

## DYNAMICS OF PHYSICAL AND CHEMICAL PROPERTIES OF A VERMICOMPOSTING MATRIX



### Environmental Science

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### ABSTRACT

Vermicomposting is considered as one of the most versatile and efficient technologies for management of organic waste materials in recent years. A variety of biodegradable waste materials can be vermicomposted at any scale and the product vermicompost is highly qualified in terms of its nutrient contents as manure. The main properties affecting the vermicomposting process are pH, temperature, oxygen and aeration, C/N ratio of the feed material, presence of sunlight, moisture content, porosity and particle size of feed material, etc. By controlling these variables, if favorable environment is given to the earthworms and microorganisms combo in the vermicomposting matrix, a good quality product is obtained which may prove efficient soil fertility additive in agriculture fields. In this article, a review of dynamics of different physical and chemical properties in a vermicomposting matrix during the entire process is presented.

### INTRODUCTION

Vermicomposting technology involves bio-oxidative processes to break down and stabilize the organic materials through the joint action of earthworms and microorganisms in an aerobic environment. The process converts the organic materials into a stable and hygienic product. Although vermicomposting involves natural biodegradation of materials, yet it is dependent on a set of physical and chemical properties within the process. In the whole process, the role of microorganisms, both in earthworm guts and in the feedstock, is the biochemical degradation of organic matter whilst the earthworms are responsible for the fragmentation of the substrate, which increases the surface area exposed to microorganisms [1]. Thus, earthworms directly modify the physical properties of the materials and indirectly modify its chemical properties. The optimization of vermicomposting requires a proper understanding of the entire process, type of earthworm species, the organic materials involved, and the interactions of various physical and chemical parameters of the materials such as pH, temperature, moisture content, porosity, aeration, presence of light, C/N ratio, etc. These properties directly influence the process in various ways.

Now-a-days, a combined system, composting followed by vermicomposting is preferred over the traditional composting or vermicomposting to handle the organic waste materials [2]. Ngo et al [3] compared vermicompost and compost produced from buffalo manure and stated that vermicompost had better C/N ratio and contained stronger modified lignin compared to regular compost. Moreover, vermicompost is reported to have greater market acceptance based on better appearance and higher nutrient content and microbial activity than compost [4]. The present review paper gives an insight into the overall process dynamics by analyzing the changes in the physical and chemical properties as the decomposition proceeds in time.

### DYNAMICS OF PHYSICAL AND CHEMICAL PROPERTIES OF VERMICOMPOSTING

The physical and chemical properties of the vermicomposting play a key role in determining the quality of the vermicompost. Table 1 encapsulates various process variables and their optimum range in vermicomposting.

As the feed substrate is the only source of food for the biotic community in the vermicomposting matrix, nature of the substrate is the most basic controlling factor in the process. The composition of the substrate, based on plant/animal origin, mainly contains carbohydrates, nitrogen compounds and cellulose, hemicellulose, lignin, etc. At the onset, carbohydrates are readily converted to carbon dioxide and water, and the degradation of nitrogenous compounds results mainly in the production of ammonia. In the later stages, cellulose, hemicelluloses and then lignin are finally degraded [5].

The quantity of feed material that can be consumed per day by earthworms depends on a number of factors like particle size, decomposition state, C/N ratio, salt content in food etc. [6]. The quantity of food taken by a worm varies from 100 to 300 mg/g body weight/day [7]. Worms are very sensitive to salts. The feed material should have less than 0.5% salt contents [8,9].

C/N ratio of feed material affects the earthworms' growth and reproduction. If C/N ratio is too high or too low, waste degradation becomes a slow process. Plants cannot assimilate mineral nitrogen unless the C/N is in the range of 25–20/1. Many studies show that the C/N ratio in soils with litter is brought down to less than 25/1 by the intervention of earthworms [10,11].

Adequate moisture content in vermicomposting matrix is essential for the working of earthworms and keeps sustaining adequate microbial population active. The optimum range of moisture in vermicomposting system has been reported to be between 60 to 80% [12], though physical and chemical differences in feed stocks may cause slight variations.

**TABLE – 1**  
**OPTIMUM PROCESS PARAMETERS FOR VERMICOMPOSTING**

S. No.	Factor	Optimum range
1	Moisture content	60-80%
2	Temperature	15 -28oC
3	pH	6.5-8.5
4	Oxygen and Aeration	<ul style="list-style-type: none"> <li>• Frequent turning of waste</li> <li>• Excessive moisture should be avoided</li> <li>• Greasy and oily wastes should not present</li> </ul>
5	Nature of Feed substrate	<ul style="list-style-type: none"> <li>• Should be free from toxic, non-biodegradable wastes, salts</li> <li>• Should have optimum C/N ratio, high porosity and less particle size</li> </ul>
6	Presence of light	Earthworms are light-sensitive, so vermicomposting bins should either be placed at dark places or be covered

**Source: [1]**

The excessive moisture may cause anaerobic conditions in the matrix, while lower moisture in feed may dry up the earthworms [13].

Temperature is an important parameter in determining biotic activities in the matrix. Optimum temperature range during

vermicomposting process is 12–28°C. During winter to remain system active, the temperature should be maintained above 10°C and in summer it should not exceed 35°C [14]. At very low temperatures, earthworms are not able to reproduce and their metabolic activities get reduced [15].

The earthworms and microorganisms work better in the range of pH values, 5.5–8.5 in vermicomposting matrix. However, optimum pH is neutral or near neutral. As the process proceeds, the pH values of the feed substrate undergo considerable changes.

As vermicomposting being an aerobic biodegradation process, oxygen is the lifeline for the process. Aeration is provided at appropriate stages of vermicomposting, by the mechanical means of aeration, i.e., turning is done or air is supplied through pipes in large matrix. Factors such as high levels of fatty/oily substances in the feedstock or excessive moisture combined with poor aeration may render anaerobic conditions in vermicomposting matrix which may depress the earthworms and their feeding activities may be reduced under these conditions [15].

#### PHYSICAL AND BIOCHEMICAL CHANGES DURING VERMICOMPOSTING

Numerous studies have been conducted in yesteryears to study these physico-chemical changes and the most commonly studied parameters included pH, organic carbon, NPK, enzymes, heavy metals etc. A brief description of these parameters is given below:

##### pH

pH of organic matter is an important factor for the survival and growth of earthworms. In the process, usually pH decreases from alkaline to acidic or neutral. Pramanik et al. [16] postulated that decomposition of organic matter leads to the formation of ammonium ions and humic acids. The presence of carboxylic and phenolic groups in humic acids caused lowering of pH and ammonium ions increased the pH of the system. The combined effect of these two oppositely charged groups regulates the pH of vermicompost leading to a shift of pH towards neutrality.

##### NITROGEN CONTENT

The nitrogen content of vermicompost is dependent on the initial nitrogen content present in the organic wastes and the extent of decomposition. Viel et al. [17] have suggested that organic carbon loss due to utilization of organic matter by microbes and earthworms during mineralization of organic matter might be responsible for nitrogen addition. Addition of nitrogen in the form of mucus, nitrogenous excretory substances, body fluids, growth stimulating hormones and enzymes from earthworms has also been reported [18]. Kavian and Ghatneker [19] suggested the enhanced population of nitrogen fixers (*Azotobacter* and *Rhizobium*) in matrix while working on vermicomposting of paper mill sludge.

##### ORGANIC CARBON

Decrease in the amounts of total organic carbon (OC) has been observed during vermicomposting process. Garg et al. [20] have reported a 58.4% reduction in organic carbon in cow dung and 55.4% reduction in horse dung after 90 days of vermicomposting. Kaviraj and Sharma [21] have reported a 20–45% loss of organic carbon during vermicomposting of municipality wastes. Earthworms and microorganisms uses large portion of carbon as sources of energy and nitrogen for building cell structure brings about decomposition of organic matter [22].

##### PHOSPHORUS CONTENT

Phosphorus content is usually higher in vermicompost than parent material. Satchell and Martin [23] found an increase in 25% in phosphorous content of paper waste sludge, after worm activity. Increase in phosphorus content was attributed to direct action of worm gut enzymes and indirectly by stimulation of the micro flora. They also concluded that addition of phosphorus to vermicompost also pre-

vents nitrogen loss through ammonia volatilization. Suthar and Singh [24] have attributed the release of available P content from organic waste to earthworm gut phosphatases, and P-solubilizing microorganisms present in worm casts.

##### POTASSIUM CONTENT

There are contradictory reports regarding the potassium content in vermicomposts obtained from different organic wastes. Benitez et al. [25] have reported that the leachate collected during vermicomposting process had higher potassium concentration. An increase in potassium content in vermicompost after bioconversion of sugar industry waste has been observed by Sangwan et al [26]. These differences in the observations can be attributed to the differences in the chemical nature of the inorganic wastes used in vermicomposting system.

##### C/N RATIO

C/N ratio is an important index for the estimation of maturity of organic wastes. The loss of CO<sub>2</sub> in the process of respiration and production of mucus and nitrogenous excrements are responsible for C/N ratio changes during vermicomposting. Mostly all vermicomposting studies have reported a decrease in C/N ratio of organic wastes, although decrease in C/N ratio is different for different organic wastes. Vermicompost quality is closely related to its stability and maturity, the maturity implies a potential for the development of beneficial effects when they are used as growth media. In general, decrease in C:N ratio can be taken as a reliable index of compost maturity when combined with other parameters such as CO<sub>2</sub> evolution from mature compost, water soluble C and content of humic substances.

##### CONCLUSIONS

Vermicomposting produces a higher quality product, vermicompost, which has significant quantities of macro and micro-nutrients. A large number of organic wastes can be used as raw material for vermicomposting and can converted into a stable and sanitized vermicompost. Some studies undertaken on integrated composting and vermicomposting has shown promising potential for the management of organic wastes along with the pathogen control at high temperature. More research is required on the optimization of different physical and chemical properties of integrated system of composting and vermicomposting to have a sustainable and economically cheaper process.

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