Odourless indoor composting of kitchen waste : Standardization of biotechnological approach using bioreactor and microbial inoculums

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Abstract

One of the most serious causes for our streets becoming filthy and water bodies polluted is the cooked and un-cooked food waste thrown out of household kitchens and restaurants. This project aims at (i) development of microbial inoculum for quick composting of kitchen waste, (ii) standardization of odourless indoor composting of kitchen waste through biotechnological approach using automated bioreactors and microbial inoculums for quick composting and (iii) an outdoor, non-automated composting unit also aided by microbial inoculum.

A consortium of microorganisms comprising 14 thermophilic bacteria, 6 actinomycetes and 7 fungi, capable of enhancing decomposition of food waste and converting it into useful compost was developed. The organisms were tested for production of amylase, protease, cellulose, pectinase, Keratinase and polyphenolase which play important role in food waste bio-degradation. The identified microorganisms, originally isolated from a wide array of ecological niche was pre-tested as microbial inoculum for quick composting of food waste. The organisms were identified and tested to exclude pathogenicity to human beings and animals. The talcum based inoculum, packed similar to commercial preparation, was distributed to farmers and house wives for pre-testing its efficiency. The demand from housewives for the inoculum, and the feed-back obtained from them were encouraging.

A working prototype of an indoor composting machine is developed as proof of concept of an odour-free composting machine for use inside kitchen. The machine is similar to a top-loading washing machine, 600mm x 550mm x 900mm size, made of 3mm double-walled stainless steel shell with powder coated exterior. There are three chambers with a total capacity to hold 30-40 kg waste. All types of bio-degradable kitchen waste can be disposed in the machine. The consortium of microbial inoculum is also dispensed inside the bioreactor for quick composting. The environment inside the bio-reactor is automatically regulated electronically for optimum metabolic activity of the thermophilic microbial inoculum for fast decomposition of waste within a few days. The moisture content and temperature inside the bioreactor are maintained automatically with the aid of sensors.

The out-door unit is comprised of a plastic drum or barrel of 150 litre capacity. The inside of the chamber is partitioned into two equal volume chambers. The barrel is mounted on a stand of 75cm height. It can rotate on a steel pipe axis passed through the centre of the barrel. An electrically operated grinder is mounted at the mouth of the inlet through which waste materials are put inside the barrel. A mixture of saw dust and coir pith enriched with microbial inoculum are dispensed inside the bioreactor along with waste. When one chamber of the barrel is ¾ filled, filling the other chamber can be started. A door at the middle of each chamber facilitates removal of finished compost. A drain hole on the opposite side (bottom) facilitates removal of leachates. The drum type bioreactor also work satisfactorily well outside the kitchen and produce good quality compost.

1. Introduction

The waste problem, especially the problem of biodegradable kitchen waste and non-degradable plastic waste has become not only an environmental challenge but also a serious social and health hazard. In several corporations and municipalities, the centralised waste disposal facilities have become defunct due to the opposition from local residents against the stinking environment and the leachates oozing out from decaying organic waste contaminating drinking water sources. In several places, the issue has precipitated into serious law and order problem. Hence, finding quick solutions to the current impasse has become imperative. This project proposal aims at standardization of odourless indoor composting of kitchen waste through biotechnological approach using bioreactor and microbial inoculum.

Among the several types of solid waste being accumulated on the streets and dumping yards, domestic waste, especially kitchen waste is the worst. Food wastes of all types putrefy, produce foul odour and serve as growth media for pests and pathogens. Hence, this project is highly relevant for solving the environmental, social and health problems resulting from accumulation of domestic waste on the streets and roads of Kerala rendering urban life miserable.

Flat residents and other urban dwellers with no land space available around their residence find it extremely difficult to dispose of kitchen waste in an environment friendly way other than depositing at common places for collection to be arranged by local bodies. Recent attempts to solve this problem on a war footing have brought forth several methods, from biogas production to pot composting and pipe composting. But these methods cannot be practiced with ease inside kitchen itself or on balcony of a flat as they produce foul smell. Such methods also require additional space adjacent to the house or a compound to keep the pots or fix the pipes. In this project, we envisaged fabricating two types of bio-reactors in which microbial inoculum is added for odour-free composting of all types of kitchen waste. Odour-free method of composting food/vegetable waste inside kitchen or on balcony/terrace will provide urban dwellers

and flat residents home-made compost for balcony/terrace cultivation of organic vegetables besides avoiding street pollution.

The objectives of the study are:

i. Development of efficient consortium of microorganisms for odour-free composting of food waste.
ii. Fabrication and testing of a bio-reactor provided with accessories for controlling micro-environment within the chamber for odour-free, indoor composting of food waste and suitable for keeping inside kitchen or its vicinity.
iii. Fabrication of a composting chamber for odour-free composting of food waste and garden waste for outside kitchen using the consortium of microorganisms.

2. Materials and Methods

2.1. Development of consortium of microorganisms

2.1.1. Soil sample collection

A total of sixty source samples including soil samples and decomposing organic materials were collected from different localities (areas dumped with kitchen wastes, animal dung, termite soil mount, vermin casts, poultry manure, decaying wood, fermented food items, soil from paddy field, river side, coastal areas, oil and hair contaminated areas, factory effluent contaminated areas and rhizosphere soil samples) of different regions of Kottayam, Idukki and Ernakulam districts.

2.1.2. Isolation of microorganisms

Microorganisms were isolated using standard serial dilution method. Nutrient agar medium, Sabouraud dextrose agar medium, yeast malt extract agar medium and MRS agar medium were used for the isolation of bacteria, fungi, antinomycetes and Lactobacillus strains.

Number of colonies developed after incubation were calculated using the formula,

$$\text{No. of colonies (cfu/g of sample)} = \frac{\text{No. of colonies obtained}}{\text{Dry weight of sample x dilution of plated sample}}$$

The morphologically different strains isolated were purified and maintained on suitable selective agar slants at 4^0C and under 50% glycerol for further studies.

2.1.3. Determination of metabolic characteristics

The isolated strains were spot inoculated on selective media such as starch agar, skim milk agar, Pectin agar, MMN agar, casein agar and CMC agar to determine the ability of the isolates to produce amylase, protease, pectinase, polyphenolase, keratinase and cellulase

respectively. The inoculated plates were incubated and the enzyme production was determined on the basis of zone of clearance around each colony after incubation. For starch and pectin agar, the zone of clearance was observed by flooding the plates with iodine solution after incubation (37^0C for 24hrs for bacteria, room temperature for one week for fungi and actinomycetes). For CMC agar, the plates were flooded with 0.1% Congo red solution for ten minutes and then destained using Sodium chloride solution for 10 minutes after incubation.

Solubilisation index was calculated using the formula,

$$\text{Solubilisation index} = \frac{\text{Colony diameter + Zone diameter}}{\text{Colony diameter}}$$

The isolates were also tested for their oil degrading capacity by inoculating them in medium containing different hydrocarbons.

2.1.4. Screening of the isolates

The isolates showing high enzyme solubilisation index or producing more than one enzyme were selected for further studies.

Compatibility testing

Cross streak method was used for testing compatibility between microorganisms. Selective agar plates were prepared and inoculated with each isolate by a single streak in the centre of the Petri dish. After 2 days of incubation at 37°C, the plates were seeded with indicator bacteria by a single streak at 90° angle to the central growth. The microbial interactions were analyzed by the observation of the size of the inhibition zone after incubation. Isolates not showing antagonism were selected.

Effect of temperature on growth of the isolates

Each isolate was spot inoculated into selective media and incubated at various temperatures (30, 40, 50, 60 and 70^0C). After incubation, growth rate was determined by measuring the colony diameter in cm.

Effect of pH on growth of the isolates

Each isolate was spot inoculated into selective media and incubated at various pH ranges (2, 4, 6, 8, 10 and 12). After incubation, growth rate was determined by measuring the colony diameter in cm.

Effect of oxygen for growth

Each isolate was spot inoculated into selective media and incubated under aerobic and anaerobic conditions. After incubation, growth rate was determined by measuring the colony diameter in cm.

Screening of isolates for consortia preparation

By considering all the above factors, the isolates were again screened for the preparation of consortium required for the degradation of kitchen waste.

Identification of the isolates shortlisted for consortium preparation

Bacterial isolates were identified on the basis of morphological, cultural and biochemical characteristics. Fungal and actinomycete isolates were identified based on their macroscopic and microscopic characteristics.

The following tests were done for identification of bacteria and actinomycetes.

i. Morphological features
ii. Gram staining
iii. Spore staining
iv. Indole test
v. Methyl red test
vi. Voges Proskauer test
vii. Citrate utilization test
viii. Urease test

ix. Catalase

x. Oxidase

xi. Carbohydrate fermentation test

xii. TSI (Tripple sugar Iron Agar)

xiii. Hydrogen sulfide (H_2S) production:

xiv. Nitrate reduction test

Identification of fungal isolates were done based on microscopic examination of Lactophenol cotton blue stained slide preparations.

Preparation of microbial consortium

Each bacterial, fungal and actinomycete isolate was inoculated separately into 20 ml of nutrient broth, potato dextrose broth and yeast malt extract broth respectively. After their successive growth, viable count was measured and each of them were mixed with 100g of sterile talc powder and stored separately.

Shelf life of the microorganisms in the talc powder was analysed at different time intervals (10, 20, 30, 50, 70 and 90 days) by pour plate method.

Determination of food waste degradation (5Kg)

Two composting models, Pipe (partially anaerobic) and Kamba (aerobic) were selected for the determination of food waste degradation. Degradation rate of food waste was analysed under different treatments as follows,

T1 - Control

T2 - Consortium (Kamba)

T3 - Consortium + saw dust (Kamba)

T4 - Consortium (Pipe)

T5 - Consortium + saw dust (pipe)

T6 - Control (Pipe)

10g of microbial consortium and 50g of saw dust per Kg of food waste was added layer wise in the corresponding treatments. Each talc-based isolate was mixed just before the application. The degradation rate of food waste was analysed after 25 days by measuring the volume of waste reduction and moisture content. The isolates suitable for consortium preparation were finalised after the experiment.

Trials with larger amount of kitchen waste

After the successful degradation of 5kg kitchen waste by the consortia, large scale trials were tried with same composting models. Pipe compost model was filled with 20Kg waste and Kamba filled with 10Kg of food waste in each container. The heaps were periodically stirred and water was sprinkled for proper aeration and moisture.

The study was conducted under the following treatments.

T1 = Control (contains only food waste)
T2 = Control + consortium (waste + combination of microorganisms)
T3 = Control + sawdust
T4 = Control + consortium + sawdust

10g of microbial consortium and 50g of saw dust per Kg of food waste was added layer wise in the corresponding treatments. Each isolate with talc as carrier were mixed just before the application. Physical, chemical and microbiological parameters were analysed during composting process in the same models. Physical parameters include temperature, moisture, volume of waste reduction; chemical parameters include pH, microbial enzymes, and microbiological parameters include aerobic and anaerobic microbial count of bacteria, fungi and actinomycetes. Qualitative parameters such as smell, presence or absence of flies and maggots and the colour of the compost were also observed visually and recorded.

3. RESULTS AND DISCUSSION

3.1. Isolation of microorganisms

The samples, except fermented items and milk or oil contaminated samples were rich with fungal isolates. Actinomycete population was found more in soil of termite mounts, ants and vermin castings. Paddy field sample contained more bacterial and fungal populations. Other samples showing high bacterial population count are cow dung, fish waste, vermin castings, dairy waste effluent contaminated soil samples. Seventy morphologically different bacterial isolates, 30 fungal isolates and 27 actinomycete isolates were selected for the study.

3.2. Determination of metabolic characteristics

All the 127 isolates produced in varied ranges any one or more of the desired enzymes required to degrade the kitchen waste. Most of the bacterial and fungal isolates produced the enzyme protease, but the fungal isolate F10 produced four enzymes namely amylase, polyphenolase, cellulase and pectinase. Some bacterial isolates showed oil degradation activity and some fungal and actinomycete isolates produced keratinase enzyme efficiently. The isolates from actinomycete group produced most of the enzymes.

3.3. Screening of the isolates

From the initial 127 isolates comprising bacteria, fungi and actinomycetes, 31 bacterial isolates, 20 fungal isolates and 10 actinomycete isolates were selected subsequently for detailed screening test on the basis of high enzyme solubilisation index or the ability to produce more than one enzyme.

3.3.1. Compatibility testing

Six bacterial isolates and one fungal isolate showed antagonism to other bacterial and fungal isolates. These isolates were excluded from the detailed study. Actinomycetes did not show any antagonistic activities among themselves.

3.3.2. Effect of temperature on growth of the isolates

Except B43 and B47, other bacterial isolates were able to grow up to 60^0C. Except B38, B40, B46 and B50, others were thermophilic. All the fungal isolates showed maximum growth at 50^0C except F8 and F 10, which showed maximum growth at 60^0C. Actinomycete isolates showed maximum growth at 40^0C. Some isolates A1, A2, A3, A4 and A10 showed growth up to 50^0C and A3 showed maximum growth at 60^0C.

3.3.3. Effect of pH on growth of the isolates

All the bacterial isolates showed optimum growth between the pH ranges 6-8. The fungal isolates showed growth between pH 4 to 8 and optimum growth at pH 6. Actinomycete isolates showed good growth between pH 6 to 8.

3.3.4. Effect of oxygen for growth

Most of the bacterial isolates are aerobic, and among them 8 isolates showed growth under anaerobic conditions also. All the fungal isolate showed aerobic growth and only F18 showed anaerobic growth. Two isolates among actinomycetes showed anaerobic growth.

3.3.5. Final screening of isolates for consortia preparation

The following 14 bacterial isolates, 7 fungal isolates and 6 actinomycete isolates were selected for final screening using Kamba and Pipe composting methods for preparation of consortium.

Bacterial isolates: B6, B14, B20, B21, B22, B30, B35, B36, B55, B57, B67, B68, B69 and B70
Fungal isolates: F5, F8, F10, F13, F18, F21 and F23
Actinomycetes: A3, A4, A5, A6, A7 and A10

3.3.6. Identification of the isolates

The identified isolates were shown in table No.1-3. Among the bacterial isolates, the genus *Bacillus* was the most abundant one.

Table 1. Bacteria included in the consortium of microorganisms

S. No.	Bacterial isolates	Identified organism
1	B6	*Bacillus sphaericus*
2	B14	*B. pumilis*
3	B20	*Alcaligenes faecalis*
4	B21	*Pseudomonas sp.*
5	B22	*B. megaterium*
6	B30	*B. staerothermophilus*
7	B35	*B. circulans*
8	B36	*B. coagulans*
9	B55	*Clostridium thermocelium*
10	B57	*Thermus sp*
11	B67	*B. subtilis*
12	B68	*B. licheniformis*
13	B69	*B. brevis*
14	B70	*Flavobacterium sp*

Table 2. Actinomycetes included in the consortium of microorganisms

S. No.	Actinomycete isolates	Identified organism
1	A3	*Streptomyces thermofuscus*
2	A4	*S. rectus*
3	A5	*Actinobifida chromogena*
4	A6	*Nocardia sp.*
5	A7	*Microbiospora bispora*
6	A10	*S. thermovulgaris*

Table 3. Fungi included in the consortium of microorganisms

S. No.	Fungal isolates	Identified organism
1	F5	*Humicola insolens*
2	F8	*Papulospra thermophila*
3	F10	*Sporotrichum thermophilum*
4	F13	*Aspergillus niger*
5	F18	*Paecilomyces variotti*
6	F21	*Malbranchea pulchella*
7	F23	*A. fumigatus*

3.3.7. Preparation of microbial consortium

Bacterial isolates showed 10^8 colonies per ml of growth medium used for preparation of inoculum, and among them *B. staerothermophilus* and *B. subtilis* showed more population

count. Fungal isolates showed 10^6 colonies per ml and among them *S. thermophilum* showed more population count. Actinomycete isolates showed 10^4 colonies per ml and among them *Nocardia sp* showed more population count.

3.3.8. Shelf life of the microbial consortium

All the bacterial isolates were able to survive up to 90 days when talc powder was used as the carrier (Fig. 1). Most of them were actively growing and multiplying up to 20 days and after that their growth rate gradually decreased. *B. spahericus, B. pumilis, B. subtilis, Pseudomonas* sp., and *Flavobacterium* sp. showed similar growth rate. Fungal and actinomycete isolates showed almost similar growth rate up to 90 days.

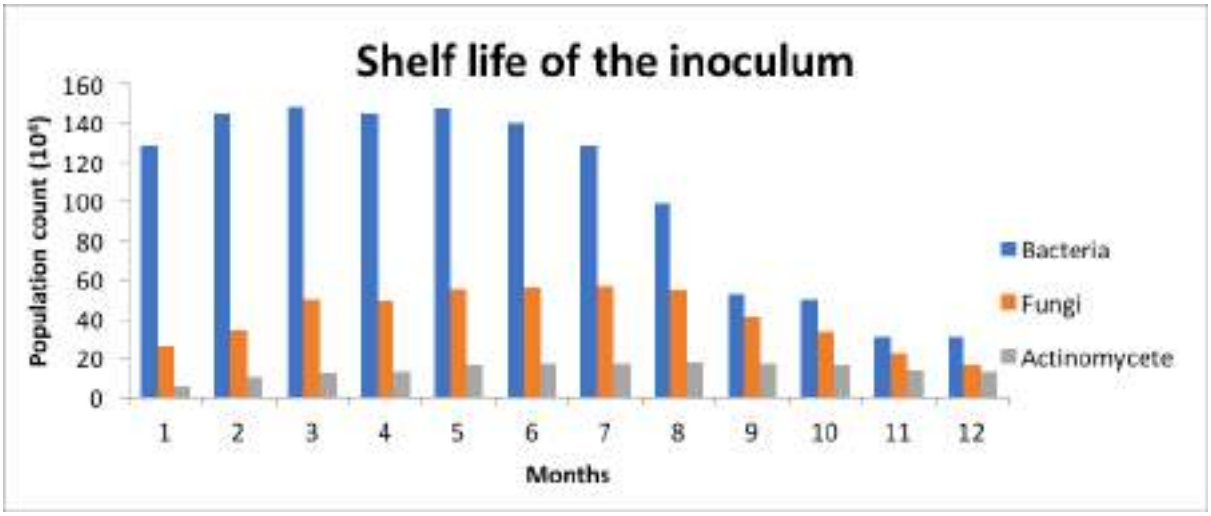

Fig.1. Average shelf life of consortium of microorganisms

3.3.9. Food waste degradation in aerobic (Kamba) and partial anaerobic (PVC pipes)

Volume of food waste in aerobic system (Kamba) decreased faster than the partial anaerobic system (Pipe). Similarly, moisture content was found less in Kamba when compared with pipe. The degradation rate increased with decrease in moisture content.

3.3.10. Trials with higher amount of kitchen waste in Kamba & PVC pipe

3.3.10.1. Qualitative parameters considered

Smell

The parameters were almost same in both chambers of Kamba. Initially, there was no smell. The smell increased after ten days to some extent and finally there was no bad smell after 40 days. Compost in T1 (waste alone) and T2 (waste + microbial consortium) gave earthy smell where as sawdust added waste gave woody smell. Initially, Pipe compost behaved similar to Kamba for a week; later it turned to stinking smell upto 110 days and then decreased. Sawdust added pipe gave woody smell after 30 days. The intolerable smell of the Pipe composting (control) continued even after 170 days.

Colour

In Kamba, the colour of the waste turned into brown after 20 days in the control, where as the colour of the waste in the treated chambers turned to brown after 10 days and then to black after 30 days. In pipe, the colour of upper layers changed faster than the bottom layers. The waste in the control pipe took 140 days to turn into brown. In sawdust added pipe, the waste turned to black after 140 days and in control it turned to black watery after 140 days.

Flies

There were no flies in the consortium added Kamba and sawdust added Kamba chambers, but it appeared after 30 days in control Kamba. Flies appeared in all the pipe treatments after 10 days and it was absent after 140 days in sawdust and consortium added pipe. In consortium added waste, it disappeared after 170 days.

Maggots

Control and consortium added Kamba showed the presence of maggots after 30 days and it disappeared within 10 days from consortium added Kamba. There was no maggots in sawdust added Kamba. In pipe composting, maggots appeared from the 20^{th} day. They disappeared after 110^{th} day from the control pipe. Comparatively, the number of maggots was less in the consortium added pipe than in the control Pipe.

3.3.10.2. Physical and biochemical environment during aerobic composting inside pots

The physical and biochemical environment observed during aerobic composting done in Kamba pots using 10 kg food waste was very much encouraging. Microbial population

count, enzyme activity, moisture content and temperature at different intervals are given in Figs. 2-5 respectively. Bacterial count increased tremendously during peak days of biodegradation and decreased to the lowest level at 40^{th} day (Fig. 2). The same pattern was followed for microbial enzyme activity during composting (Fig. 3). The moisture content decreased less than half its original value in microbial inoculum-added Kamba pots while in untreated pots, moisture content decreased only marginally (Fig. 4). The effect of microbial inoculum on temperature variation within decomposing food waste was very prominent in microbial consortium treated food waste (Fig. 5). The temperature reached upto 60°C in treated pots while there was only a marginal increase in untreated pots. The increase in temperature is due to the metabolic activity of inoculated thermophilic micro-organisms.

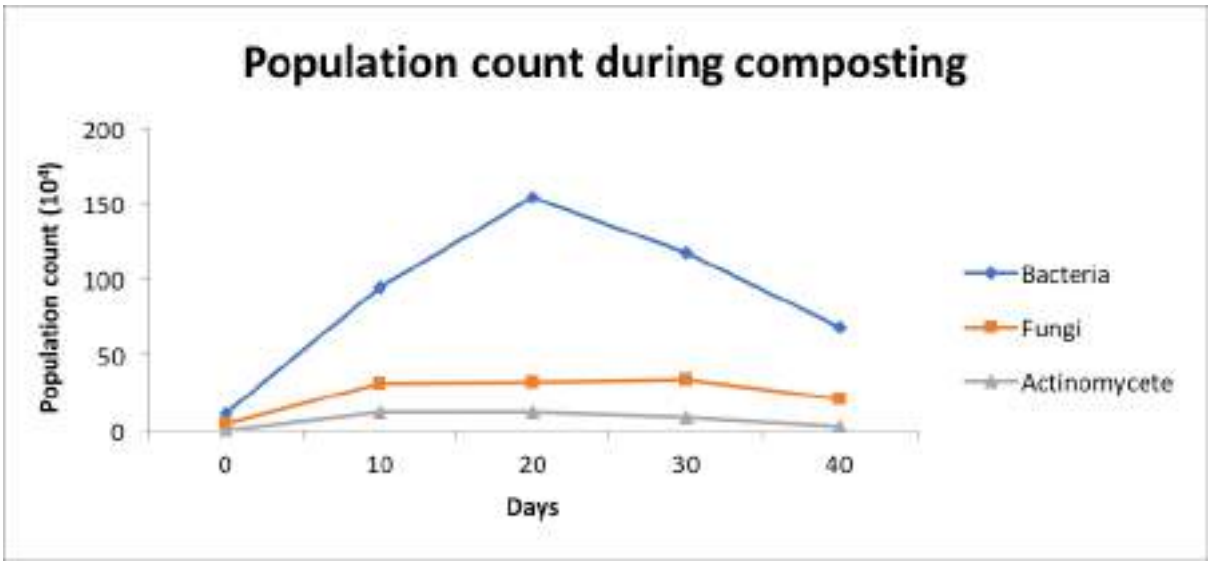

Fig. 2. Microbial population count during aerobic composting of food waste in Kamba pots

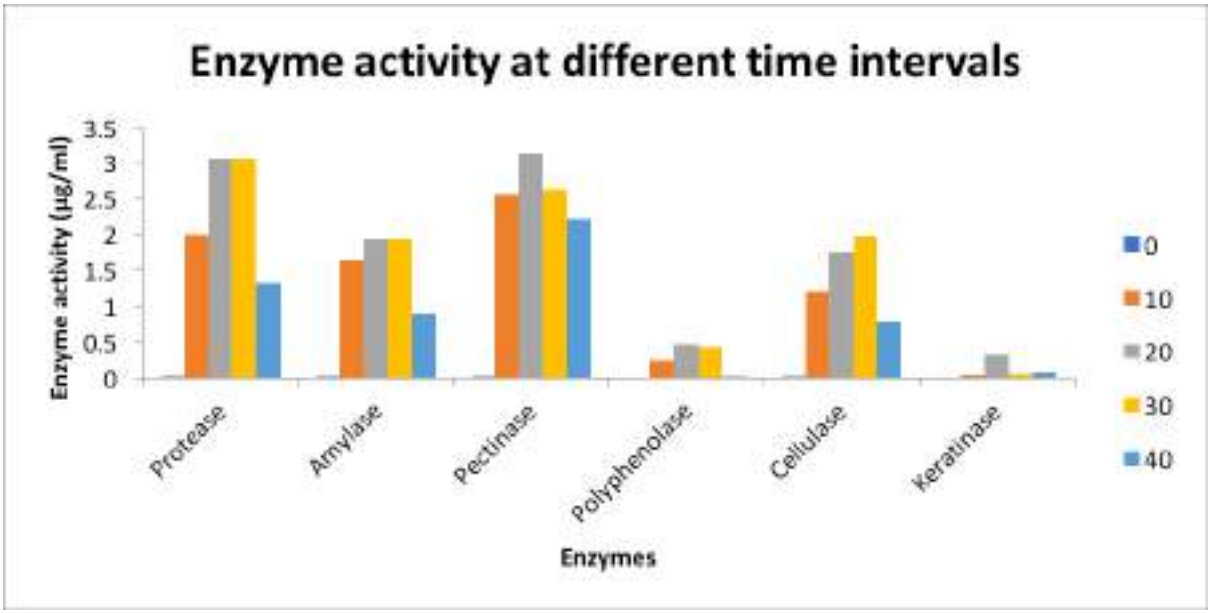

Fig. 3 Enzyme activity of microbial population during aerobic composting of food waste in Kamba pots

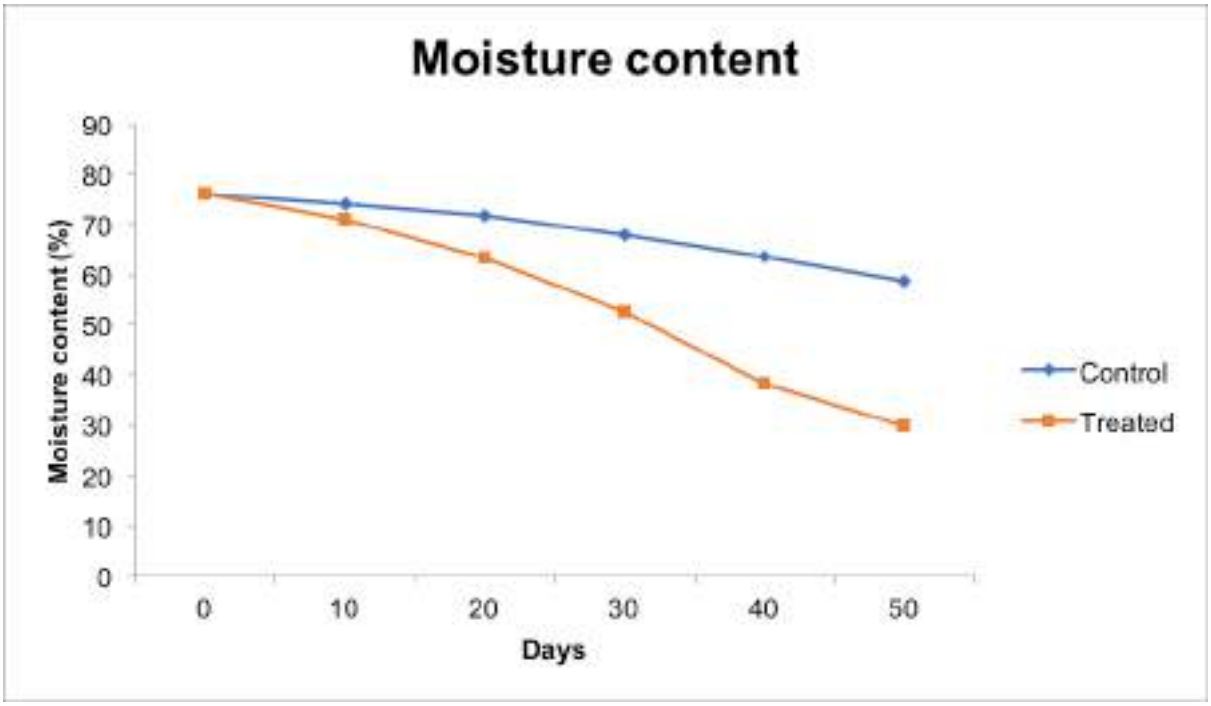

Fig. 4. Decline in moisture content during aerobic composting of food waste in Kamba pots

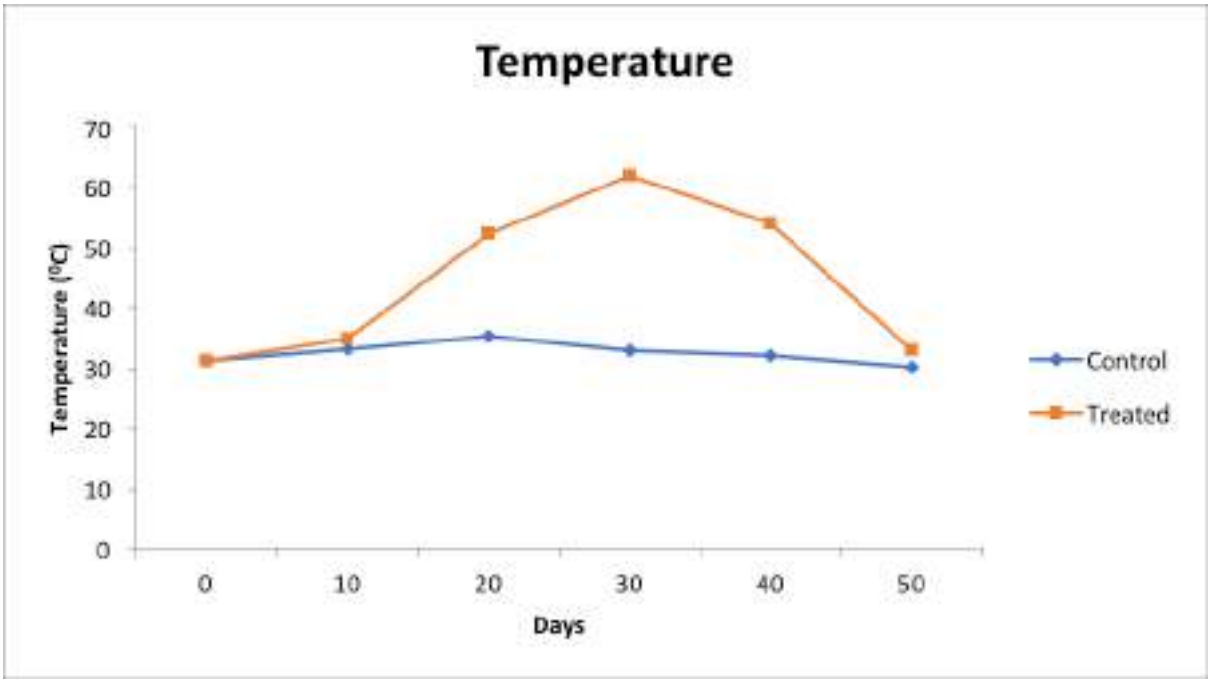

Fig. 5. Increase in temperature during aerobic composting of food waste in due to thermophilic microbial inoculum.

3.4. AUTOMATIC HOME COMPOSTING MACHINE

3.4.1. Fabrication of bio-rector for odour-free food waste composting

A working prototype of an indoor composting machine is developed as proof of concept of an odour-free composting machine for use inside kitchen. The machine is similar to a top-loading washing machine, 600mm x 550mm x 900mm size, made of 3mm double-walled stainless steel shell with powder coated exterior (Figs. 6-13). There are three chambers with a total capacity to hold 30-40 kg waste (Fig.8). The top chamber is of maximum 5 Kg capacity (net weight of solid waste for a six-member family estimating 3 to 4 Kg waste per day (Fig. 9). There is a flip pad opening from this chamber to the lower second chamber. An electrically operating lever mechanism open and close the flip pads. The following items are arranged in this chamber: mechanical stirrer to mix the waste; sensors to detect the temperature, moisture content, leachate collecting system etc. The second chamber is lower to the first chamber and of 20 Kg capacity (net volume of solid waste 2 Kg x 10 days) (Fig.10). This chamber has a bottom plate with holes of specified size for passing digested materials into the third chamber. The following items are arranged in this chamber: mechanical stirrer to mix the waste; sensors to detect the temperature, moisture.

All types of bio-degradable kitchen waste can be disposed in the machine. The consortium of microbial inoculum for enhancing composting is also dispensed inside the bioreactor. The environment inside the bio-reactor is automatically regulated electronically for optimum metabolic activity of the thermophilic microbial inoculum for fast decomposition of waste (Fig. 11 & 12). The moisture content and temperature inside the bioreactor are maintained with the aid of sensors. The faculties and students of the Electronics and Communication Engineering Department of Rajiv Gandhi Institute of Technology, Kottayam were the consultants for setting up the electronic control system (Fig. 13).

3.4.2. Major components

The Home composting Machine has the following components:

i. Two chambers for aerobic digestion
ii. One chamber for compost with removable compost tray
iii. Mechanical stirrer in the aerobic chambers (arm processor)

iv. Temperature and moisture detecting and controlling devices (electronic sensory rods)

v. Odour detection and controlling devices (electronic sensory rods)

vi. Leachate collecting system (from chamber 1 & 2)

vii. Electronic Display panel showing the temperature, moisture, working mode, alarm etc.

viii. Motor, gear system etc.

The arm processor performs the following activities

- It accepts the input from the moisture sensor and control the thermo regulator system (non-contact) to heat the bio-waste in order to reduce the moisture content below 50%, but without increasing the temperature beyond 60^0 C.
- It controls the motor which, in turn, rotates the stirring handle in fixed time interval

Bio-degradable kitchen waste materials contain high water content. When the water content replaces air in the composting machine, anaerobic digestion occurs which is not encouraged for domestic use due to production of foul smell. To overcome these problems, the machine is designed to regulate the water content in the waste material to about 40-50%. The temperature inside the chamber is maintained less than 60^0C. Proper agitation is provided to the waste mass to help uniform decomposition of the mass. The entire components which perform additional functions are provided within the body of the machine.

Fig. 6. The automatic composting machine

Fig. 7. One side and top lid kept open

Fig. 8. Interior of the composting machine with 3 chambers. Compost collected at bottom tray.

Fig. 9. Control systems and top chamber where waste is initially disposed

Fig. 10. Decomposing kitchen waste inside the upper chamber of the machine

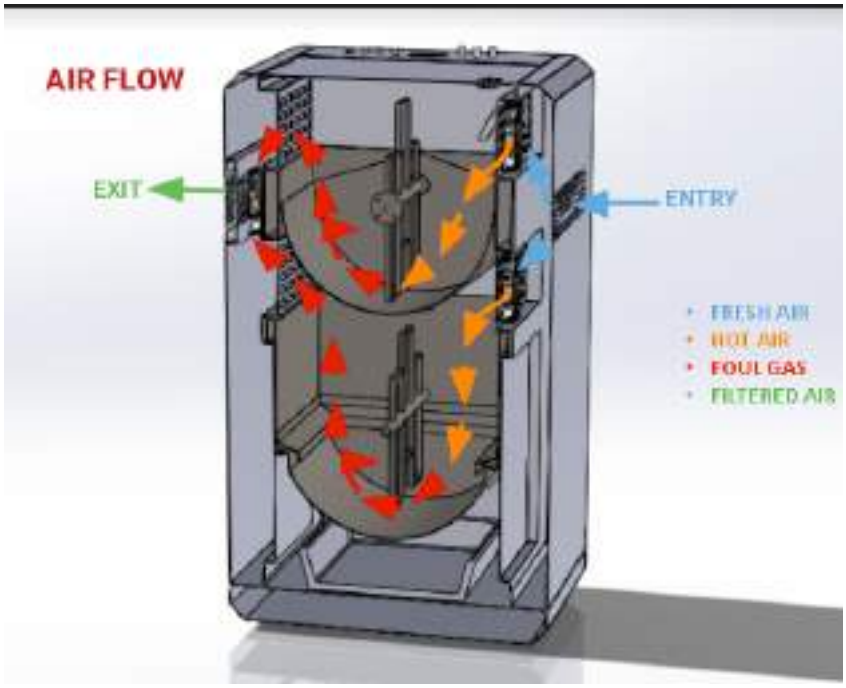

Fig. 11. Computer simulation of air flow inside the machine

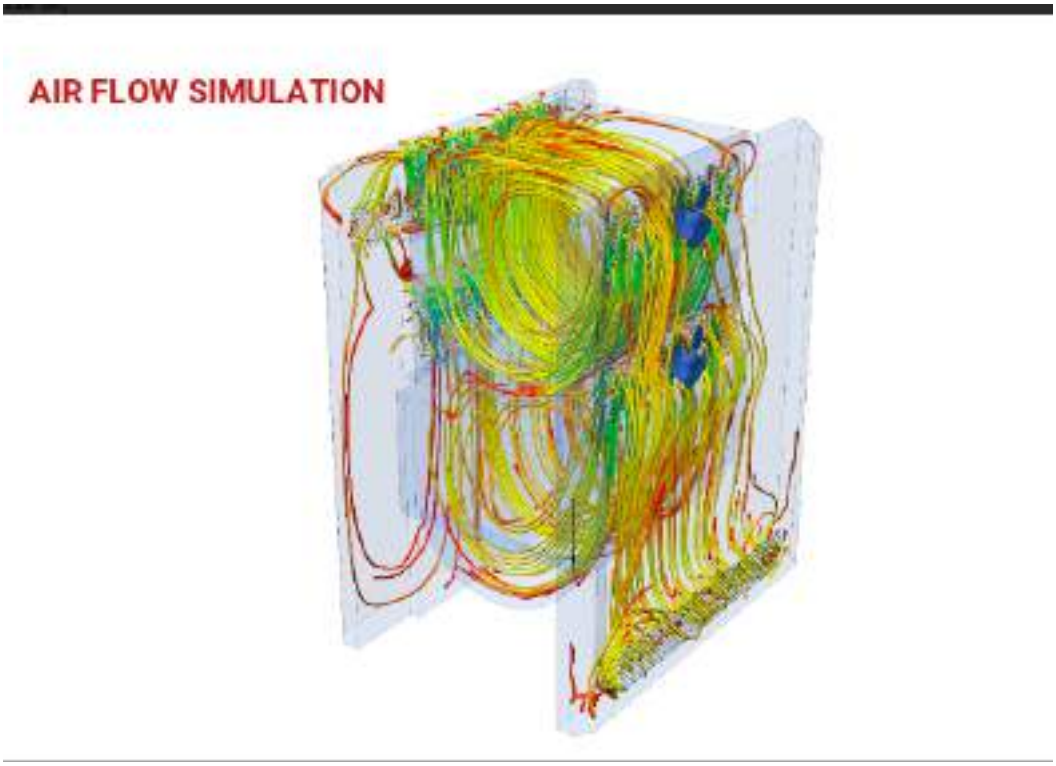

Fig. 12. Computer simulation of air flow inside the machine

Fig. 13. The composting machine when brought to Rajiv Gandhi Institute of Technology, Pampady, Kottayam. The Electronic and Communication Engg. Dept. faculties and TIES project team are also seen.

The third chamber is a rectangular tray that can be taken out through a side door. Heating mechanism and sensors are available in this chamber too. Its capacity is 10-15 Kg for powdered compost. A leachate tank is kept at the sides of this chamber, that also removable and with leachate releasing valves etc.

3.5. Out-door food waste composting bio-reactor

The out-door unit is comprised of a plastic drum of 150 litre capacity (Fig. 14-15). The inside chamber is partitioned into two equal volume chambers (bioreactors). The barrel is mounted on a stand of 75cm height. An electrically operated grinder is mounted at the mouth of the inlet and through which waste materials are put inside the barrel (Fig.15). The barrel can rotate on a steel pipe passed through the centre of the barrel (Fig. 16). A mixture of saw dust and coir pith along with microbial inoculum are put inside the bioreactor. The barrel can be rotated along its axis. Once one chamber of the barrel is ¾ filled, filling the other chamber can be started. A door at the middle of each chamber facilitates removal of finished compost. A drain hole on the opposite side (bottom) facilitates removal of leachates. Different combinations of shape and size of barrel, stirring and rotation of the chamber, etc. had been tried during the initial trial (Fig.17).

Fig. 14. Plastic barrel fixed with a heating element for intermittent heating for promoting thermophilic microbial inoculum.

Fig. 15. Grinder fitted at the mouth of the barrel for grinding into short pieces of the waste materials.

Fig. 16. Horizontal rod provided for gentle rotation of the barrel and blade attached to it for tilting and stirring of the waste inside the barrel.

Fig. 17. A few models tried at the initial stage of the trial

The disposal of organic waste with high moisture, organic content and biodegradability is a serious problem as landfill has its own limitations due to its environmental impact. A possible way to dispose of this waste without causing any environmental hazard is by aerobic digestion in bioreactors using microorganisms. The present study has been under taken to fabricate an indoor composting machine for composting kitchen waste using a consortium of thermophilic microorganisms and electronically manipulating the micro-environment inside the composting machine for efficient composting. Microorganisms were screened on the basis of their ability to produce enzymes such as Protease, Amylase, Cellulose, Polyphenolase, Pectinase and Keratinase. The most important parameters for the growth of microorganism are temperature, oxygen, moisture, pH and substrate composition.

The consortium of microorganisms was selected based on lab experiments and after pretest through aerobic decomposition trials using Kampa pots. The microbial population increased inside the composting chambers depending upon the physical and chemical characteristics of the waste. Since the consortium comprised of thermophilic microorganisms, the temperature rose upto the optimum level (45-60^{o}C) for a short time only as it was not possible to control the microenvironment inside the pots. Hence, the composting speed was very low; besides, there was bad smell and maggot growth inside the Kamba pots at certain stages.

The indoor composting machine fabricated in this project is being tested continuously. The trial run showed efficient working of the machine and quick composting as expected. So far, such a machine is not available in the market in India. After running for three months, it is felt that larger vegetable pieces thrown as rejections from the kitchen needs to be cut into small pieces for quick composting. Such waste materials have to be ground before depositing inside the composting machine. As an alternative, a small grinder has to be fixed at an appropriate place on the machine.

The outdoor composting machine also performed well when saw dust was also used as supplements for promoting microbial growth. Speed of composting and quality of compost obtained was high when saw dust was added along with the microbial inoculum. The use of

grinder resulted in quick composting. This may be because larger surface area of the ground waste materials are available for the microorganisms to colonise and degrade he organic waste.

4. Contributions made towards increasing the state of knowledge

Though fabrication of different types of bio-bins, bioreactors and composting pots have been carried out for kitchen waste composting, very few attempts have been made for designing and fabricating an automated composting machine suitable to keep inside kitchen for composting food waste. For using such a machine inside kitchen, the primary requirement is that it should be free of fowl odour, free of maggots besides user friendly composting. No such machine is now available in the market. To that extent, the present achievement of making a cute, washing machine like instrument for dumping kitchen waste generated inside kitchen and its quick composting is a great success. Packets and bottles of consortium of several microorganisms developed in the present project for enhancing composting of all types of waste materials are available for sale now. But there is no scientific proof of its efficiency. The consortium of thermophilic microorganisms developed in the present project are responsible for speedy and efficient composting. Development of a consortium of thermophilic microorganisms capable of excreting enzymes responsible for biodegradation of all types of organic waste materials and their public acceptance is also an achievement and improvement over the present state of knowledge.

5. Summary and scope of the future work

The proof of concept is demonstrated in respect of both type of machines. However, they have to be taken to the next level of perfection. Technical work on this aspect is continued at Tropical Institute of Ecological Sciences with the help of Technology Incubation Centre of Rajiv Gandhi Institute of Technology, Kottayam and MET's School of Engineering, Mala. We propose to make a few more machines, smaller in size but more efficient in utility through additional gadgets and components.