JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

EFFECT OF MICROBIAL INOCULANT ON VERMICOMPOSTING USING VEGETABLE MARKET WASTE – A REVIEW

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Abstract: India produces over 42 million tonnes of solid trash yearly. Rapid urbanization has put the nation's garbage management under tremendous strain. Additionally, 18% of the fruit and vegetable crop in India is lost each year. The best approach to recycle organic waste is by composting. Vermicompost is another form of compost in which waste materials are turned into compost using earthworms. Microbial inoculants may be quite important in this. Microbial inoculation, a challenging agricultural practice that has an impact on the environment, is a progressive way to increase crop yields while reducing the need for artificial fertilizers. Microbial inoculants are used to improve the quality of the soil, crops, and human health. Composting is a progressive process that takes time, as we are aware. Therefore, it is what introduced them to using vermicomposting and microbial inoculants in order to enhance the compost's characteristics and reap the most benefits. Thus, the concept of combining all three approaches into compost is born. To enhance the quality of the soil and promote plant development, we need to think of a way to use vegetable market trash in agriculture. This experiment is intended for farmers who have a certain type of farm, such as fields of cabbage, onions, or bananas. Additionally, the experiment aids in establishing the distinction between compost produced from separated waste and typically mixed vegetable waste.

Index Terms – **Compost, Vermicompost, Microbial Inoculant, Microbes, Bin Composting.**

I. INTRODUCTION.

The management of solid waste, often known as SWM, is a significant challenge for emerging countries like India. It is anticipated that India's population, which is now predicted to be 138 crores in the year 2020, will keep expanding at a rate of 3.3–3.5% year. The annual growth in garbage generation is around 5%, based on the fact that the rate of waste generation per capita is growing at a rate of 1.3% each year[1]. In the 21st century, the agriculture and food industries of the world will face significant problems. Food safety and the responsible handling of waste stand out among these other concerns. Both waste treatment facilities and landfills are having to accommodate an ever-increasing volume of food waste[2]. The disposal of vegetable market waste along with municipal solid waste in landfills or dumpsites in India is causing a significant amount of annoyance. This annoyance manifests itself in the form of odour nuisance, the production of leachate, and the emission of greenhouse gases into the atmosphere. The proper management and utilisation of vegetable waste have emerged as one of the most pressing environmental concerns. Because of the quick expansion of both the country's population and its economy over the past few decades, India has seen a considerable rise in the quantity of trash consisting of discarded vegetables. This rise can be attributed to India's rising standard of living. The yearly production of vegetables and fruits in India is estimated to be close to 150 million tonnes. Of this total, around 50 million tonnes of garbage is generated, which is becoming a source of annoyance at municipal landfills and contributing significantly to issues of environmental pollution. Consequently, the management of these organic fractions is particularly important for the preservation of the environment and the valorisation of the by-products created during the process, regardless of the approach that is being utilised. Composting is becoming an increasingly popular method for the disposal of organic waste since it offers greater economic and environmental benefits than other major waste management strategies, and it ultimately results in a product that is more stable. The finished product has applications that include enhancing and preserving the fertility of the soil. The application of compost made from vegetable waste on a regular basis as a soil conditioner raises both the organic matter content of the soil and the carbon-to-nitrogen (C/N) ratio of the soil to higher levels than those of soil that has not been amended[3]. The biological oxidation of organic matter during the composting process is carried out by a dynamic and rapid succession of populations of aerobic bacteria. This is because composting is an exothermal process. Composting is an effective method for dealing with large quantities of these organic wastes that need to be treated.

Recycling organic waste through composting is a fantastic method. The process of composting is a slow one that takes a certain amount of time to totally disintegrate and mature. Vermicomposting and the addition of microbial inoculants are two methods that can be used to enhance the properties of compost while also optimizing their usefulness. For this reason, it is necessary for us to devise a plan for recycling the waste from vegetable markets and putting it to use in agro - ecosystems, where it will contribute to the enhancement of soil quality and the expansion of plant life. As a result, the objective of this work is to develop all three of these approaches to composting and to compare the results of each approach. This experiment is geared primarily toward farmers who focus on cultivating a single crop, such as those who raise cabbage, onions, or bananas. The experiment is also helpful in distinguishing between compost that is formed from garbage that has been segregated and the traditional compost that is made from waste that has been combined with vegetable matter.

II. COMPOSTING

Composting is a natural biological process that transforms organic materials into manure or fertilisers. The procedure is carried out with the aid of microorganisms. Catabolism of hydrolysis and oxidation of a carbonaceous substrate generates CO_2 and heat for microbial growth and metabolic requirements. Composting generates stable molecules composed mostly of carbon and nitrogen. Physiochemical parameters such as pH, electrical conductivity, moisture, C/N ratio, temperature, aeration, and particle size impact the process. Initial moisture content is one of the most important elements to consider during composting. This is possible by the use of bulking agents. Due to differences in fruit and vegetable composition and properties, these agents vary from one region to another. Various bulking agents, such as sawdust, water hyacinth, and garden prune, have been studied for their benefits and worth. In sawdust, for example, the germination index and nitrogen content were greater than in other materials. There was no evidence of a thermophilic stage in water hyacinth. The consequence of garden pruning was sawdust with a reduced total nitrogen concentration. These bulking agents stabilise the aeration rate, increase the porosity, and regulate the pH for optimal microbial growth. Temperature is an additional factor that affects microbial activity and nitrogen fixation. As composting is regarded a feasible technology for treating fruit and vegetable waste, a variety of composting techniques have been developed. Vermicomposting, a simple biotechnique that uses earthworms of various species to transform organic waste into compost, is one of the most popular procedures[4].

III. VERMICOMPOSTING.

Vermicomposting is a method of waste management that entails the decomposition of an organic portion of solid waste in an environmentally friendly manner to a level in which it can be easily stored, handled, and applied to agricultural fields without causing any negative effects. This level of decomposition allows for the material to be used in a manner that is not harmful to the environment. The goal of vermicomposting is to achieve no thermophilic degradation of organic fraction of solid waste and to stabilize it. This is accomplished by the cooperative activity of microorganisms and earthworms under situations where the environment is regulated. Simply put, it is a biotechnological process that involves the use of earthworms in the transformation of organic waste into vermicompost that is rich in nutrients. The bacteria that are present in the system are the ones who are accountable for the biochemical breakdown of the organic matter, while the earthworms are the ones that are liable for their involvement in the conditioning of the substrate and changing the biological activity. Utilizing earthworms as part of a treatment process for organic waste is a method that has a very low overall cost. There are many various species of earthworms living in an acre of soil, each of which has its own unique character and method of nourishment; as a result, the pace of soil deterioration is controlled by these earthworms. When it comes to municipal solid trash, the method of vermicomposting comes highly recommended due to the fact that it degrades the significant quantity of organic waste that is included in solid waste in a manner that is both safe and sanitary[5].

IV. MICROBIAL INOCULANTS.

In recent years, the inoculants used in composting have been researched for a variety of source materials. The microbial inoculants that were utilised in the composting of solid waste came in a variety of different formulations or compositions[6]. Composting performance may be improved with the help of microbial inoculants (MI), which speed up the decomposition process and cut down on odour. The composting process can be improved through the use of microbial inoculation with specific bacteria and/or enzyme-producing microbes. Enzymes are chemicals that are excreted and break down molecular compounds into simpler forms. Microbial inoculation works to ensure that the appropriate microbes are present in the piles at the appropriate temperature, oxygen, and moisture content at the appropriate times[7].

The microbes that live in the soil are beneficial to plants in many different ways. Some inhibit the growth of disease-causing organisms. They are able to accomplish this goal by having a competitive advantage over the pathogens or even by parasitizing them. There are other symbiotic relationships that other bacteria have with plants. That indicates that the microorganisms and the plants have a connection that is advantageous to both parties. This includes bacteria that are able to fix nitrogen, as well as fungi that live as mycorrhizae and provide the plants with nutrients that would not be accessible to them otherwise[8].

V. ROLE OF MICROBES/MICROBIAL DYNAMICS DURING COMPOSTING PROCESS.

The succession of a composting microbial community reflects its degradative capacity. Variations in a microbiome rely on source materials, dietary additions, environmental conditions (ambient or experimental), and interactions between these elements. During composting, bacteria and fungus are the most prevalent and fastest-growing microorganisms. Substrates and bacteria alter the quality of compost. They enhance organic breakdown by releasing substrate-based hydrolytic enzymes[9], which degrade complex molecules into water-soluble compounds[16]. They metabolise organics and create simple molecules that improve agriculture and maintain the environment when introduced to soil. [16]

Monitoring composting microbial profiles may show compost maturity. Initial profiling demonstrated a reduction in microbial biomass due to changes in C/N ratio and composting temperature. At mid mesophilic composting, bacterial population continued to expand, resulting in appropriate humification. During waste composting's maturation period, microbial mass gradually declined. Fungal abundance was often lower than bacterial. Adding rice husk, sawdust, wood chips, and other bulking materials to the substrate may improve microbiota. This might improve compost's C/N ratio.

VI. INTEGRATION OF COMPOSTING AND VERMICOMPOSTING.

Strong mutualism between microorganisms and earthworms might improve organic waste degradation and compost and vermicompost quality when employed as soil conditioner[6]. Earthworms' stomach and intestinal microorganisms breakdown organic matter. Microorganisms feed earthworms, while earthworms stimulate additional microbial activity by generating microbially active faeces. Vermicomposting combines microbes and earthworms to decompose organic waste. Vermicomposting is better than composting in terms of its capacity to destroy pathogens, however other research found that it lacks this power when compared to thermophilic composting. In vermicomposting, the ideal temperature for earthworms is 35ºC[6], whereas in traditional composting (including thermophilic composting), it may reach 70ºC. Vermicomposting does not reach the ideal temperature to destroy pathogens, and temperatures over 35ºC may kill earthworms, stopping the process. In this situation, composting and vermicomposting are combined to improve production. Composting and vermicomposting may be integrated in two ways. Pre vermicomposting followed by composting. By high-rate precomposting water hyacinth before vermicomposting produced improved yield.

VII. INTEGRATION OF COMPOSTING AND MICROBIAL INOCULANT.

When compared with conventional that did not include inoculant, compost heaps that had microbial inoculant added to them had higher temperatures throughout the early stages of the composting process and required less time to mature than samples that did not include inoculant. The accumulation of a larger amount of Total N, Available P, and Available K in the final compost product was attributed to the fact that the inoculant had a beneficial influence on the decomposition of organic carbon and nitrogen, as shown by the chemical parameters. A close perusal of data on enzyme activities indicated that almost of all the enzymes were high at 30 days in both the composting methods. This may be due to availability of easily degradable substances and there was a spurt in microbial activity in the initial stages. The production of metabolic intermediates including inorganic radicals might have changed the biology of the system. The initial stage of active decomposition is followed by a second stage of synthesis during composting. During this stage a change in the spectrum of the enzyme activities is expected. In the maturity stage due to lack of suitable carbon compounds for microorganisms the enzyme activity will be reduced[10]. The enzyme activities i.e. urease, phosphatase, dehydrogenase and cellulose were decreased with increasing the composting period in both the composting methods of vegetable market waste. Among the composting methods higher enzyme activities were recorded during vermicomposting over normal composting. Vermicomposting is preferred over normal composting to overcome the deficiencies in the long duration for decomposition apart from low enzyme activity in normal composting[11].

VIII. INTEGRATION OF VERMICOMPOSTING AND MICROBIAL INOCULANT.

Vermicomposting offers an alternative approach to the management of organic waste that can be broken down by living organisms. The nutritional content, as well as the enzymatic and microbial status, of vermicompost made from cow dung was found to be the greatest. Lime addition in the vermi-bin was not significantly effective in terms of the nutrient content or the enzymatic activities of vermicompost; however, the combined effect of lime and some of the microbes that were inoculated proved to have a significant effect on the quality of vermicompost. Passage of organic substrates through the earthworm guts increased acid phosphatase activity and humic acids content of the final stabilized products, and their content was significantly increased by inoculation of lignolytic fungi or free-living N-fixing bacteria. Microbial biomass C and N were reduced during vermicomposting, while microbial respiration was increased after earthworm-ingestion [12].

IX. COMPOSTING METHODS.

These treatment techniques generate different products of value. The six potential techniques are:

9.1. Windrow Composting.

The microbiological process known as composting converts organic waste into a substance that is stable, dark brown in colour, and resembles soil. This substance is known as compost. Under aerobic circumstances, this process takes place as a result of the action of microorganisms (i.e., in the presence of oxygen). Long quantities of biodegradable garbage have been accumulated here (windrows). In the middle of the piles, temperatures as high as 70 ºC may be attained as a result of the material deterioration process. The very high temperature helps to hygienize the heaps by killing off some of the disease-causing organisms and weed seeds that could otherwise be present. When a process is controlled, the primary factors, which include the organic material composition (the carbon-nitrogen ratio), particle size, free air space, aeration, temperature, moisture, and pH, are managed, guided, and changed in order to accomplish rapid degradation and high-quality compost. When the circumstances are not ideal, the procedure can be delayed down or it might not even take place at all.

We distinguish two alternatives: Small scale or self-use windrow composting plants, which tend to be manually operated and Medium to large scale commercial windrow composting plants, which tend to include more equipment and mechanisation.

Range of acceptable moisture	Coarse: 70-75% ; Fine: 55-65%
Range of acceptable C:N	20-50
pH	5.5-7.5
Suitable for	Garden trimmings, vegetable waste, fruit waste, animal manure.

Compost is the primary finished product that can be obtained through the process of composting. Compost is a soil-like material that is stable, dark brown in colour, has a crumbly texture, and smells earthy. It is possible to utilise it as a soil amendment, and the quality of the amendment depends on the feedstock used and the quality control that is performed throughout the production process. Its application is contingent on the statutory requirements as well as the quality of the finished products. Leachate, water vapour, and carbon dioxide are the three other output products that are emitted during the process of composting in addition to the compost itself.[13][14][15]

9.2. In-vessel composting and Bin composting.

In-vessel composting is the same process described above in composting; however, instead of windrows, it uses rotating vessels that are turned manually or mechanically. This technology accelerates the composting process since it allows for improved aeration.[16].

We distinguish between two alternatives: Small-scale or self-use in-vessel composting plants, tend to be manually operated. If the vessels are not rotary, this approach is also referred to as “bin composting”. Medium to large-scale commercial plants, tend to include more equipment and mechanization. The mechanized option of this technology allows for steering and adjusting process parameters, such as aeration, temperature, and moisture content, achieving a faster degradation process.

Range of acceptable moisture	Coarse: 70-75%; Fine: 55-65%
Range of acceptable C: N	20-50
pH	5.5-7.5
Suitable for	Garden trimmings, vegetable waste, fruit waste, animal manure.

The compost bin system can process large amounts of waste without taking up as much space as the windrow method and it can accommodate virtually any type of organic waste. This method involves feeding organic materials into a drum or bin. This allows good control of environmental conditions such as temperature, moisture, and airflow. The material is mechanically turned or mixed to make sure the material is aerated. The dimension of the vessel can vary in size and capacity. This method produces compost in just a few weeks thus taking comparatively lesser time than conventional composting methods.[17] The main output product from in-vessel composting is also compost.[13]–[15]

9.3. Vermicomposting.

Aerobic breakdown and stabilisation of organic material by microorganisms and earthworms. Microbes assist aerobically breakdown organic materials. The trash is then fed to earthworms, which produce vermicompost. Earthworms enhance microbial activity by creating nutrient-rich vermicompost. Eisenia fetida is a common worm. Vermicomposting produces vermicompost, leachate, and worms. Vermicompost is dark-brown, granular soil. Vermicompost contains higher nutritional contents than compost due to the grinding effect of earthworms' guts. Small-scale systems use leachate from worm bins as liquid fertiliser.

Range of acceptable moisture	60-80%
Range of acceptable C:N	10-25
pH	Acceptable: 4.5 – 9, Optimum: 7.5 - 8
Suitable for	Garden trimmings, vegetable waste, fruit waste, MSW

The primary by products of vermicomposting are worms, leachate (worm tea), and vermicompost. The vermicompost is a solid, granular, dark-brown substance that resembles dirt. These granules are a characteristic of vermicompost and are formed as a result of the grinding action in the earthworms' guts. Studies have revealed that vermicompost contains more nutrients than compost. Additionally, worm bin leachate can be applied as a liquid fertiliser, which is usually applied in small-scale systems. The earthworms are full of critical amino acids needed for animal feed and are 65% protein rich. They are either utilised as an addition in fish or poultry feed or are regarded as a healthy pro-biotic feed.[6], [13]

9.4. Anaerobic digestion

Through the microbiological process of anaerobic digestion, organic materials are biochemically broken down while also producing nutrient-rich digestate and biogas as fuel. Under anaerobic conditions, microbial activity causes this process to happen (i.e., in absence of oxygen). It can be found often in a variety of natural settings, including wetlands and ruminant stomachs. The fixed-dome digester, floating-drum digester, and tubular digester are the three primary digester types taken into account.

Range of acceptable moisture	80-95%
Range of acceptable C:N	16-25
pH	6.7-7.5
Suitable for	Garden trimmings, vegetable waste, fruit waste, MSW

The main products of anaerobic digestion are biogas and digestate. The biogas is a combustible gas fuel formed through the conversion of organic carbon in the feedstock into its most reduced form (CH_4) and its most oxidized state (CO_2). Apart from CH_4 (55–60%) and CO_2 (35–40%), biogas also contains several other gaseous ‘‘impurities’’, such as hydrogen sulphide, nitrogen, oxygen and hydrogen. The energy value of biogas derives from the contained methane and shows typical lower heating values (LHV) for biogas of 21–24 MJ/m³ or around 6 kWh/m³[13].

9.5. Black soldier fly (BSF) processing.

Processing black soldier flies (BSF) is a new method for treating organic waste. It involves biologically converting the biowaste into insect larvae biomass and a treated organic waste residue using the larvae of the Black Soldier Fly (BSF), Hermetia illucens. 30% crude fat and 35% protein make up the larvae. Potentially useful as a source of feed for chicken and fish farmers is this insect protein. The BSF larvae consume biowaste as they grow and develop up until the stage of pupation, at which point they are harvested. The entire development from egg to adult lasts 20–35 days under controlled conditions (28°C, 75% relative humidity). They live for a week as flies and spend that time concentrating on reproduction. Since they are flies and do not consume food, they cannot spread disease. On a wet weight basis, waste reduction of up to 80% has been proven. The leftover material, which resembles compost, is nutrient- and organic-rich. Additionally, a high rate of up to 25% (on a wet weight basis) waste to biomass conversion is feasible[16].

Range of acceptable moisture	70-80%
Range of acceptable C:N	Non-influencial
pH	4.5-8.9
Suitable for	Garden trimmings, vegetable waste, fruit waste, MSW

The main products resulting from the BSF technology are the larvae and the residue. The harvested prepupae contain 40% protein and 30% fat. The grown larvae can be used as a (partial) replacement for fish meal in animal feed as defatted insect meal contains a similar protein and amino-acid profile to fishmeal. Other possible products to be explored are the production of biodiesel from larvae or the use of the chitin and the oil. The residue, on the other hand, still contains valuable nutrients and might be used as a soil amendment. However, due to the short processing time, the residue needs to undergo a maturation phase in order to prevent oxygen depletion in the soil which inhibits seed germination or suppresses root and plant growth[13][18], [19]

9.6. Slow pyrolysis

Slow pyrolysis, also known as carbonization, is a thermochemical reaction in which organic matter is broken down at high temperatures (between 300 and 600 °C) without the presence of oxygen. This procedure generates solid (char), liquid (bio-oil), and gaseous products over the course of hours or days. It is well acknowledged that the process variables of temperature, heating rate, residence time, and reactor pressure have the greatest impact on the distribution of the final product. The biomass's chemical makeup, which is made up of three primary polymers (namely, cellulose, hemicelluloses, and lignin), as well as the particle size, shape, and physical qualities (ash content, density, moisture content, etc.) also play a significant role[13]. The process is endothermic in tiny reactors and need an outside heating source. A portion of the material in the reactor can be burned to provide this energy (autothermal systems), or it can come from the outside (indirect heating). Reactors are further categorised according to whether or not they recycle and internally burn the pyrolysis gases (retort kilns) (non-retort kilns).

Range of acceptable moisture	10-15%
Range of acceptable C:N	Non- influential
pH	Non- influential
Suitable for	Dry, unmixed, homogeneous, uncontaminated substrate, preferably with high carbon and low ash content. For example: Woody or fibrous materials, Cardboard and paper.

The relative amounts of the main products of pyrolysis, char (the black, solid residue), bio-oil (the brown vapour condensate), and syngas (the non-condensable vapour), depend on several factors including the heating rate, peak temperature and residence time. Approximate percentages are 35% char, 30% bio-oil and 35% syngas.[13], [20].

CONCLUSION.

The landfilling technique of waste disposal will not be feasible in upcoming years, thus there is an urgent need to find an alternative technique for disposal of MSW. Also, if the organic matter in waste is just dumped into the landfills it causes various environmental issues. Thus, we can use the bin composting technique to treat this organic matter from the waste in rapid manner. To accelerate the process of composting furthermore, we can also use various additives & bulking agents which facilitate the process of composting. Adding mineral, organic or biological materials during composting and vermicomposting affects composting parameters and may be used to influence the key parameters of the composting process, such as aeration and porosity of the pile, and composting duration by manipulating the thermophilic period.

Vermicomposting is an alternate method for handling organic waste that can be decomposed by living organisms. It was discovered that vermicompost generated from cow manure had the highest nutrient content, enzymatic activity, and microbiological status. Lime addition in the vermi-bin had no influence on the nutrient content or enzymatic activity of vermicompost; however, the combined effect of lime and some of the inoculated microorganisms had a substantial effect on vermicompost quality. Inoculation of lignolytic fungus or free-living N-fixing bacteria considerably improved the acid phosphatase activity and humic acid content of the final stabilised products. During vermicomposting, microbial biomass C and N decreased, but microbial respiration increased after earthworm feeding.

Compost heaps with added microbial inoculant had higher temperatures throughout the early stages of the composting process and took less time to mature than conventional samples that did not contain inoculant. According to the chemical parameters, the inoculant had a positive effect on the decomposition of organic carbon and nitrogen, which led to a greater accumulation of Total N, Available P, and Available K in the final compost product. During composting, the initial phase of active breakdown is followed by a second phase of synthesis. During this phase, a shift in the enzyme activity spectrum is anticipated. Enzyme activity will decrease throughout the maturation stage due to a lack of appropriate carbon molecules for microorganisms. In both methods of composting vegetable market trash, the enzyme activity, including urease, phosphatase, dehydrogenase, and cellulose, reduced as the composting time increased. In comparison to other composting techniques, vermicomposting exhibited the highest enzyme activity. Vermicomposting is favoured over conventional composting to compensate for the long breakdown time and low enzyme activity of conventional composting.

This review highlights the fact that the combination of vermicomposting with microbial inoculant has shown the potential for being more useful than traditional compost. This is due to the fact that vermicomposting produces nutrients in a form that is easily obtainable, which makes it simpler for plants to soak up and make use of the nutrients.

ACKNOWLEDGMENT

To achieve any goal successfully takes the work and efforts of a large number of individuals. For this reason, I would like to express my gratitude to the Principal of the Government College of Engineering in Amravati, the Head of the Civil Engineering Department, and my Guide Dr. M. N. Hedaoo for their support.

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