Indian Institute of Technology Guwahati

Dr. Ajay Kalamdhad
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Dept. of Civil Engineering
Indian Institute of Technology Guwahati

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+91-9678621395
Fax: +91-361-258-2440
Email: kajay@iitg.ernet.in
kalamdhad@gmail.com

July 16, 2015

To,
Shri G. Balasubramanian
Deputy Advisor (PHE)
12th Floor, Paryavaran Bhawan
Lodhi Road, CGO Complex
New Delhi - 110003
Phone:011 24363747

Letter no. W.11035/07/2011-CRSP (R&D)
Subject: Submission of project completion report and audited UC

Sir,

My project entitled "Potential of aerobic digestion (composting) and anaerobic digestion of kitchen waste" (Letter no. W.11035/07/2011-CRSP (R&D)) has been completed, so please find the five copies of project completion report (PCR) with five copies of executive summary of the research project. Also find the audited utilization certificate (UCs) for year 2012-15. Project closure report will be submitted after reimbursement of deficit balance as shown in UC year 2014-15.

Regards

(Ajay Kalamdhad)

14-15

FORM GFR 19A

UTILISATION CERTIFICATE

Sl. No.	Sanction Order Number and date	Amount (₹)
01.	W-11035/07/2011-CRSP(R&D) dated 01.01.2015	₹ 4,63,600.00
	TOTAL	₹ 4,63,600.00

Certified that out of ₹ **4,63,600.00 (Rupees Four Lacs Sixty Three Thousand Six Hundred)** only of Grants-in-Aid received during the period from 01.04.2014 to 31.05.2015 in favour of the Registrar, IIT Guwahati, under Government of India, Ministry of Drinking Water & Sanitation, Swachh Bharat Mission (Gramin), 12th Floor, Paryavaran Bhawan, Lodhi Road, CGO Complex, New Delhi – 110 003, vide the Sanction Order Number given above and ₹ **48,645.00** only on account of un-spent balance of the previous period, a sum of **Rs. 5,19,089.50 (Rupees Five Lacs Nineteen Thousand Eighty Nine and Paise Fifty)** only has been utilized/~~to be utilised~~ (including committed Contingency Expenses of Rs. 5,000/-) for the Project entitled **"Potential of Aerobic Digestion (Composting) and Anaerobic Digestion of Kitchen Waste"** , for which it was sanctioned and that the balance as on 31.05.2015 is (-) ₹ **6,844.50. That is, deficit balance is ₹ 6,844.50 as on 31.05.2015**.

Certified that we are satisfied that the condition on which the grant-in-aid was sanctioned have been duly fulfilled/~~are being fulfilled~~ so far as it appears from our verification and that we have exercised the following checks on test basis to see that the money was actually utilized for the purpose for which it was sanctioned.

Kinds of checks exercised

1. Bills and other records
2. Vouchers
3. Sanction Letter etc.

For SANJAY BHATTACHARJEE & CO.
Chartered Accountants

23/06/2015

(Sanjay Bhattacharjee)
Proprietor
Firm Regn. No. : 324542E, M. No. 059605

24/06/15

Principal Investigator

26/6/15

Registrar

Auditor

INDIAN INSTITUTE OF TECHNOLOGY
GUWAHATI - 781039
DIST. : KAMRUP, ASSAM

STATEMENT OF ACCOUNT FOR THE PERIOD FROM 01.04.2014 TO 31.05.2015 IN RESPECT OF RECEIPT & UTILISATION OF FUNDS TOWARDS THE PROJECT TITLED "POTENTIAL OF AEROBIC DIGESTION (COMPOSTING) AND ANAEROBIC DIGESTION OF KITCHEN WASTE"

RECEIPT	AMOUNT ₹	UTILISATION	AMOUNT ₹
Opening Balance	48645.00	Manpower	396600.00
Grant in Aid received from Government of India, Ministry of Drinking Water & Sanitation, Swachh Bharat Mission (Gramin) vide Sanction No. & date : W-11035/07/2011-CRSP(R&D) dated 01.01.2015	463600.00	Contingency	8997.50
		Equipment	79892.00
		Institutional Overhead	33600.00
Excess of Utilisation over Receipts	6844.50		
TOTAL	**519089.50**	**TOTAL**	**519089.50**

Dated, Guwahatii - 5
The 23rd June, 2015

Signed in terms of our separate Certificate of even date
For Sanjay Bhattacharjee & Co.
FRN. 324542E

SANJAY BHATTACHARJEE & CO. Guwahati FRN : 324542E Chartered Accountants

23/06/2015

(CA. Sanjay Bhattacharjee)
Membership No. 59605
Proprietor

13-14

FORM GFR 19A

UTILISATION CERTIFICATE

Sl. No.	Sanction Order Number and date	Amount (₹)
01.	.....	₹ 0.00
	TOTAL	₹ 0.00

Certified that out of ₹ **0.00 (Rupees Nil)** only of Grants-in-Aid received during the FY. 2013-14 in favour of the Registrar, IIT Guwahati, under Government of India, Ministry of Drinking Water & Sanitation, CRSP Division, 12th Floor, Paryavaran Bhawan, Lodhi Road, CGO Complex, New Delhi – 110 003, vide the Sanction Order Number given above and ₹ **3,66,985.00** only on account of un-spent balance of the previous period, a sum of **Rs. 3,18,340.00 (Rupees Three Lacs Eighteen Thousand Three Hundred and Forty)** only has been utilized/~~to be utilised~~ for the Project entitled **"Potential of Aerobic Digestion (Composting) and Anaerobic Digestion of Kitchen Waste"** , for which it was sanctioned and that the balance of ₹ **48,645.00** remains unutilized as on 31.03.2014.

Certified that we are satisfied that the condition on which the grant-in-aid was sanctioned have been duly fulfilled/ are being fulfilled so far as it appears from our verification and that we have exercised the following checks on test basis to see that the money was actually utilized for the purpose for which it was sanctioned.

Kinds of checks exercised

1. Bills and other records
2. Vouchers
3. Sanction Letters etc.

For SANJAY BHATTACHARJEE & CO.
Chartered Accountants

(Sanjay Bhattacharjee)
Proprietor
Firm Regn. No. : 324542E, M. No. 059605

05/06/14

Principal Investigator
(Dr. Ajay Kalamdhad)

Registrar

Registrar
Indian Institute of Technology Guwahati
Guwahati-781039

Auditor

INDIAN INSTITUTE OF TECHNOLOGY
GUWAHATI - 781039
DIST. : KAMRUP, ASSAM

STATEMENT OF ACCOUNT FOR THE FINANCIAL YEAR 2013-14 IN RESPECT OF RECEIPT & UTILISATION OF FUNDS TOWARDS THE PROJECT TITLED "POTENTIAL OF AEROBIC DIGESTION (COMPOSTING) AND ANAEROBIC DIGESTION OF KITCHEN WASTE"

RECEIPT	AMOUNT ₹	UTILISATION	AMOUNT ₹
Opening Balance	366985.00	Manpower	195394.00
Grant in Aid received from Ministry of Drinking Water & Sanitation, Govt. of India vide Sanction No. & date : Nil	0.00	Contingency	31501.00
		Travel	16665.00
		Equipment	52073.00
		Consumables	22707.00
		Excess of Receipt over Utilisation	48645.00
TOTAL	**366985.00**	**TOTAL**	**366985.00**

Dated, Guwahatii - 5
The 4th June, 2014

Signed in terms of our separate Certificate of even date
For Sanjay Bhattacharjee & Co.
FRN. 324542E

SANJAY BHATTACHARJEE & CO. Guwahati FRN : 324542E Chartered Accountants

(CA. Sanjay Bhattacharjee)
Membership No. 59605
Proprietor

FORM GFR 19A

UTILISATION CERTIFICATE

Sl. No.	Sanction Order Number and date	Amount
01.	No. W.11035/07/2011-CRSP (R&D) dated 12.12.2011	Rs. 9,63,000.00
	TOTAL	Rs. 9,63,000.00

Certified that out of **Rs. 9,63,000.00 (Rupees Nine Lacs Sixty Three Thousand)** only of Grants-in-Aid received during the FY. 2011-12 in favour of the Registrar, IIT Guwahati, under Government of India, Ministry of Drinking Water & Sanitation, CRSP Division, 12th Floor, Paryavaran Bhawan, Lodhi Road, CGO Complex, New Delhi – 110 003, vide the Sanction Order Number given above and **Rs. NIL** only on account of un-spent balance of the previous period, a sum of **Rs. 5,96,015.00 (Rupees Five Lacs Ninety Six Thousand and Fifteen)** only has been utilized/~~to be utilised~~ for **"Potential of Aerobic Digestion (Composting) and Anaerobic Digestion of Kitchen Waste"** , for which it was sanctioned and that the balance of **Rs. 3,66,985.00** remains unutilized as on 31.03.2013.

Certified that we are satisfied that the condition on which the grant-in-aid was sanctioned have been duly fulfilled/ ~~are being fulfilled~~ so far as it appears from our verification and that we have exercised the following checks on test basis to see that the money was actually utilized for the purpose for which it was sanctioned.

Kinds of checks exercised

1. Bills and other records
2. Vouchers etc.
3. Sanction Letters etc.

For SANJAY BHATTACHARJEE & CO.
Chartered Accountants

(Sanjay Bhattacharjee)
Proprietor
Firm Regn. No. : 324542E, M. No. 059605

08/10/13
Principal Investigator

19.10.13
Registrar

Registrar
IIT Guwahati
Guwahati-781 039

Auditor

INDIAN INSTITUTE OF TECHNOLOGY
GUWAHATI - 781039
DIST. : KAMRUP, ASSAM

STATEMENT OF ACCOUNT AS ON 31ST MARCH, 2013 IN RESPECT OF RECEIPT & UTILISATION OF FUNDS TOWARDS THE PROJECT TITLED "POTENTIAL OF AEROBIC DIGESTION (COMPOSTING) AND ANAEROBIC DIGESTION OF KITCHEN WASTE"

RECEIPT	AMOUNT Rs.	UTILISATION	AMOUNT Rs.
Grant in Aid received from Ministry of Drinking Water & Sanitation, Govt. of India vide Sanction No. & date : No. W.11035/07/2011-CRSP (R&D) dated 12.12.2011	963000.00	Manpower	240645.00
		Contingency	83211.00
		Travel	4020.00
		Equipment	68716.00
		Consumables	103123.00
		Institute Overhead (IDF)	96300.00
		Excess of Receipt over Utilisation	366985.00
TOTAL	963000.00	TOTAL	963000.00

Audited

Dated Guwahati - 5
The 8th October, 2013

Signed in terms of our separate Certificate of even date
For Sanjay Bhattacharjee & Co
FRN. 324542E

(CA Sanjay Bhattacharjee)
Proprietor

EXECUTIVE SUMMARY

Title of the project	Potential of Aerobic Digestion (Composting) and Anaerobic Digestion of Kitchen Waste
Sanction order no.	No. W.11035/07/2011-CRSP(R&D)
Principal Investigator	**Dr. Ajay Kalamdhad,** Associate Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati-791039
Implementation Institute	Indian Institute of Technology Guwahati, Guwahati-781039

1. INTRODUCTION

Municipal solid waste is causing major environmental problems in most of the Indian cities. The higher proportion of organic waste is the major cause for these environmental issues, predominantly emitting greenhouse gases and producing leachate in landfills and dumpsites. Many researchers and urban local bodies have recommended composting and anaerobic digestion of these organic fractions for the recycling of organic matter and nutrients to the environment. Eventhough low C/N ratio has been recommended for drum composting, leachate production has been reported from the organic waste composting. Addition of rice straw, dry leaves and sawdust were reported to provide proper aeration and porosity resulting in moisture control. But these materials are rich in lignocellulose composition normally resistant to microbial degradation and will take longer time for degradation. Therefore, the quality of final compost and duration for the process are of major concern to study upon. However, for anaerobic digestion of food waste with high VS content can improve the quantity and quality of biogas. Addition of effective inoculum is necessary in the reactors with the substrate to achieve higher biogas production.

Therefore, the present study involved the application of waste carbide sludge addition and white-rot fungi i.e. *Phanerochaete Chrysosporium* to increase the volatile solids reduction and lignocellulose degradation during drum composting of mixed organic waste. In addition, different composting methodologies i.e. drum composting; pile composting and vermicomposting were also compared with the best combinations for higher degradation of organic matter. In the case of anaerobic digestion, suitable inoculum can increase the degradation rate, enhance biogas production, shorten the starting time, and more stable digestion process. Studies were done on the basis of F/M ratio of different waste composition and different inoculums to attain the maximum gas production. The trials were done to find the proper F/M ratio for its higher growth. The study utilized the best livestock inoculum to attain

higher methane yield from the FW at different F/M ratio of five different livestock inoculum such as poultry dung (PD), goat dung (GD), cow dung (CD), piggery dung (PGD) and rhinoceros dung (RD). The best inoculum was tested in the batch reactors and lab scale continuous mode. Finally, pilot scale digester of 1.0 m^3 was fabricated and operated for its efficiency.

2. EXPERIMETAL METHODOLOGY

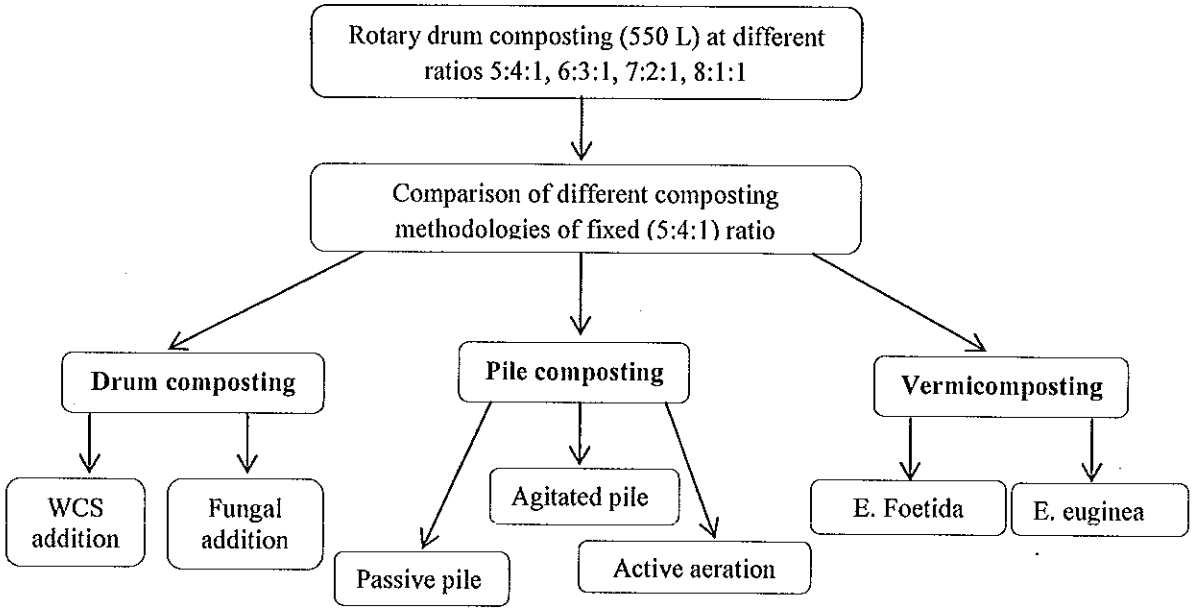

Fig. 1. Composting of vegetable waste

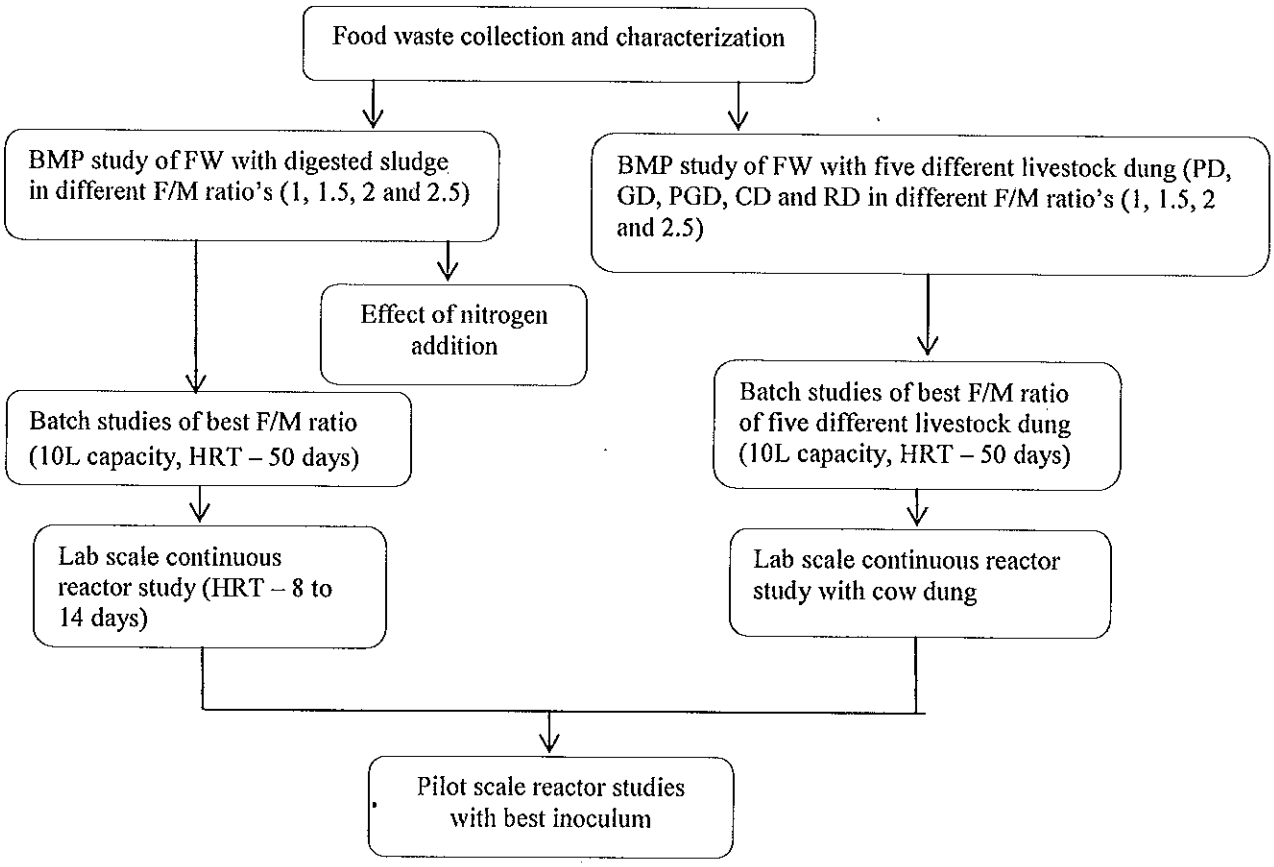

Fig. 2. Anaerobic digestion of food waste

3. OUTCOME OF THE RESAERCH WORK

3.1 COMPOSTING

- Rotary drum composting of vegetable waste was found successful with the combinations of cow dung, saw dust and dried leaves. A maximum of 66.4°C was observed in 5:4:1 ratio along with 10 kg addition of dried leaves (total 100 kg mass volume) and temperature level in the range of 55-62°C for 4-7 days leading to 11% VS reduction and higher destruction of pathogens within 20 days. Maximum degradation of organic matter was observed during day 2 to 8 of composting i.e. active thermophilic stage, followed by further stabilization. Insufficient addition of bulking agents during the process lead to the production of leachate thereby deteriorating the quality of compost. However, higher addition of bulking agents added more lignocellulose concentration to the process, which took longer time for further degradation.
- Vermicomposting of vegetable waste by using *E. fetida* was very effective as compared to *Eudrilus eugeniae*, without pretreatment of vegetable waste. Higher biomass production was observed during the 45 days of vermicomposting. Pretreating vegetable waste during the active thermophilic phase in rotary drum composter proved to be more beneficial for treatment in vermicomposting over direct utilization of vegetable waste using *E. fetida.* Higher loss of TOC and higher count of earthworm biomass was observed at the end of the process. The overall composting period was reduced to 28 days as compared to 45 days by pretreating the vegetable waste using drum composter followed by vermicomposting using *E. fetida.*
- Agitation, mixing and aeration of the composting materials was found crucial during pile composting of vegetable waste operated at agitated pile (AP), passive pile (PP) and forced aeration pile (FAP) condition. The degradation pattern of organic matter was completely different in comparison of all the three operated conditions. A maximum of 22.9% of reduction was observed in trial FAP followed by 19.6 and 9.4% in trial PP and AP trials respectively. Moreover, 50 to 60% of organic matter degradation was occurred within 9 days of the total composting period in all the trials during the active thermophilic phase.
- A maximum of 11% VS reduction was observed during drum composting, 19.3% during fungal inoculation, 22.4% during 1% WCS addition, 19-23% during pile operation and 15.4% drum followed by vermicomposting. The final compost was completely stabilized with lower OUR and CO_2 evolution.

3.2 ANAEROBIC DIGETSION

- In Anaerobic BMP of FW with DS as inoculum, the highest of 59% VS reduction was observed in F/M ratio 2 maintained reactors with higher methane yield. The results concluded that only the requisite amount of food is mandatory for microorganisms to get better anaerobic digestion of FW neither more nor less to achieve higher methane yield.
- In batch studies FW with DS as inoculum, percentage of VS reduction followed the same trend as the best F/M ratio 2 in BMP of food waste. Maximum of 996 mL/ d methane production rate was achieved in this study. The VFA productio was high at initial days later it was stabilized by the methane producers.
- In BMP studies with different livestock dung as inoculum, the results of study demonstrated that there were significant differences between different inoculums. The reactors inoculated with CD had shorter initial time and achieved higher biogas production than reactors inoculated with other inoculums. CD followed by PGD with the highest activity and most suitable nutrient content, achieved the highest methane production and showed the best degradation among all livestock inoculums.
- In batch studies with different livestock dung as inoculum, the results of study validated that there were substantial differences between different inoculums. The reactors inoculated with CD and PGD have shorter lag time and achieved higher biogas production than reactors inoculated with PD, RD and GD.
- Highest methane production of 16 L/d was achieved in lowest HRT of 10 days was achieved in Lab scale ABBR with CD as inoculum. ABBR provides the favorable conditions for both the acidogens and methanogens to achieve their best. Phase II in ABBR provided good conditions for methanogens as like Upflow anaerobic sludge blanket process. Phase I increase the travelling length and improve the attached growth process to improve hydrolysis and acidogenesis. Pilot scale study confirmed the trend on VS reduction percentage and biogas production. In pilot scale study the maximum gas production yields was 0.58 m^3/ d.
- Therefore, the study concludes that the anaerobic digestion of food waste produces the energy valuable gas. According to the activity of the inoculum the amount of gas production and percentage of VS reduction varies. Adaptability of inoculum to the substrate enhances the degradation. The new reactor ABBR design for the anaerobic degradation of organic waste enhanced the degradation in continuous phase.

EXECUTIVE SUMMARY

Title of the project	Potential of Aerobic Digestion (Composting) and Anaerobic Digestion of Kitchen Waste
Sanction order no.	No. W.11035/07/2011-CRSP(R&D)
Principal Investigator	**Dr. Ajay Kalamdhad,** Associate Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati-791039
Implementation Institute	Indian Institute of Technology Guwahati, Guwahati-781039

1. INTRODUCTION

Municipal solid waste is causing major environmental problems in most of the Indian cities. The higher proportion of organic waste is the major cause for these environmental issues, predominantly emitting greenhouse gases and producing leachate in landfills and dumpsites. Many researchers and urban local bodies have recommended composting and anaerobic digestion of these organic fractions for the recycling of organic matter and nutrients to the environment. Eventhough low C/N ratio has been recommended for drum composting, leachate production has been reported from the organic waste composting. Addition of rice straw, dry leaves and sawdust were reported to provide proper aeration and porosity resulting in moisture control. But these materials are rich in lignocellulose composition normally resistant to microbial degradation and will take longer time for degradation. Therefore, the quality of final compost and duration for the process are of major concern to study upon. However, for anaerobic digestion of food waste with high VS content can improve the quantity and quality of biogas. Addition of effective inoculum is necessary in the reactors with the substrate to achieve higher biogas production.

Therefore, the present study involved the application of waste carbide sludge addition and white-rot fungi i.e. *Phanerochaete Chrysosporium* to increase the volatile solids reduction and lignocellulose degradation during drum composting of mixed organic waste. In addition, different composting methodologies i.e. drum composting; pile composting and vermicomposting were also compared with the best combinations for higher degradation of organic matter. In the case of anaerobic digestion, suitable inoculum can increase the degradation rate, enhance biogas production, shorten the starting time, and more stable digestion process. Studies were done on the basis of F/M ratio of different waste composition and different inoculums to attain the maximum gas production. The trials were done to find the proper F/M ratio for its higher growth. The study utilized the best livestock inoculum to attain

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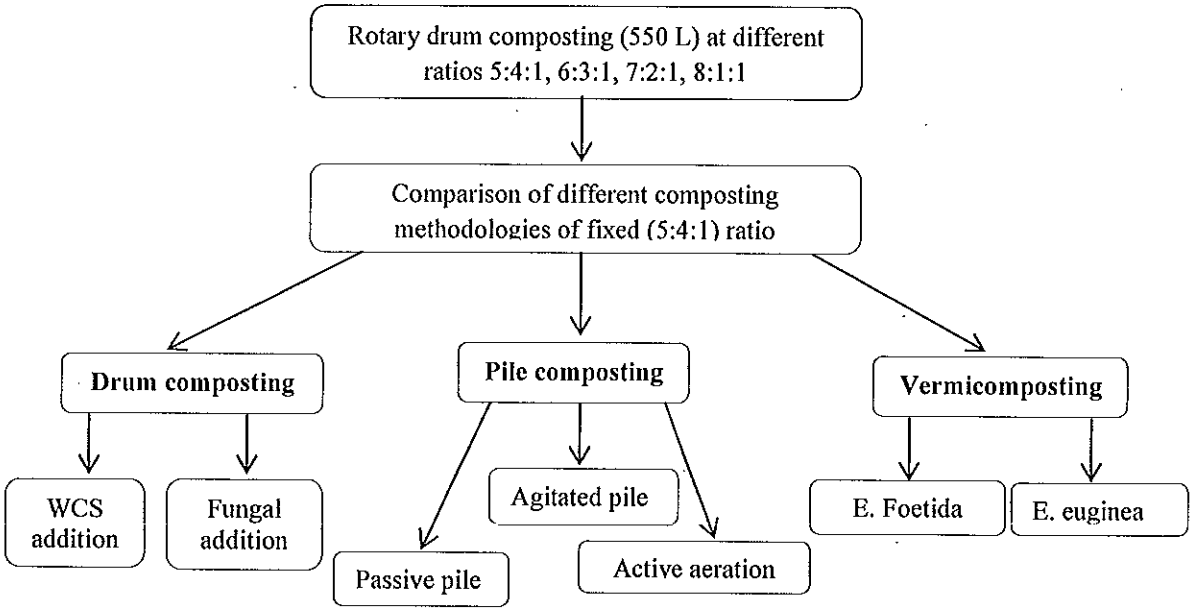

Fig. 1. Composting of vegetable waste

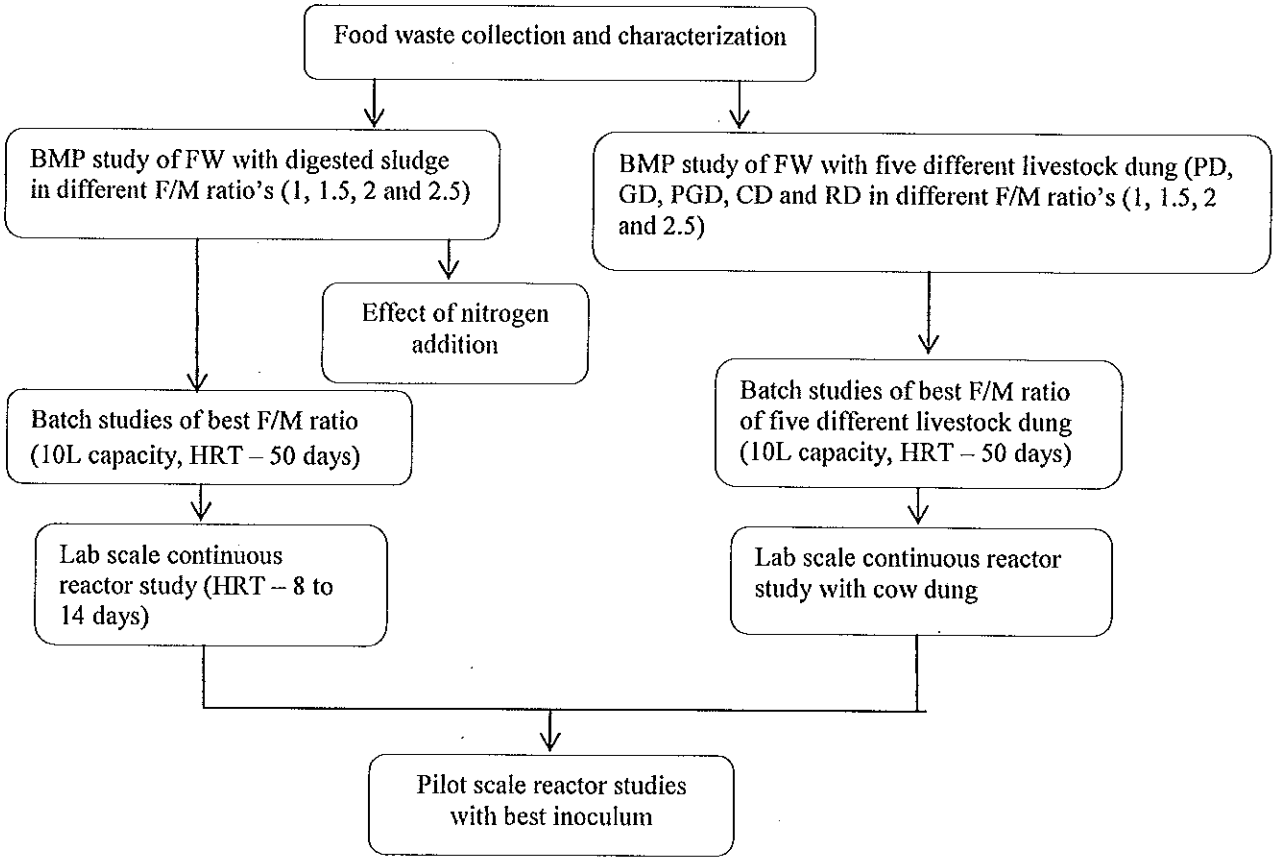

Fig. 2. Anaerobic digestion of food waste

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EXECUTIVE SUMMARY

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Sanction order no.	No. W.11035/07/2011-CRSP(R&D)
Principal Investigator	**Dr. Ajay Kalamdhad,** Associate Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati-791039
Implementation Institute	Indian Institute of Technology Guwahati, Guwahati-781039

1. INTRODUCTION

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2. EXPERIMETAL METHODOLOGY

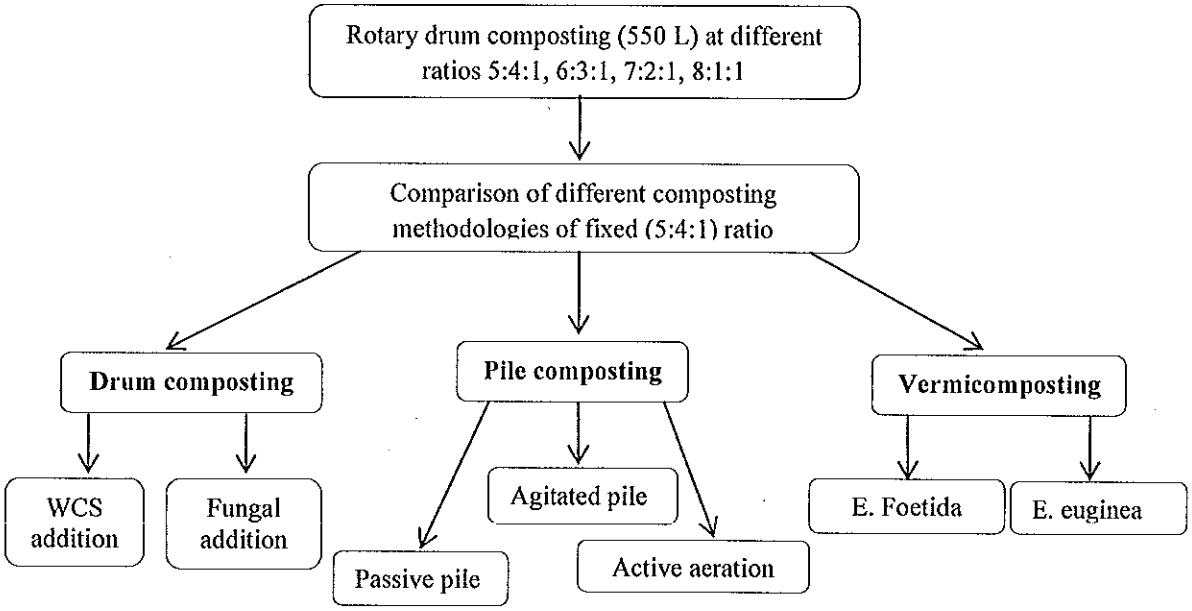

Fig. 1. Composting of vegetable waste

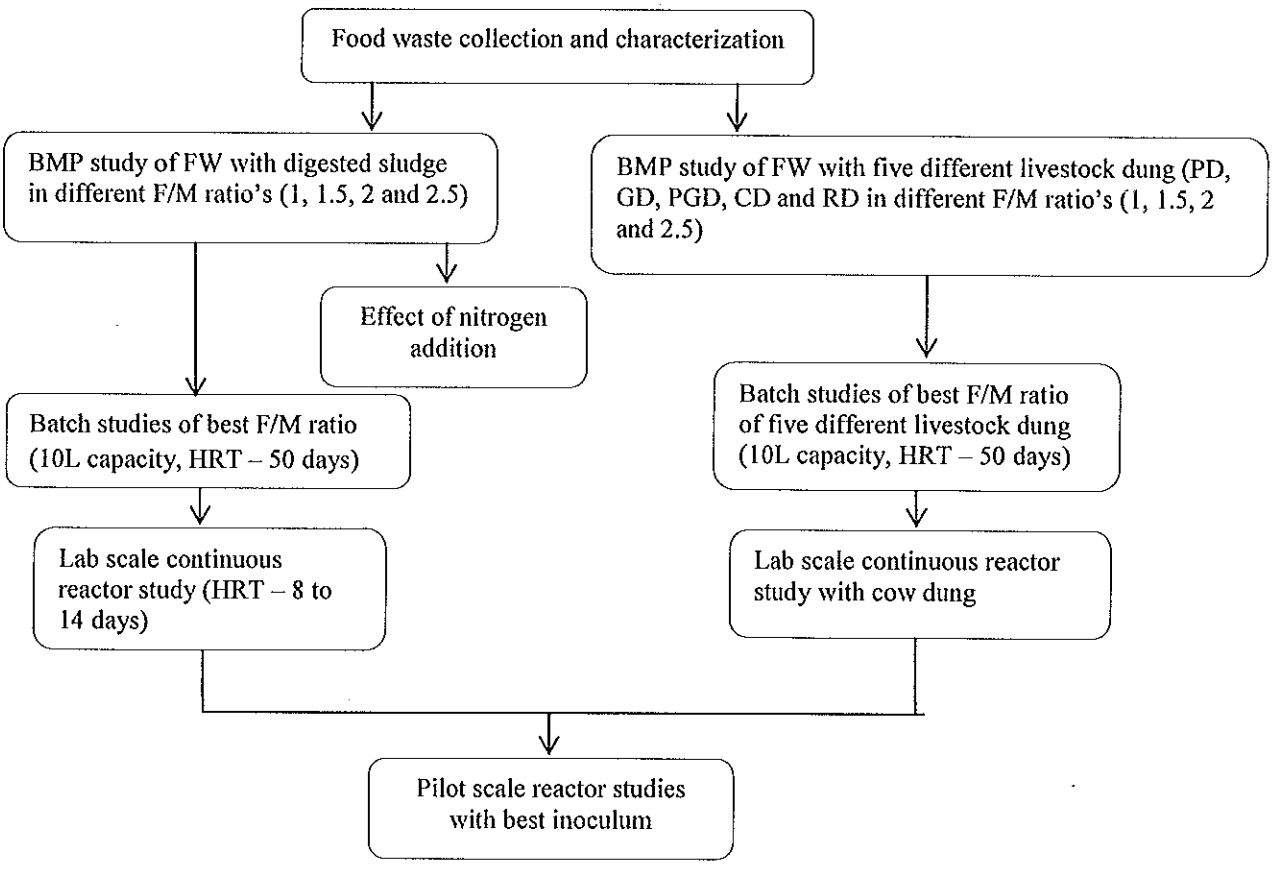

Fig. 2. Anaerobic digestion of food waste

3. OUTCOME OF THE RESAERCH WORK

3.1 COMPOSTING

- Rotary drum composting of vegetable waste was found successful with the combinations of cow dung, saw dust and dried leaves. A maximum of 66.4°C was observed in 5:4:1 ratio along with 10 kg addition of dried leaves (total 100 kg mass volume) and temperature level in the range of 55-62°C for 4-7 days leading to 11% VS reduction and higher destruction of pathogens within 20 days. Maximum degradation of organic matter was observed during day 2 to 8 of composting i.e. active thermophilic stage, followed by further stabilization. Insufficient addition of bulking agents during the process lead to the production of leachate thereby deteriorating the quality of compost. However, higher addition of bulking agents added more lignocellulose concentration to the process, which took longer time for further degradation.
- Vermicomposting of vegetable waste by using *E. fetida* was very effective as compared to *Eudrilus eugeniae*, without pretreatment of vegetable waste. Higher biomass production was observed during the 45 days of vermicomposting. Pretreating vegetable waste during the active thermophilic phase in rotary drum composter proved to be more beneficial for treatment in vermicomposting over direct utilization of vegetable waste using *E. fetida.* Higher loss of TOC and higher count of earthworm biomass was observed at the end of the process. The overall composting period was reduced to 28 days as compared to 45 days by pretreating the vegetable waste using drum composter followed by vermicomposting using *E. fetida.*
- Agitation, mixing and aeration of the composting materials was found crucial during pile composting of vegetable waste operated at agitated pile (AP), passive pile (PP) and forced aeration pile (FAP) condition. The degradation pattern of organic matter was completely different in comparison of all the three operated conditions. A maximum of 22.9% of reduction was observed in trial FAP followed by 19.6 and 9.4% in trial PP and AP trials respectively. Moreover, 50 to 60% of organic matter degradation was occurred within 9 days of the total composting period in all the trials during the active thermophilic phase.
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3.2 ANAEROBIC DIGETSION

- In Anaerobic BMP of FW with DS as inoculum, the highest of 59% VS reduction was observed in F/M ratio 2 maintained reactors with higher methane yield. The results concluded that only the requisite amount of food is mandatory for microorganisms to get better anaerobic digestion of FW neither more nor less to achieve higher methane yield.
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- Therefore, the study concludes that the anaerobic digestion of food waste produces the energy valuable gas. According to the activity of the inoculum the amount of gas production and percentage of VS reduction varies. Adaptability of inoculum to the substrate enhances the degradation. The new reactor ABBR design for the anaerobic degradation of organic waste enhanced the degradation in continuous phase.

EXECUTIVE SUMMARY

Title of the project	Potential of Aerobic Digestion (Composting) and Anaerobic Digestion of Kitchen Waste
Sanction order no.	No. W.11035/07/2011-CRSP(R&D)
Principal Investigator	**Dr. Ajay Kalamdhad,** Associate Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati-791039
Implementation Institute	Indian Institute of Technology Guwahati, Guwahati-781039

1. INTRODUCTION

Municipal solid waste is causing major environmental problems in most of the Indian cities. The higher proportion of organic waste is the major cause for these environmental issues, predominantly emitting greenhouse gases and producing leachate in landfills and dumpsites. Many researchers and urban local bodies have recommended composting and anaerobic digestion of these organic fractions for the recycling of organic matter and nutrients to the environment. Eventhough low C/N ratio has been recommended for drum composting, leachate production has been reported from the organic waste composting. Addition of rice straw, dry leaves and sawdust were reported to provide proper aeration and porosity resulting in moisture control. But these materials are rich in lignocellulose composition normally resistant to microbial degradation and will take longer time for degradation. Therefore, the quality of final compost and duration for the process are of major concern to study upon. However, for anaerobic digestion of food waste with high VS content can improve the quantity and quality of biogas. Addition of effective inoculum is necessary in the reactors with the substrate to achieve higher biogas production.

Therefore, the present study involved the application of waste carbide sludge addition and white-rot fungi i.e. *Phanerochaete Chrysosporium* to increase the volatile solids reduction and lignocellulose degradation during drum composting of mixed organic waste. In addition, different composting methodologies i.e. drum composting; pile composting and vermicomposting were also compared with the best combinations for higher degradation of organic matter. In the case of anaerobic digestion, suitable inoculum can increase the degradation rate, enhance biogas production, shorten the starting time, and more stable digestion process. Studies were done on the basis of F/M ratio of different waste composition and different inoculums to attain the maximum gas production. The trials were done to find the proper F/M ratio for its higher growth. The study utilized the best livestock inoculum to attain

higher methane yield from the FW at different F/M ratio of five different livestock inoculum such as poultry dung (PD), goat dung (GD), cow dung (CD), piggery dung (PGD) and rhinoceros dung (RD). The best inoculum was tested in the batch reactors and lab scale continuous mode. Finally, pilot scale digester of 1.0 m^3 was fabricated and operated for its efficiency.

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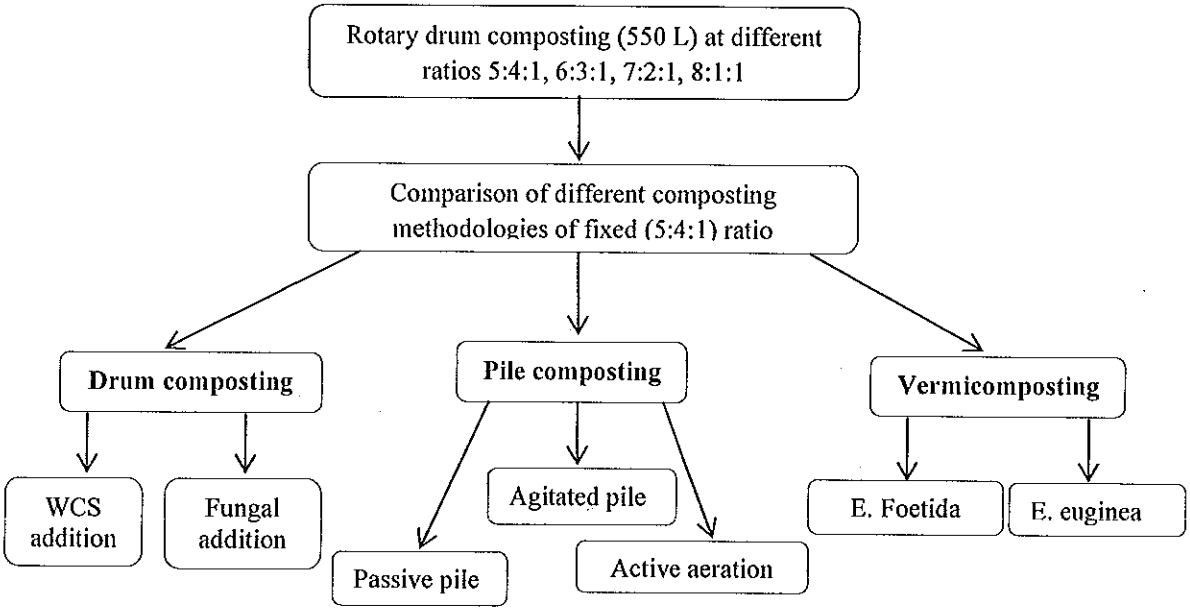
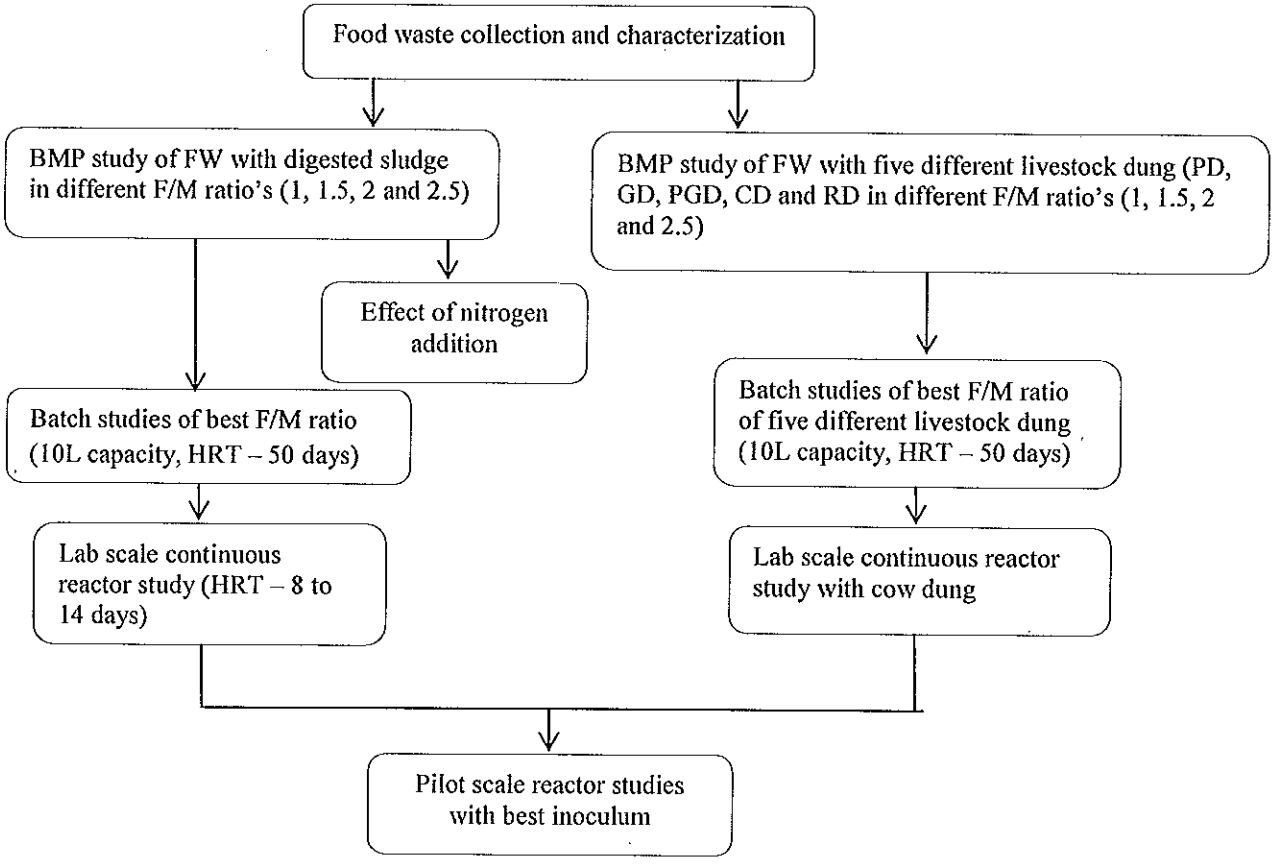


Fig. 1. Composting of vegetable waste



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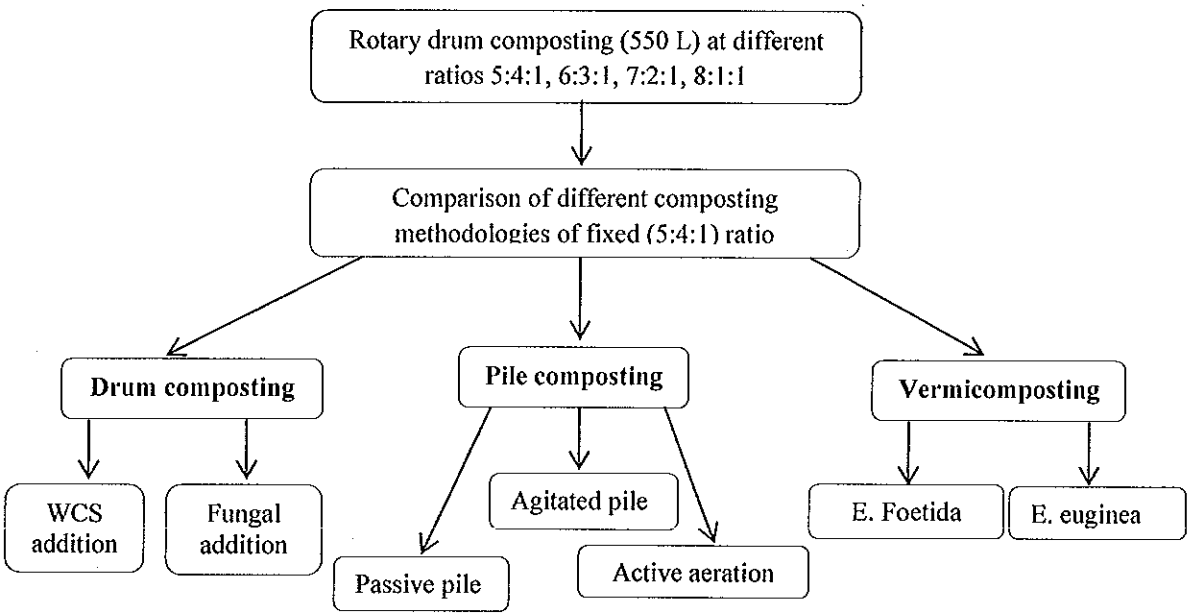

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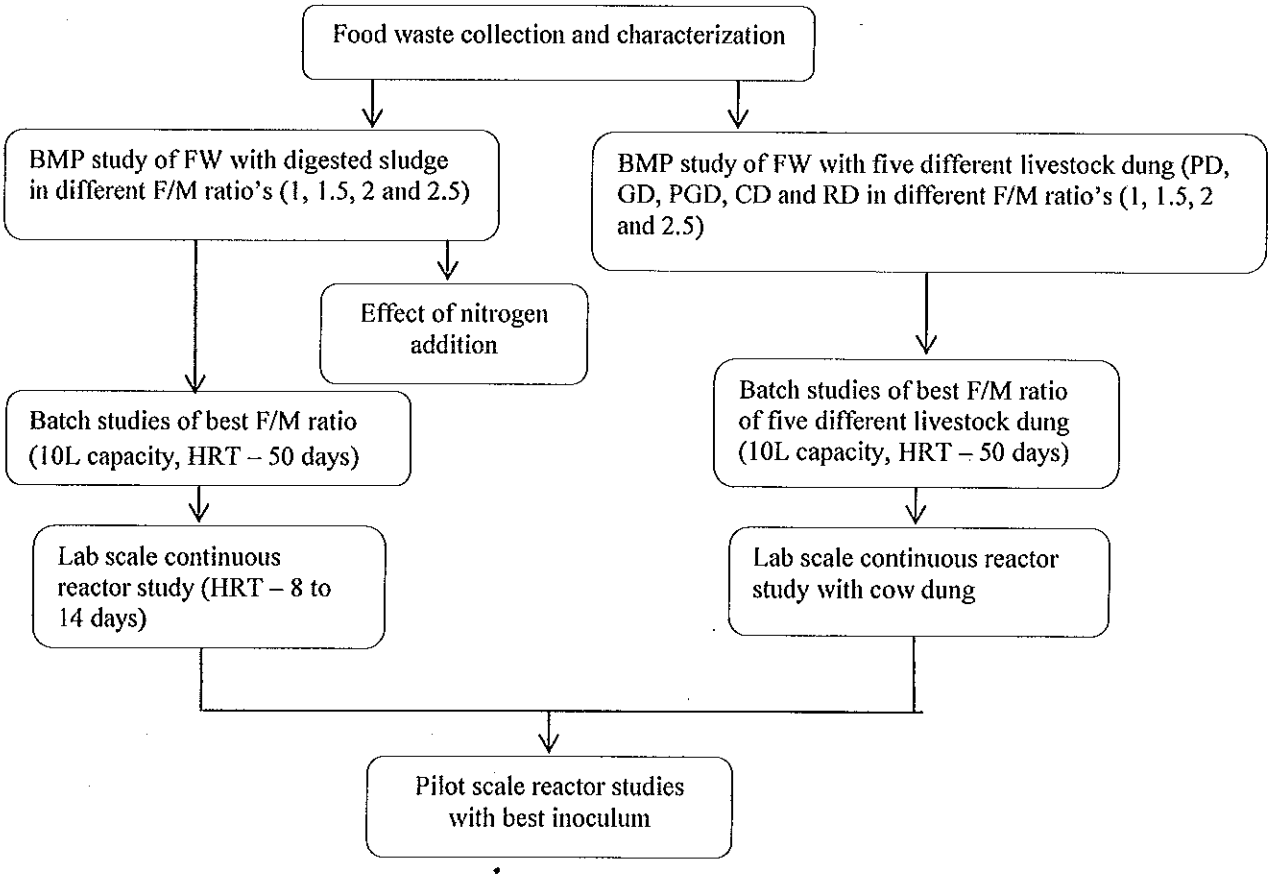

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