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Enhancement of Bio-Degradation of Bio-Solids Via Microbial Inoculation in Integrated Composting and Vermicomposting Technology

Alkesh Patidar*, **Richa Gupta and Archana Tiwari**

Rajiv Gandhi Proudyogiki Vishwavidhyalaya, Bhopal

Abstract

Combine thermophilic composting and the vermicomposting approach bring the advantages of both the process and have been raised as a sustainable means for the proficient utilization of the agro-industrial processing wastes. And thus, waste gets converted into worth added products which help in recycling organic matter back into the soil to maintain soil structure and richness. Mixed microbial inoculation improve and speed up the above combine approach through enhancing the biodegradation of aliphatics, proteins, and polysaccharides and increment in the molecular weight, humic and fulvic like compound content, as well as humification degree of composting materials. Inoculations improve the efficiency and reduce time period of composting processes by different microbes into the composting of lignocellulosic waste, the lignin degradation is enhance, and the carbon utilization ability of microbial communities is also improve. This review focuses on the efficiency of microbial inoculation in the combine composting and subsequent vermicomposting of different waste and factors affecting inoculation.

Keywords: Microbial inoculation; Ligninolytic enzymes; Biodegradation

Introduction

In recent years, human activities have reached such a point of progress that the recycling capacity of nature has been exceeded, and the accumulation of waste has become a serious environmental and economic problem. To manage this, there is a marked drift towards the use of new technologies, mainly based on biological processes like composting and vermicomposting for recycling and resourceful utilization of organic agro-industrial waste. In this way, it is possible to preserve the available resources and to recover the natural products, and in some cases, to warfare the disposal problems and lessen the pollution effects.

Composting

It is defined as a microbiological process that converts waste into organic manure rich in plant nutrients and humus [1]. Composting offers real advantages not only by reducing the volumes of waste but also by recycling nutrients and organic matter and improving soils. Since the decomposition process is aerobic, composting also generates less greenhouse gases as compared to landfilling. Disadvantages associated with thermophilic composting are the long duration process and so that loss of nutrient occurs during the process and frequent turning is needed to maintain aerobic condition [2,3] show that emissions can vary between -0.900 (net savings) to 0.300 (net load) t of CO_2 e per tonne of wet waste composted.

Vermicomposting

Vermicomposting of agro-industrial wastes if utilized competently; represent a vast resource of plant nutrients. Various studies have shown that vermicomposting of organic waste accelerates organic matter stabilization [4] and gives a product rich in chelating and phytohormonal elements [5] which has a high content of stabilized humic substances. Vermicomposting as a principle originates from the fact that earthworms fragment the substrate thereby increasing its surface area for further microbial action. During this process, through microbial action the essential plant nutrients present in the feed material are converted into forms that are much more soluble and available to plants than those in the parent substrate [6]. The key weakness in the vermicomposting process is that, in distinction to traditional thermophillic composting (where thermophillic bacteria can raise the material temperature to more than 70°C), the vermicomposting processes must be maintained at temperatures below 35°C. Experience of worms to temperatures above this will destroy them. The vermicomposting process temperature is therefore not high enough for satisfactory pathogen kill and hence the product does not pass EPA rules for pathogen reduction.

Combine composting-vermicomposting

The integrated composting and vermicomposting in recent times consider as a way of achieving stabilize product [7]. A combine approach brings the advantages of both thermophillic composting and the vermicomposting process and minimize the adverse impact of waste on environment. The product obtained with desirable characteristics and at a faster rate than either of the individual processes [6]. Through composting the required temperature for ensuring satisfactory pathogen kill would be achieved and product pass EPA rules for pathogen reduction. Through vermicomposting, the rate of decomposition of organic materials increased and microbially active casts would be achieved. The compost obtained from different Agro-industrial processing wastes which have been tested for combine composting and vermicomposting process in yesteryears will be of high quality and cheap. Composting enables refinement of the waste and eradication of noxious compounds, and the subsequent vermicomposting reduces particle size and increases nutrient accessibility. Combine approach involve both thermophilic composting and subsequent vermicomposting of the compostable substrate which improve the overall process and product quality. Addition of composted material

***Corresponding author:** Rajiv Gandhi Proudyogiki Vishwavidhyalaya, Bhopal, Madhya Pradesh India, Email: pati.ak9@gmail.com

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obtained from the thermophilic composting with earthworms reduces the duration of the treatment process [8]. The two combine processes are as follows-

Thermophilic composting- it involves the accelerated degradation of organic matter by microorganisms under controlled conditions, in which the organic material undergoes a characteristic thermophilic stage that allows sanitization of the waste by the elimination of pathogenic microorganisms [9]. Two phases can be distinguished in composting: (i) the thermophilic stage, where decomposition takes place more intensively and which therefore constitutes the active phase of composting; and (ii) a maturing stage which is marked by the decrease of the temperature to the mesophilic range and where the remaining organic compounds are degraded at a slower rate. The duration of the active phase depends on the characteristics of the waste (amount of easily decomposable substances) and on the management of the controlling parameters (aeration and watering). The extent of the maturation phase is also variable and it is normally marked by the disappearance of the phytotoxical compounds.

Subsequent vermicomposting- it involves the bio-oxidation and stabilization of organic material by the joint action of earthworms and microorganisms. Although it is the microorganisms that biochemically degrade the organic matter, earthworms are the crucial drivers of the process, as they aerate, condition and fragment the substrate, thereby drastically altering the microbial activity. Earthworms act as mechanical blenders and by comminuting the organic matter they modify its physical and chemical status by gradually reducing the ratio of C: N and increasing the surface area exposed to microorganisms – thus making it much more favourable for microbial activity and further decomposition [10]. Therefore two phases can also be distinguished here, (i) an active phase where the earthworms process the waste modifying its physical state and microbial composition [11], and (ii) a maturation-like phase marked by the displacement of the earthworms towards fresher layers of undigested waste, where the microbes take over in the decomposition of the waste.

Combine approach bring- Stabilized product, sanitization of waste and elimination of toxic waste, reduction in expenses and time period of composting than either of the individual processes.

Microbial inoculation

Different wastes contain high concentrations of easily degradable organic substances with high moisture content and high density. Wood and straw which has approximately 40% cellulose, 20–30% hemicelluloses and lignin [12] is difficult to breakdown in a normal composting process and can take considerable period of time. Thus, the success of the composting process and the usefulness of compost as an organic amendment are determined by microbial enzymes like cellulase, xylanase, manganese peroxidase, lignin peroxidase and Laccase which are responsible for the breakdown of several organic compounds. Zeng et al [13] showed the above higher enzymes activities with Phanerochaete chrysosporium inoculation during agricultural waste composting. Although, the microbial community naturally present in wastes usually carries out the process satisfactorily, the inoculation of residues with lignocellulolytic microorganisms is a strategy that could potentially enhance the way the process takes place or the properties of the final product. Inoculation with bacteria and fungi which can breakdown ligno-cellulolytic material has been reported to be effective in composting [14].

Microbial inoculation in composting followed vermicomposting

Inoculation increases cellulase activity, promote biodegradation of organic matter and accelerate composting process [15]. Composting of manure and other organic wastes is a microbiologically mediated process with which the readily degradable organic matter in organic wastes is degraded and stabilized (Figure 1). During the process, part of organic C is released as CO_2, part incorporated into microbial cells and part humified. The organic nitrogen primarily as protein prior to composting is mineralized to inorganic N (NH_4-N and NO_3-N), which is then re-synthesized into other forms of organic N in microbial biomass and humic substances during the composting process. Degradation of organic C during composting is carried out by bacteria, fungi, and actinomycetes, depending on the stage of degradation, the characteristics of materials, and temperature [16]. Actinomycetes prefer moist but aerobic conditions with neutral or slightly alkaline pH. There are many thermophilic actinomycetes, which can tolerate composting temperatures in the 50s°C and low 60s°C. Actinomycetes tend to be common in the later stages of composting and can exhibit extensive growth. Bacteria are by far the most important decomposers during the most active stages of composting due to rapid growing ability on soluble substrates and tolerant of high temperatures. Inoculation with Phanerochaete chrysosporium increases the humification degree of humic acid (HA) when inoculated during the curing stage, but not during the active stage [17]. The study conducted by Pal et al [18] suggested the effectiveness of inoculation with isolated Geobacillus strains which boost the total bacterial count led to enhanced biological in the thermophilic stage of vegetable waste composting.

Mixed and multi-stage inoculation

According to Zbytniewski and Buszewski [19] and He et al 20], the composting process can be divided into three phases. The first stage is dominated by the rapid decomposition of easily bio-degradable organic matter, such as aliphatics, proteins, and polysaccharides. This stage primarily occurs during the first few weeks. Deodorizing microbes can be used to degrade aliphatics and proteins. Therefore, the inoculation of these microbes enhances the decomposition of composting materials. The second stage is dominated by the humification of organic matter (mainly cellulose and lignin) and formation of humic-like substances. In general, this stage primarily occurs during the thermophilic phase and the cooling period of the active stage of composting. Cellulose decomposition bacteria are very necessary in this stage. The final stage is dominated by the stabilization of transformed organic material, which primarily occurs during the curing stage of composting.

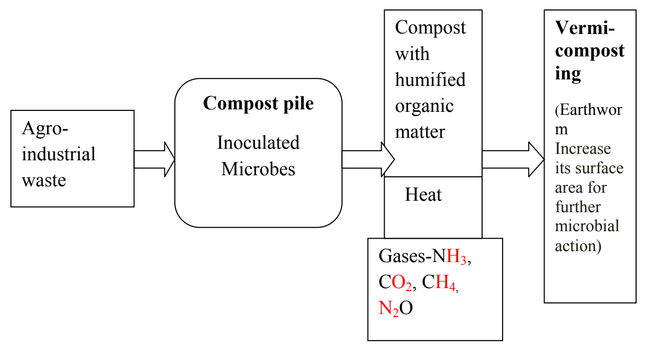

Figure 1: Microbial inoculation in composting with subsequent vermicomposting.

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Most bio-degradable organic matter, such as aliphatics, proteins, and polysaccharides, has been degraded during this last stage. The primary composting material is lignin, which is the most refractory organic compound among those found in compost. Lignin decomposition bacteria are very essential during this last stage. Therefore, inoculation of lignin decomposition bacteria during the curing stage improves the stabilization of composting organic matter. Using the multi-stage inoculation method, microbes were inoculated based on the composition of the composting materials and on temperature. Therefore, the multi-stage inoculation best enhanced composting progress and efficiency. Wei et al [21] showed that mixed inoculation with complex microorganisms and ligno-cellulolytic microorganisms during composting of municipal solid waste had a clear advantage over inoculation with complex microorganisms or lingo-cellulolytic microorganisms alone. The difference between time periods of degradation between uninoculated and inoculated composting and vermicomposting process of different waste is seen between Table 1 and Table 2.

Factors affecting inoculation efficiency in biotransformation raw material

Qualitative and quantitative chemical composition and, microbiological activity, relies on raw material used for composting and is one of the most influential factors. Given the strong variations between substrates in that matter [22], it is not difficult to understand the different ability of microorganisms used as inoculants to biotransform the organic matter on each material, as it has been stated by other authors [23]. Thus, a prior study may be necessary to know the suitability of every microbial species or even strain for a specific substrate when a composting process is to be improved.

Temperature

Temperature is the most dominant factor of controlling composting reaction as its effect on microbial metabolic. Temperature of incubation may influence the pattern of activity of ligno-cellulolytic enzymes.[24] described temperature values between 20 and 30°C as the most advantageous for the enzymatic activity of lignin biodegradation. [25] reported that the enhancement of microbial activities was induced by increasing temperature.

Effects of turning

Nakasaki et al [26] studied effects of turning on the microbial consortia during swine manure composting and noted that during composting, turning inhance the degradation of organic matter by transferring the undamaged organics at unfavorable temperatures to favorable temperatures in order to allow degradation by microorganisms that degrade more vigorously.

Microbial Type and Their Activity

Biotransformation of organic matter is a very complex process and it depends upon the type of microbes to be selected in inoculation and their activity. In vitro studies by Vargas-Garcia [27] in 2006 on lignocellulose degradation by microbial strains isolated from composting processes showed that inoculation may contribute to the degradation process if a good microbial selection is made. For example in their resurch, out of thirteen microorganisms (five bacteria, one actinomycete, and seven fungi) isolated from compost windrows grown on agricultural wastes and analyzed for cellulose, hemicellulose, and lignin degradation, strain B541 was the most active cellulose degrader (51%), while isolate B122 showed higher lignin degradation activity (68%).

Type of Technology Follow

Composting and vermicomposting are two of the best-known processes for the biological stabilization of solid organic wastes.

S. No.	Agro-Industrial waste	Supplement used	Earthworm used	Time period of degradation	C/N Ratio	References
1	Cattle manure	Animal manure and agri-culture waste	*Eisenia Andrei*	55 days	11.3	Lazcano et al., (2008)
2	Source segregated household waste	Shredded wood Chips	*Dendrobaena veneta*	112 Days	17	Frederickson et al., (2007)
3	Municipal organic Waste	Biosolids	*Eugenia Fetid*	120	11-14	Tognetti et al., (2007)
4	Mixtures of dairy manure	Shredded paper Waste	*Eugenia Fetid*	8 Weeks	15	Mupondi et al., (2010)
5	Kitchen waste	Grass clippings, Shredded paper	*L. rubellus, E. fetida*	21 Days	Below 20	Nair et al., (2006)
6	Water hyacinth	Cow dung slurry	*Eudrilus eugeniae*	210 Days	_	Gajalakshmi et al., (2002)
7	Spinach waste	animal dung	*Eugenia Fetid*	79 Days	_	Sharma et al., (2011)
8	Biosolids	paper-mulch	*Eisenia fetida*	4 Weeks	_	Ndegwa and Thompson (2001)
9	Sludge	Saw dust	*Eisenia fetida*	5 Month	13.26	Alidadi et al., (2005)

Table 1: Different Agro-industrial processing wastes which have been tested for combine composting and vermicomposting process in yesteryears

S. No.	AgroIndustrial waste	Supplement used	Earthworm used	Inoculation used	Time period of degradation	C/N Ratio	References
1	sugar-cane waste by-products	bagasse and sugar-cane trash	*Drawida willsi Mi-chaelsen*	*P. sajorcaju, T. viridae, A. niger, P. striata*	70 Days	35	Shweta et al., (2010)
2	Wheat straw	-	*Eisenia foetida*	*Pleurotus sajor-caju, Trichoderma harzianum, Aspergillus niger and Azo-tobacter chroococcum*	70 Days	12.75	Singh and Sharma (2002)
3	Asphaltens from Pres-tige oil spill	cow bed and potato peelings	*Eisenia foetida*	*Stenotrophomonas maltophilia, Scedosporium apiospermium*	6 Month	14.62	Martın-Gil et al., (2008)

Table 2: Wastes which have been undergo microbial inoculation and combine composting and vermicomposting.

But individually both have certain limitation, for vermicomposting technique some epigeic earthworm species require pre-decomposed waste [28]. So to take the maximum benefits of this process it would be desirable to decrease the pre-decomposition time period of the waste initially with certain efficient microbes which could be used as inoculants during pre-decomposition to reduce the time of composting. So combine approach of composting and vermicomposting is most efficient technology for inoculation.

Heavy Metals Content

Heavy metals contained in the raw materials of compost may affect bio-disintegration of farming wastes, can modify the microbial metabolism and exert influence on their reproduction [29]. Jie Gu et al [30] showed that at a low content, Cu improve the capacities of inoculated microbial communities to convert and utilize carbon sources in the form of polymer, thus speeding up the decomposition of agricultural wastes, and at a high content, Cu presented inhibiting effect on microbial communities to utilize complex macromolecular carbon sources due to inhibition of activity of enzymes produced by microbes and thus decomposition of agricultural wastes extend.

Current Status of Inoculation

The use of inoculants in composting processes has been clear from some of the research conducted which shows that inoculation in composting processes can be a useful tool to increase the humification degree in the final product and, therefore, to improve the agricultural quality of compost by achieving a higher stabilization and maturity levels. For efficient pattern of inoculation and to determine activity in natural environments further studies are necessary.

Conclusion

Combine composting and vermicomposting bring the advantages of both the processes and inoculation additionally improve the properties of final product. Combine technology with inoculation is time reducing and environmental friendly method and maximum biotransformation of organic matter can be achieved. Inoculants may be a useful tool in composting processes when the capabilities of microorganisms are suitable for the characteristics of the waste to be composted. Knowledge of different phases of composting and substrate composition is important for specific inoculation in composting and vermicomposting and is more effective way of biodegradation of waste.

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