

Bioconversion of Kitchen Waste into Biofertilizers Using Microorganisms

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Abstract: The increase in cooking waste that must be disposed of results from rapid urbanization and population growth and waste disposal systems that fail to manage the generated waste. The study aimed to find the most effective microbes that could decompose organic kitchen waste while enhancing its value for agricultural purposes.

Researchers needed to collect and categorize kitchen waste materials which contained food waste and vegetable peelings before they could apply microbial solutions that combined fungal and bacterial cultures for kitchen waste treatment. The researchers maintained total control of all environmental factors which included humidity and temperature and ventilation during their bioconversion experiments that took place in a controlled environment. The finished product analysis showed an increase in nitrogen and phosphorus and potassium nutrient levels while organic waste decreased during the process.

The findings demonstrate that microbial activity plays a crucial role in both enhancing organic matter decomposition and maintaining the stability of processed materials. The research shows that using microbes to convert waste is a good long-term way to manage waste. This method allows nutrients to be recycled by reducing waste and supporting sustainable farming, which helps protect the environment.

Keywords: Kitchen Waste Bioconversion, Microbial Decomposition, Biofertilizer Production, Organic Waste Management, Sustainable Agriculture etc.

Introduction - Food waste is now a big problem for the environment and for people around the world because cities are getting bigger, populations are growing, and people are changing the way they shop. The Food and Agriculture Organization (FAO) says that about one-third of the food that people around the world grow for themselves is lost or wasted each year [1]. That's 1.3 billion tons. Most of the trash that people throw away at home is kitchen waste, which includes vegetable peels, fruit scraps, leftover food, eggshells, and other biodegradable organic materials. In India and other developing countries, kitchen waste makes up about 50 to 60 percent of all solid waste in cities. Landfilling and open dumping are common ways that people get rid of trash today. These methods cause a lot of harm to the environment, such as releasing greenhouse gases, making bad smells, and contaminating soil and groundwater with leachate. Landfills make methane when organic waste breaks down. Methane is a greenhouse gas that is twenty-five times more effective at warming the planet than carbon dioxide.

The existing environmental problems have led researchers to create sustainable waste management solutions which transform organic waste into valuable products. The bioconversion of kitchen waste into

biofertilizers through microorganism use stands as a highly promising method. Bioconversion establishes the method through which microorganisms including bacteria and fungi and actinomycetes transform organic materials into stable basic chemical substances. The microbes break down complex organic materials which consist of carbohydrates and proteins and lipids into chemical compounds that plants can absorb as nutrients [2]. Microorganisms use their metabolic systems and enzymes to convert kitchen waste into compost-like materials which contain essential nutrients that support plant development including nitrogen and phosphorous and potassium and micronutrients.

The process of microbial bioconversion accomplishes two goals which involve reducing organic waste while producing safe biofertilizers that promote sustainable agricultural methods. The research assessed how microbial bioconversion worked as a sustainable method to transform food scraps into biofertilizers that contained essential nutrients. The study aimed to find the most effective microbes that could decompose organic kitchen waste while enhancing its value for agricultural purposes.

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combined fungal and bacterial cultures for kitchen waste treatment. The researchers maintained total control of all environmental factors which included humidity and temperature and ventilation during their bioconversion experiments that took place in a controlled environment. The finished product analysis showed an increase in nitrogen and phosphorus and potassium nutrient levels while organic waste decreased during the process.

Literature Review

Kitchen Waste Generation and Composition: Kitchen garbage constitutes a significant portion of biodegradable municipal solid waste produced globally. The Food and Agriculture Organization estimates that roughly 1.3 billion tons of food are wasted each year which represents nearly one-third of world food output [3]. In urban areas households create food waste which accounts for 40% to 60% of municipal solid waste depending on their lifestyle and income levels and dietary practices. In rapidly developing countries such as India kitchen waste production has increased due to rising population numbers and expanding cities and changing consumer behavior. The Central Pollution Control Board reports that Indian towns generate approximately 150000 tons of municipal solid waste each day which mainly consists of biodegradable kitchen waste. The standard constituents of kitchen trash include vegetable peels fruit remnants cooked food remnants tea leaves eggshells bread and dairy by-products. The organic waste contains high levels of biodegradable material which includes carbohydrates proteins lipids cellulose and lignin. Kitchen waste contains moisture content that ranges between 70% and 85% which enables microbial decomposition but also causes rapid putrefaction when waste remains unmanaged [4]. Kitchen garbage provides essential plant nutrients such as nitrogen phosphorus potassium and calcium along with trace elements. The components of kitchen waste serve as a valuable raw material which can undergo biological conversion to produce compost and biofertilizers. The successful utilization of organic materials plays a vital role in decreasing landfill waste while supporting environmentally friendly nutrient recycling practices.

Microbial Bioconversion Principles : Microbial bioconversion is a biological process wherein microbes convert complex organic matter into simpler stable nutrient-dense molecules. The process of kitchen waste management requires microbial organisms, which include bacteria and fungus and actinomycetes, to break down organic materials through their enzyme-based processes. Bacteria function as the main microorganisms that start the process of decomposition because they can multiply rapidly while breaking down both sugar and amino acid and protein substances [5]. Composting systems commonly contain microbial species from the *Bacillus* and *Pseudomonas* genera because these bacteria can produce extracellular enzymes such as proteases and amylases and

lipases. Fungi perform an essential function in breaking down advanced organic polymer materials. *Aspergillus* and *Penicillium* are filamentous fungi that produce enzymes that break down cellulose and lignin. This process makes it possible to turn plant materials into useful products. Actinomycetes serve as a conduit between bacterial and fungal entities to finalize the decomposition process. Microbes break down chitin and lignin materials into substances that look like humus using the *Streptomyces* genus. The microbial community must decompose organic matter via its metabolic processes to sustain its existence. Plants can get the nutrients they need to grow through this process. The microbial bioconversion process is the main natural way to turn organic waste into biofertilizers.

Existing Technologies for Organic Waste Conversion :

Multiple biological innovations exist to convert organic waste into beneficial farming materials. The main methods used for this purpose include anaerobic digestion and composting and vermicomposting and microbial fermentation. The microorganisms establish stable humus-like substances through their process of breaking down organic waste which occurs under controlled aerobic conditions that maintain optimal temperature and moisture and airflow systems [6]. The composting process generates heat through microbial activities, which creates a temperature rise that accelerates waste decomposition while simultaneously destroying harmful microorganisms.

Eisenia fetida is a type of earthworm that helps with vermicomposting, which is an environmentally friendly way to speed up the breakdown of organic matter using natural processes [7]. Earthworms and microbes work together to turn organic waste into vermicompost that is rich in nutrients, which helps plants grow. Anaerobic digestion is a natural process that breaks down organic matter by not having oxygen. Anaerobic digestion functions as a natural process which decomposes organic material through its absence of oxygen. The process produces biogas through its creation of two main gases which consist of carbon dioxide and methane. The digestate functions as a biofertilizer which contains high levels of essential nutrients. Microbes are employed in microbial fermentation processes to convert kitchen waste into two products which include biofertilizers and composting inoculants that contain high levels of enzymes. Research projects are currently investigating various technologies which include Teruo Higa's effective microorganism systems to improve speed of organic waste decomposition. The three technologies support sustainable waste management by their ability to reduce landfill disposal which leads to decreased greenhouse gas emissions and their capacity to support nutrient recovery for agricultural purposes.

Materials and Methods

Collection and Preparation of Kitchen Waste: The bioconversion experiment used kitchen waste from residential areas and school cafeteria operations to

demonstrate typical organic waste produced by households. The collection process resulted in the collection of fruit peels tea leaves eggshells and cooked food scraps as the main materials. The team performed manual removal of plastic and metal items together with non-biodegradable packaging materials to ensure that only organic materials underwent processing. The team used distilled water to perform a light cleaning of the waste material which removed surface dust and other contaminants after they completed waste sorting. The team conducted waste cleaning operations to prepare the material for cutting into pieces which measured 2 to 3 centimeters because this process would create additional surface area which microbes require for their breakdown activities [8]. The material underwent pre-treatment through partial drying which occurred in shaded areas for a duration of 24 hours to remove excess moisture and prevent anaerobic decomposition during initial processing. The team created a waste processing system which required homogenization of the material before transferring it to fermentation containers where they added microbial inoculation. The standard preparation process established identical base compositions for each instance while it improved microbial efficiency in converting organic waste into biofertilizer through conversion.

Table 1: Typical Composition of Collected Kitchen Waste

Waste Component	Approximate Percentage (%)
Vegetable peels	35
Fruit residues	25
Cooked food leftovers	20
Tea leaves and coffee grounds	10
Eggshells and others	10

Microorganisms Used : The researchers selected specific microbes for bioconversion because those microbes excelled at breaking down organic materials while producing valuable chemical compounds. Researchers selected various Bacillus bacteria because these bacteria produce protease and amylase enzymes which enable the digestion of protein and carbohydrate components found in kitchen waste. The researchers introduced Lactobacillus lactic acid bacteria to improve fermentation and eliminate harmful pathogens through their organic acid production. The researchers introduced Aspergillus filamentous fungi because these fungi possess powerful enzyme systems which enable them to decompose plant-based waste through their cellulolytic and ligninolytic abilities [9]. The research team maintained all microbe cultures in a sterile environment after they collected the samples from laboratory culture collections before they introduced them to the organic waste mixture.

Table 2: Microbial Cultures Used for Bioconversion

Microorganism	Type	Functional Role
Bacillus spp.	Bacteria	Degradation of proteins and carbohydrates

Lactobacillus spp.	Bacteria	Fermentation and acid production
Aspergillus spp.	Fungus	Breakdown of cellulose and plant fibers

Bioconversion Process : The 10 liter containers with air holes were used for fermentation after staff members had cleaned up kitchen waste. The container received 5 kilograms of organic waste substrate which had previously been processed. The researchers used a mixed microbial inoculum which they prepared at a 5% weight per weight concentration. The researcher used a waste matrix homogenization process to achieve uniform germ distribution throughout the sample. The bioconversion process necessitates a semi-aerobic environment which enabled both bacterial and fungal metabolic activities [10]. The researchers maintained constant moisture levels by spraying distilled water onto the surface which resulted in 60 to 65 percent humidity. The investigators determined the ideal parameters for enzymatic activity and microbial proliferation by maintaining pot temperatures within the range of 28°C to 32°C. To mitigate the risk of anaerobic conditions and to improve aeration, the team manually rotated the material bi-daily. Complete degradation of the organic waste was achieved within a fermentation period of 20 to 25 days. The microbial population subsequently converted the waste into a biofertilizer, suitable for agricultural application following the transformation of the waste into a dark, solid, soil-like substance characterized by reduced odor and enhanced nutrient content.

Table 3: Operational Conditions of the Bioconversion Process

Parameter	Value
Container capacity	10 L
Substrate weight	5 kg
Microbial inoculum	5% (w/w)
Temperature	28–32°C
Moisture content	60–65%
Fermentation duration	20–25 days

Analytical Methods : The biofertilizer underwent an overall manner based series of tests to assess its physical, chemical, & biological properties. A digital pH meter here was used to measure the pH of the substrate as it decomposed nature. Standard spectrophotometric and flame photometric methods were used to find the amounts of phosphorus and potassium. The Walkley–Black method was used to measure organic carbon content which allowed researchers to calculate the carbon-to-nitrogen ratio that indicates compost maturity. The researchers used repeated dilution and plate count methods to determine the number of viable microbes present during the bioconversion process [11]. The measurements determined the efficiency of microbial biofertilizer breakdown and the quantity of nutrients that entered the final product.

Table 4: Parameters Analyzed During Biofertilizer Evaluation

Parameter	Method Used
pH	Digital pH meter
Nitrogen (N)	Kjeldahl method
Phosphorus (P)	Spectrophotometric analysis
Potassium (K)	Flame photometry
Organic Carbon	Walkley–Black method
Microbial population	Plate count method

Results and Discussion

Decomposition Efficiency : Researchers monitored organic matter changes and mass loss measurements and physical property alterations throughout the bioconversion process to evaluate kitchen waste decomposition efficiency. The results showed that as microbial decay progressed there was a substantial reduction in total organic matter. The collected kitchen waste contained high moisture content and unstable organic compounds at the initial stage. The waste contained approximately 78 to 82 percent organic material. The first ten days of microbial treatment demonstrated the presence of substrates that break down quickly through their availability of sugars and starches and proteins. The total waste volume decreased because of this process which led to a 30 percent waste reduction [12]. The waste material underwent complete biological breakdown after 25 days of fermentation because its total volume decreased by 55 to 60 percent. The process showed that microbes maintained their metabolic activity because the measured temperature changes throughout the process. The thermophilic stage reached its highest temperature when it reached 40 degrees Celsius. The increased temperature accelerated the process which resulted in more efficient pathogen elimination through chemical compound breakdown. The research results demonstrate that microbial bioconversion process accelerates kitchen trash organic material decomposition rate.

Table 5: Changes in Organic Waste Characteristics During Bioconversion

Parameter	Initial Value	Final Value
Organic matter (%)	80	42
Waste mass reduction (%)	–	58
C:N ratio	30:1	16:1
Temperature (°C)	28	40 (peak)

Nutrient Enrichment of Biofertilizer : The researchers examined the final biofertilizer nutrient composition to evaluate the effectiveness of bacteria bioconversion in increasing plant usable nutrients. Laboratory experiments showed that essential macronutrients which include nitrogen and phosphorus and potassium experienced substantial increases during the fermentation process. The initial state of raw kitchen waste contained low nitrogen amounts because it contained complex organic proteins which needed to undergo mineralization. The microbial degradation process increased total nitrogen levels from approximately 0.8% to 1.9%. The microbes succeeded in transforming organic nitrogen into stable nitrogen

compounds which remained intact. Microorganisms degraded bound phosphate compounds which existed in food waste and plant materials to increase phosphorus levels from 0.4% to 1.1% [13]. The breakdown of organic matter released mineral salts which resulted in a potassium increase from 0.9% to approximately 1.7%. The end biofertilizer product contained essential macronutrients and multiple micronutrients which support plant development. The list of nutrients included calcium magnesium iron and zinc. The soil becomes more fertile through the process which produces essential nutrients that support plant metabolic functions. The improved nutrient composition demonstrates that microbial bioconversion technology maintains organic waste stability while producing agricultural materials which promote sustainable crop development.

Table 6: Nutrient Composition of Biofertilizer

Nutrient	Initial Content (%)	Final Content (%)
Nitrogen (N)	0.8	1.9
Phosphorus (P)	0.4	1.1
Potassium (K)	0.9	1.7
Calcium (Ca)	0.5	0.9
Magnesium (Mg)	0.3	0.6

Role of Microbial Activity : The kitchen waste was converted into nutrient-rich biofertilizer through several biochemical and enzymatic processes that microbes performed. The Bacillus bacteria utilized their metabolic heat to decompose their substrate material by digesting basic organic compounds which included sugars and amino acids. These bacteria produced external enzymes which included proteases and amylases and lipases that digested the leftover food proteins and starch and fats. Lactic acid bacteria, like Lactobacillus, helped the decomposition process along by making organic acids that dropped the pH a little and stopped pathogenic microorganism from growing [14]. Fungi like Aspergillus took control of subsequent process steps because they produced cellulases and lignin-degrading enzymes which converted plant materials into base organic components. Microbial respiration produced carbon dioxide and water and mineral nutrients which rendered organic matter more stable over time. The microbes created humus-like substances which enhanced soil structure and raised nutrient availability when used as biofertilizer.

Table 7: Enzymatic Functions of Microorganisms

Microorganism	Major Enzymes Produced	Function
Bacillus spp.	Protease, Amylase	Breakdown of proteins and starch
Lactobacillus spp.	Fermentative enzymes	Organic acid production
Aspergillus spp.	Cellulase, Ligninase	Degradation of plant fibers

Environmental and Agricultural Benefits : Producing biofertilizer method also prevents leachate from developing, which poses a risk of contaminating underground water

sources and soil surfaces. The biofertilizer produced through this process delivers agricultural benefits by enriching soil health through organic matter increase and microbial community expansion [15]. The process of creating biofertilizers from kitchen waste results in reduced requirements for chemical fertilizers which lead to land deterioration and environmental contamination. The practice of transforming organic waste into agricultural products enables farms to maintain sustainable operations while simultaneously addressing the increasing problem of organic waste disposal in urban areas.

Table 8: Environmental Benefits of Kitchen Waste Bioconversion

Benefit	Impact
Waste volume reduction	Decreases landfill burden
Methane emission reduction	Mitigates climate change
Soil fertility improvement	Enhances crop productivity
Nutrient recycling	Supports sustainable agriculture

Challenges and Limitations: Bacteria convert food scraps into biofertilizer which provides both environmental and agricultural advantages. The method contains excessive limitations which prevent it from achieving its desired effectiveness. The decomposition process and nutrient retention capacity of food waste depends on the specific type of waste material. The preparation and processing stages face operational difficulties because non-biodegradable materials such as plastics and metals and synthetic packaging products enter the system. The microbial activity requires precise environmental conditions which include temperature and pH and moisture control, but achieving these conditions proves difficult for large operations. The process of scaling the system presents challenges which create difficulties for operations.

Conclusion: The combination of bacteria with fungi and other beneficial microorganisms enables them to rapidly decompose complex organic materials found in food waste while producing compost-like stable end products. The research findings demonstrate that waste reduction reached significant levels while nutrients increased and agricultural biofertilizer production occurred. This method not only provides an organic waste disposal solution but also enhances soil fertility while promoting environmentally sustainable agricultural practices. The process of microbiological bioconversion functions as a waste management solution which enables agricultural systems to maintain productivity while recycling materials.

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