Average range |
|----------------------------|---------------|
| Carbon Nitrogen ratio      | 30:1          |
4. Chemical properties of Compost
A stable mature compost shows the following chemical properties.

Table 2. Showing chemical properties ranges for compost [24].

| Chemical property          | Average range                  |
|----------------------------|--------------------------------|
| $pH$                       | 6.3-7.8                        |
| Electrical conductivity    | 2.6-4.1 dS m$^{-1}$            |
| Total organic carbon       | 16.6-23.89%                    |
| Phosphorus                 | .27-1.13%                      |
| Potassium                  | .27-2.11%                      |

5. Types of Organic Wastes for Composting.
As a big amount of organic waste is put for land filling. Composting can be a better alternative to waste management [25]. The different types of organic waste that can be used in composting are as follow:

5.1 Agriculture Waste:
The waste produced during agriculture is poorly managed most of the time the waste is burned or incinerated. Composting of different types of agriculture waste has been studied [26]. Rice straws, wheat straws, potato plants and mustard stovers were used for composting [27]. Composting of succulent plants, shrubs and trees with cow dung was also done [28].

5.2 Municipal Solid Waste:
municipal solid waste includes both commercial waste and domestic waste[29]. According to studies municipal solid waste can be used for composting because it contains a large amount of biodegradable waste. The quality of compost obtained from municipal solid waste can be improved by adding some inoculating agents like garden waste, cow dung, poultry waste etc. [30]. Composting of municipal solid waste is being appreciated and encouraged in many developed countries and researchers also studied the benefit of municipal solid waste compost in agriculture [31].

5.3 Kitchen Waste:
For composting the kitchen waste, a bio composter was used. The study showed temperature range $64^0C$- $32.7^0C$. The $pH$ was acidic in starting days but rose up to 8.6 and set at 6.3 as average. The nutrients of compost N, P, K were between 1.16-1.2%, 0.03-0.053%, 0.3-0.38% respectively [32]. Another study on mixed vegetables and fruit waste taken in a heap was studied. For this the
temperature range between 350-450°C. The PH range was 7.75-7.84 and N,P,K range was 0.03-0.07%, 0.002-0.005% and 0.32-0.36% respectively [33].

6. Methods of Composting
Different types of composting methods are available which have their advantages and disadvantages. Some of the methods are as follow:

6.1 Vessel composting:
This type of composting refers to preparing compost in a closed vessel or container. This method uses forced aeration and mechanical turning for the process of composting. It is labour intensive and an expensive method of composting [34].

6.2 Windrow composting:
In this method the organic waste is placed on a long narrow windrow which should be turned on a regular basis for aeration. It is a costly but rapid way of composting [34].

6.3 Static composting:
It is a traditional way of composting. This method is cheaper than other methods but at the same time it is also a time-consuming method. For this the waste is put into piles and let down for passive aeration which results in slow degradation of organic waste [34].

6.4 Vermicomposting:
This method uses the involvement of earthworms for the degradation of organic waste [35]. They eat all types of organic wastes and their excreta is called “casting” which contains nitrate, forms of phosphorus, potassium, calcium, magnesium etc. all nutrients required for soil fertility [36].

6.5 Sheet composting:
In such composting the organic waste is directly spread onto the soil as mulch. This waste is tilled with a hoe, garden fork or spades and leaves it to decay. This method is a cheap and straightforward way of composting [37].

6.6 Indian Bangalore composting:
This method is useful for night soil and organic wastes. For such composting one-meter-deep trenches are dug out where the night soil and the organic waste is placed in alternate layers and finally it is covered with 15-20 cm thick layers of organic waste. It is left for three months without turning or watering. In this method the final product is obtained in six to eight months [38].

If we study the feasibility or rate of degradation process during composting the organic waste containing aliphatic or polysaccharide compounds can degrade easily whereas aromatic compounds require more time for degradation[39]. The important parameter for mature compost is the humic acid. To study the humification change E4/E6 ratio is used. It shows the quality of humic acid and aromatization level of the compost. If the ratio is below five, the sample is called as humic acid. Whereas if it is above five it is said as fulvic acid [40]. To observe the humification in composting it is needed to acknowledge the whole process and evolution of organic matter [41]. The spectroscopic
method is also significantly useful for measuring the compost maturity [42]. In compost the most readily active biological parameter which indicates compost stability is the water soluble carbon as it consists of sugars, phenolic substances, hemi-cellulose, peptides, amino acids and other easily biodegradable substances [43]. The chemical and biological changes during composting indicate that there is microbial succession which depends on temperature change during composting[44]. Out of all the microorganisms present during composting fungi and bacteria are in the highest population [45]. These microorganisms are divided according to the temperature during the process. The temperature changes during this divide composting in 3 stages which are:

- Initial mesophilic
- Thermophilic
- Final mesophilic [46], [47].

![Diagram showing different stages of composting with respect to temperature.]

During compost formation there is formation of $NH_4^+$ ions and these ammonium ions are volatile in form of ammonia gas [48].

$$NH_4^+ (\text{compost}) \leftrightarrow H^+ + NH_3(\text{gas}) \leftrightarrow NH_3(\text{atmosphere})$$

While composting some bulking agents can also be added which also increase the rate of composting. Research shows rice husk and sawdust are good bulking agents [48].

7. Conclusion

Composting is one of the simplest and most effective methods which produce a natural fertilizer for the growth of a plant. This method has also become essential for the proper management of wastes.
The methodology of composting is very simple and the use of compost depends on its physical and chemical behaviour. The waste material used in composting should be organic and biodegradable because the whole process is about degradation and converting of complex compounds into simpler one. There are different types of waste available for composting which can be kitchen waste, agriculture waste or municipal solid waste etc. The process of composting can be done by a variety of methods- vermicomposting, in vessel composting, windrow composting, sheet composting etc. all these methods have differently benefits as well as some drawbacks. It depends on the type of waste or study that which composting method should be used. Composting should be done by considering all the parameters which affect the process and the quality of compost. Temperature is one of the important parameters because of which the whole process is divided in three stages. More studies of different composting method, type of waste used for composting and the parameters effecting the rate can improve the quality of compost and can generalize its use with the replacement of chemical fertilizer.

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