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A Novel Method for Kitchen Anaerobic and Aerobic Digestion

Organic Kitchen Waste Recycler

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Abstract— **The waste management has come into the major consideration across the globe .Huge amount of waste generated in kitchen is not properly utilized and dumped as landfills ,which in turn pollutes both air and land in vein .To provide a solution for this problem, KAD (Kitchen Anaerobic and Aerobic Digestor) - A Kitchen waste recycler is designed by conceptualizing an Digestor and a Composter to give by- products of manure and Bio gas in mini scale ,but by proliferation making it large amounts . KAD is to be placed in Kitchen itself under the existing Sink space, also designed for inodorous. The by-products, i.e. Biogas can be collected and used as a temporary substitute for LPG and manure collected can be used for Gardening purposes .Hence effectively utilizing the kitchen waste by encouraging Zero Kitchen waste concept and a Green Environment.**

Keywords- *Zero waste; waste management; Waste utilization; kitchen Digestor,Composter*

I. INTRODUCTION

A lot of waste is generated from each household in the form of solid waste, sludge that are disposed improperly. Municipal Solid Waste (MSW) of Chennai city was taken up for field investigation on waste collection, segregation, questionnaire survey face-to-face interviews were employed among the residents for this study. Municipal Solid Waste (MSW) was collected, segregated and weighted with the help of Hand in Hand - A Non-Government Organization (NGO) .Household waste was classified into eight categories viz., Organic matter/food waste, Paper and Cardboard, plastics, glasses, foot wares, cloths, and metals and miscellaneous. The study concluded that total amount of waste generation arrived with the available dataset was about 1632 kg/month. Among the classes Organic matter/food waste was highest (54.18%); miscellaneous (18.81%) and metals (0.40%). Waste generated from plastics resulted to (11.71%) and from footwear (1.01%) and Methane and N2O emission from landfill was of 1.24 Kg/yr and 760 Kg/yr. Results of this study established waste disposed during weekend period was relatively higher than weekdays. Proportion of waste like glasses, clothes, Paper and Cardboard and Card Board and foot wares are higher during weekends and low during weekdays. An appropriate planning of waste management has to be inculcated among the residents of Chennai for a sustainable solid waste management.

Primary data collection covering 100 peoples which were selected randomly. Data were analyzed according to the descriptive statistics. Different organic wastes comprising plant and animal constituents such as vegetable waste- lady's finger, Brinjal, Radish, Beans carrot, chow-chow, beetroot, clustered beans, snake gourd, tomatoes, egg shell, feather, skin etc. The results also showed that 58% of the households were not aware of waste recycling, reuse & reduction.

Form this we can conclude that, there is a lot of waste which is being generated in the house holds which is not being managed properly and simply being dumped into landfills.

Another article says that 1.3lakh metric tonnes of waste is being generated in cities and towns everyday out of which 0.91 lakh metric tonnes (68%) is being collected and 0.42 lakh metric tonnes (32%) is being littered by houses alone , then consider the amount of waste generated in markets, hotels , and other urban areas.

Trying the find out a solution for this, we started working and came up with a idea of utilizing this house hold organic waste into an effective useful source which will be in the form of Bio Gas and the end product to get useful manure for gardening purposes.

II. LITERATURE SURVEY

Generation of methane via anaerobic process is an appropriate solution for food waste management. The process has lesser cost and low residual waste production and utilization of food waste as renewable source of energy

Degradability of food waste used as substrate mainly depends upon its chemical composition. It is quite challenging to know the exact percentage of different components of the complex substrate because of its heterogeneous nature. Various researchers have investigated the potential of food waste as a substrate for biomethanation. Viturtia et al. [1] inspected two stages of anaerobic digestion of fruit and vegetable wastes and achieved 95.1% volatile solids (VS) conversion with a methane yield of 530 mL/g VS. In a study performed by Lee et al. [2], FW was converted into methane using a 5-L continuous digester, resulting in 70% VS conversion with a methane yield of 440 mL/g VS. Gunaseelan [3] used around 54 different types of food and reported methane yield ranged from 180 to 732 mL/g VS depending on the origin of wastes. Cho et al. [4] reported 472 ml/g VS methane yield with 86% anaerobic biodegradability of the Korean food waste. Yong et al. [5] have reported 0.392 m3 CH4/kg-VS when canteen food waste mixed with straw in the ratio of 5 : 1. Food waste as a substrate has potential to provide high biogas yield in comparison to cow manure, whey, pig manure, corn silage, and so forth [6].

For anaerobes to work with high metabolic activity, it is imperative to have controlled environmental conditions. The methanogenic bacteria are very sensitive towards unfavorable survival conditions. Therefore, it is vital to maintain optimal condition to flourish the process of methanation. Bio-methanation process primarily depends upon seeding, temperature, pH, carbon-nitrogen (C/N) ratio, volatile fatty acids (VFAs), organic loading rate (OLR), alkalinity, total volatile solids (VS), and hydraulic retention time (HRT) and nutrients concentration. It was also reported that the concentrations of water soluble material such as sugar, amino acids, protein, and minerals decrease and water non soluble materials such as lignin, cellulose, and hemicellulose increase in content [7].

TABLE 2.1 THE VARIOUS REACTIONS AND THE END PRODUCTS OBTAINED

REACTION TYPE	MICRO-ORGANISM	ACTIVE GENERA	PRODUCT
Fermentation	Hydrolytic bacteria	Bacteroides, Lactobacillus, Propionibacterium, Sphingomonas, Sporobacterium, Megasphaera, Bifidobacterium	Simple sugars, peptides, fatty acids
Acidogenesis	Syntropic bacteria	Ruminococcus, Paenibacillus, Clostridium	Volatile fatty acids
Acetogenesis	Acetogenic bacteria	Desulfovibrio, Aminobacterium, Acidaminococcus	CH_3COOH
Methanogenesis	Methanogens (Archaea)	Methanosaeta, Methanolobus, Methanococcoides, Methanohalophilus, Methanosalsus, Methanohalobium, Halomethanococcus,	CH_4

A. *Optimum Conditions Required*

In an experiment performed by Gou et al. [8] co-digestion of waste activated sludge with food waste was reported to have highest gas production rate at 55°C which was 1.6 and 1.3 times higher than the gas production at 35°C and 45°C. The pH of bioreactor affects the microbial activity in anaerobic digestion and its efficiency. Wang et al. [9] reported that optimum pH range is 6.3–7.8. Initially due to excess of carbon dioxide, pH drops to 6.2 and after 10 days it starts rising and stabilizes between 7 and 8. Also, Lee et al. [10] indicated that optimum range of methanogenesis using food waste leachate was 6.5–8.2. The main reasons for pH variation are VFAs, bicarbonate concentration, and alkalinity of the system. Goel et al. [11] used NaOH and $NaHCO_3$ for controlling pH in anaerobic digestion used for bio methanation from food waste.

Mittal [12] has reported that digestion of substrate will proceed more rapidly if the C/N ratio would be 25–30 : 1. This leads to a conclusion that bacterial community use up carbon 25–30 times faster than nitrogen. If the ratio is not adequate, the nitrogen would get exhausted while there would be some carbon left which will cause bacteria to die. Excess of nitrogen would lead to ammonia formation which will inhibit the digestion process. In another study performed by Zeshan et al. [13], anaerobic digestion performed well at C/N ratio of 27. An optimum amount of carbon content was having positive effect on avoiding excessive ammonia inhibition [14].

Biodegradation of protein or other nitrogen-rich substrate produces ammonia and exists in the form of ammonium ion (NH_4^+) and NH_3 [15]. It could be beneficial for the growth of microbes or sometime have detrimental effect on them [16,17]. Ammonia plays a vital role in C/N ratio and could affect the performance of digestion process [18]. The reaction between ammonia and VFAs have been reported by Zhang et al. [19] and are as follows:

$$C_xH_yCOOH \rightleftharpoons C_xH_yCOO^- + H^+$$

$$NH_3.H_2O \rightleftharpoons NH_4^+ + OH^-$$

$$C_xH_yCOOH + NH_3 \,.\, H_2O \longrightarrow C_xH_yCOO^- + NH_4^+ + H_2O$$

Microbes use carbon to fulfil energy requirement and nitrogen for building cell wall structure. In addition, microbes also need small quantity of micro nutrient [20] such as calcium, sodium, potassium, magnesium, and chlorine. Also, for enzyme synthesis and for maintaining enzyme activity, heavy metal ions such as Cr, Co, Cu, Zn, and Ni are required in biomethanation [21]. Effect of concentration of sodium, potassium, and calcium was observed during anaerobic digestion activity.

B. *Biochemical Methane Potential (BMP)*

In an experiment performed for mixed food waste like boiled rice, cabbage, and cooked meat which were digested with cellulose as control has manifested greater rate of production of methane which is about 472 ml/g VS with total reduction in VS up to 86% [22].

In another study performed on canteen waste mixed with straw in different ratios, BMP for food waste and straw was 0.26 and 0.16 m^3 CH_4/kg-VS, respectively, which shows that food waste is easily biodegradable waste while the straw was difficult to degrade anaerobically which may be due to presence of lignin [23].

Digesting food and vegetables anaerobically yielded methane with a minimum amount of 0.3 L/g VS in every sample which also incorporate as commercial value for anaerobic digestion [24]. In an experiment conducted by Elbeshbishy et al. [25], pre-incubated seed sludge has been used along with running seed sludge for BMP test of food waste along with primary sludge. The maximum methane production rates using non-incubated inoculum were higher (114 mL $CH_4{}^{-g}$ $TCOD_{sub}$) than those using pre-incubated inoculum at all substrate-to-inoculum ratios. Lisboa and Lansing [26] co-digested four food waste substrates (meatball, chicken, cranberry, and ice cream processing wastes) for 69 days with flushed dairy manure and have reported an increase in methane production.

Biogas potential of the dry fraction from pretreatment of food waste from households has been evaluated by Murto et al. [27]. A higher methane yield (152 ± 22 m^3/ton) was obtained from digestion of the dry fraction alone. Dry fraction mixed with structural material produced lower levels of biogas (112 ± 21 m^3/ton) compared to digestion of dry fraction alone.

Autoclaved and untreated food waste BMP assay was performed by Tampio et al. [28]. Food waste was autoclaved at 1600°C, 6.2 bar. It has been reported that methane yield at all the loading rates (2, 3, 4, and 6 kg-VS/m^3/d) was 5–10% higher for untreated food waste which was 0.483 m^3 CH_4/kg VS as compared to 0.439 m^3 CH_4/kg VS obtained from autoclaved food waste.

C. *Pretreatment Methods for Food Waste*

Anaerobic digestion is now widely embraced to manage solid waste and energy recovery. Pretreatment technologies like mechanical, thermal, chemical, and biological ones may be applied prior to anaerobic digestion to reduce the crystallinity and enhance the production of methane using wasted food. Research is earlier carried out to investigate the effect of different pretreatment methods on anaerobic digestion of food waste. Microwave pretreatment of food waste, with intensity of 7.8°C/min, resulted in enhanced biogas production and about 6% and 24% higher COD solubilisation [29]. In another study done by Izumi et al. [30], 28% higher biogas production was obtained using food waste when it is treated with beads mill. Ma et al. [31] has used different pretreatment techniques to kitchen waste.

D. *Co-Digestion Of Food Waste With Other Organic Substrates*

Feedstock	Action of co- digestion	Influencing factor
Food Waste + CM	Improve methane yield and system stability	High buffering capacity and trace elements supplement
Food Waste + livestock waste	Improve methane yield and VS reduction	Higher buffering capacity
Food Waste + yard waste	Improve methane yield	Less VFA accumulation
Food Waste + dewatered sludge	Enhance system stability	Less inhibition from Na^+
Food Waste + sewage sludge	Afford high organic loading rate	High buffering capacity from ammonia
Food Waste + green waste	Improve VS reduction	C/N ratio
Food Waste + brown water	Improve methane yield	High buffering capacity
Food Waste + press water	Improved system stability and methane yield	High buffering capacity
Food Waste + distiller's grain	Improved biogas production	High buffering capacity from ammonia

TABLE 2.2 *SUMMARY OF CO-DIGESTION OF FOOD WASTE WITH OTHER ORGANIC SUBSTRATES FOR IMPROVING PERFORMANCE OF ANAEROBIC PROCESS.*

III. METHODOLOGY

A. FLOW CHART OF VARIOUS PROCESSES INVOLVED

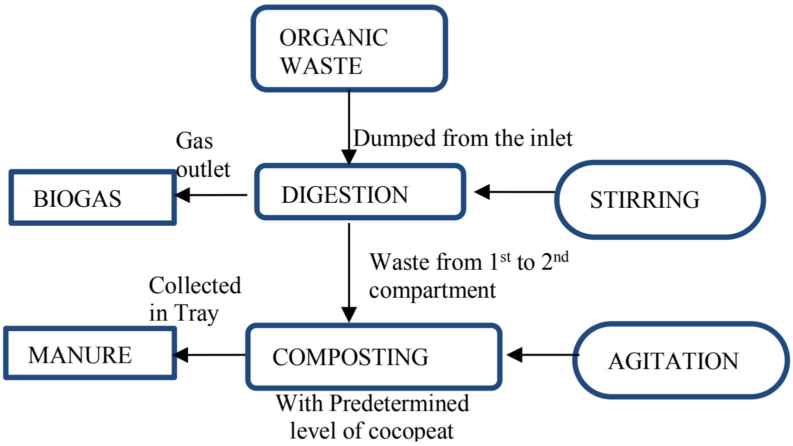

FIG 3.1 FLOW CHART

Explanation

The kitchen waste in dumped through the inlet and the inlet is sealed. In the 1st compartment the waste is let to settle and anaerobic digestion will take place, making it produce methane. The methane is sucked through a vacuum pump and stored externally.

Once the 1st compartment filled, an slider is moved to drop the waste from the 1st to the 2nd compartment. There will be a predetermined level of cocopeat , above which the waste is get collected in the 2nd compartment.

Using an agitator it is mixed with cocopeat and crushed properly. The door is opened and the entire manure is collected with the help of a tray attached below.

B. *Octopus Diagram*

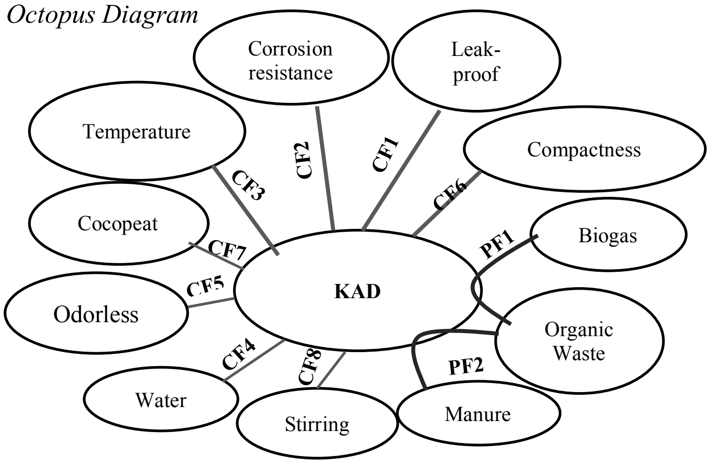

Fig 3.3 *Octopus Diagram*

PF1 –To produce biogas from the organic waste dumped
PF2 – To convert the organic waste into manure
CF1 – It must be leak-proof
CF2 – It must be corrosion resistant
CF3 – The temperature should be maintained from 30 to 60 for efficient decomposition of organic waste

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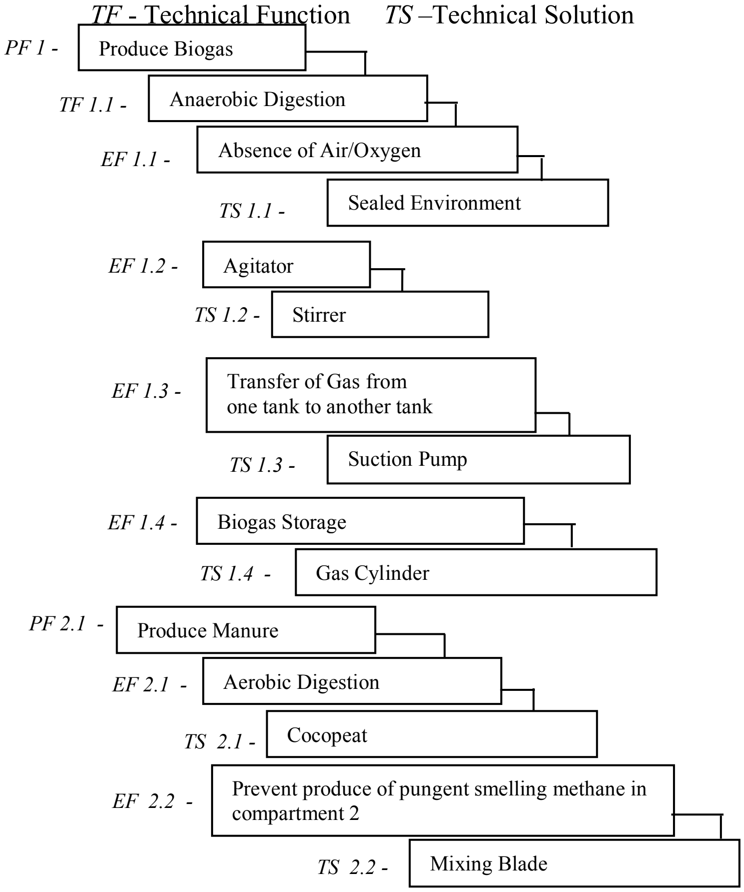
CF4 – Water input for decomposition should be accurate
CF5 – The odor should be eliminated
CF6 –Should fit under the kitchen sink
CF7 – Helps in fast decomposition rates
CF8 – Resists the formation of fungus

C. *FAST diagram*

PF - Primary Function   *EF* - Elementary Function
TF - Technical Function   *TS* –Technical Solution



E. SELECTION OF TECHNICAL SOLUTIONS

P.F. 1 – PRODUCE BIOGAS

T.S 1.1 – SEALED ENVIRONMENT : Poly methyl methacrylate(PMMA)is a transparent thermoplastic often used in sheet form as a lightweight or shatter-resistant alternative to glass. Use of Acrylic sheet as the foundation of our model including the base and walls. Acrylic sheets of various sizes (5mm,6mm& 10mm)

T.S 1.2 – STIRRER : A stirrer of similar blade design is made on nylon in correspondence to being non corrosive and economical. The stirrer helps in agitating the methane promotion in the compartment.

T.S 1.3 – SUCTION PUMP : This Suction pump helps in sucking out all the methane that is formed into a separate container that stores the methane gas that is produced.

P.F. 2 – PRODUCE MANURE

T.S 2.1 – COCOPEAT: Cocopeat is an catalytic agent which increases the rate of digestion in the aerobic digester (compartment 2) .

T.S 2.2 - MIXER BLADE: The mixer blade continuously grinds the mixture preventing the formation of methane and produce manure.

F. WORKING PRINCIPLE

1. ANAEROBIC DIGESTION

Anaerobic digestion is the process by which organic matter such as animal or food waste is broken down to produce biogas and bio-fertilizer. This process happens in the absence of oxygen in a sealed, oxygen-free tank called an anaerobic digester.

Anaerobic digestion is a series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen[32]. One of the end products is biogas, which is combusted to generate electricity and heat, or can be processed into renewable natural gas and transportation fuels.

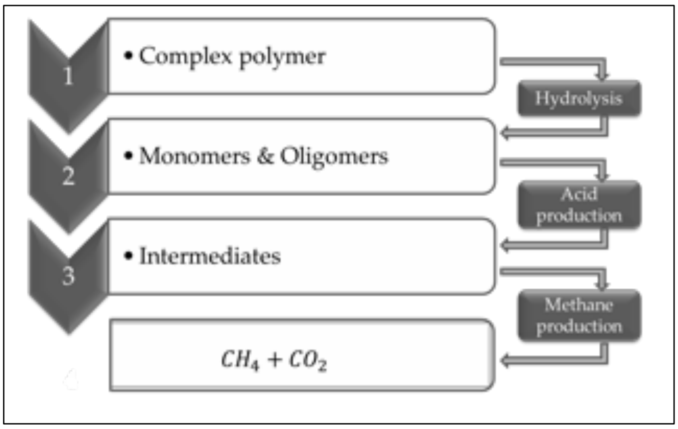


FIG 3.10 PROCESS INVOLVED ANAEROBIC DIGESTION

Anaerobic digestion consists broadly of three phases, namely, enzymatic hydrolysis, acid formation, and gas production. The below diagram depicts the digestion process.

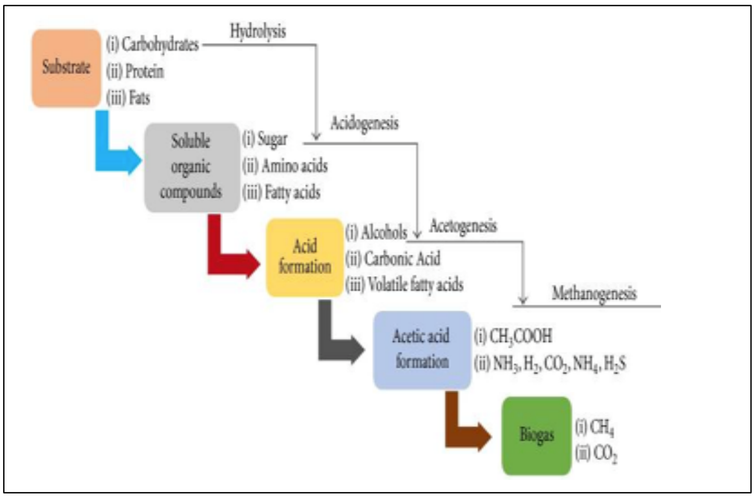


FIG 3.11 VARIOUS BY-PRODUCTS OBTAINED

2. AEROBIC DIGESTION

Aerobic Digestion offers a totally self-contained, continual feed, organic food waste disposal system designed to biologically convert solid food waste materials into manure. The main function of digester is to accelerate the process of natural decomposition by maintaining optimal levels of aeration, moisture and temperature. Under these controlled conditions, the microorganisms decompose organic waste efficiently at a much faster than the natural decay rate. It is a continuous process where microbes play the most important role in the elimination of waste[33]. Different microbes produce different enzymes these enzymes are catalysts for proteins responsible for metabolism of organic waste.

This digester is developed to revolutionize the disposal of organic waste, based on the principle that waste should be treated in the place where it's originate it. It allows you to have full control when handling organic waste on site where it is generated without relying on a third party. The digester works automatically, the customer only needs to feed the organic waste through the door. Using the wastewater treatment plant of the city, county, state, etc. , you can close the cycle of recycling organic waste onsite.

G. OVERALL WORKING OF THE DIGESTOR

In our model, the organic waste is dumped into the Compartment 1 on the top, through a sliding door opening. Here Anaerobic digestion takes place in the absence of air/oxygen thereby decomposing the organic kitchen waste into a thick and dense substance with spontaneous emission of methane gas which is later collected in a separate tank using a pump. This pump is capable of suction of up to 500L/min.

Once the Compartment 1 is filled, a small slab is present exactly between compartment 1 and compartment 2, which on opening , releases the contents of compartment 1 straight into compartment 2. In Compartment 2, a mixer blade continuously mixes the contents. This action prevents the production of methane in this compartment. Hence it makes it odorless. There is a small door in the front side of the model through which the manure that is formed can be collected.

IV EXPERIMENTAL DESIGN

A. PROBLEM STATEMENT

Organic Garbage = Air Pollution. Air pollution may seem an unlikely consequence of landfills, but in fact it is a major problem. The primary culprit is anything organic such as yards and food waste. When organic materials decompose in such anaerobic conditions they produce methane, a greenhouse gas. Burying organic waste in landfill is a big problem and it's not just because of the resources we lose. When organic waste is dumped in landfill, it undergoes anaerobic decomposition (because of the lack of oxygen) and generates methane. When released into the atmosphere, methane is 25 times more potent a greenhouse gas than carbon dioxide. Methane is, however, also a valuable resource. The natural gas piped into our homes is primarily methane.
Organic waste can also be treated to make compost and soil conditioning products, as many people do in their backyards and gardens. India faces the same problem of more generation of organic waste most in metropolitan cities such as Delhi, Mumbai, Chennai, Kolkata, Hyderabad, etc.

B. *EXPERIMENTS CONDUCTED*

1. EXPERIMENT 1: (DIGESTION)

Aim: To determine the rate of decomposition by anaerobic digestion without stirring

Materials Used: 3 Kg waste, 3 pots, Measurement Jar, Weight Scale, Stirrer
Duration: 2 weeks

Procedure:
The three pots were filled with 1 kg of kitchen waste. Pot 1 was filled with 750 ml of water forming a slurry mixture, Pot 2 was filled with 500 ml of water and Pot 3 was filled with 250ml of water. All the three pot were given constant stirring twice a day for a week.
Pot 1 was filled with 750 ml of water forming a slurry mixture, Pot 2 was filled with 500 ml of water and Pot 3 was filled with 250ml of water. All the three pots were **not stirred** and left to decompose.

Observation:
Instead of decomposition and creating methane, Web typed fungus was formed on the topmost surface and it started to decay. Which is not suitable for anaerobic digestion.

Results:
Hence the experiment was conducted and it was found stirring plays an important role for good decomposition and continuous release of methane gas.

TABLE 4.1 OBSERVATION FOR EXPERIMENT 1

Pot No.	Kitchen Waste in Kg	Water in ml	Stirring	Remark
1	1	750	No	Decay of Kitchen waste within 3-4 days
2	1	500	No	Decay of Kitchen waste within 7 days
3	1	250	No	Decay of Kitchen waste within 10 days

FIG 4.1 FORMATION OF FUNGUS

Note : Formation of webbed fungal algae is not suitable for biogas generation, rather it rots the waste .

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2. EXPERIMENT 2: (DIGESTION)

Aim: To determine the rate of decomposition by anaerobic digestion with varying levels of water input.

Materials Used: 3 Kg waste, 3 pots, Measurement Jar, Weight Scale, Stirrer

Procedure:

The three pots were filled with 1 kg of kitchen waste. Pot 1 was filled with 750 ml of water forming a slurry mixture, Pot 2 was filled with 500 ml of water and Pot 3 was filled with 250ml of water.

All the three pot were given constant stirring twice a day for a week. Pot 1 was filled with 750 ml of water forming a slurry mixture, Pot 2 was filled with 500 ml of water and Pot 3 was filled with 250ml of water. All the three pot were given constant stirring twice a day for two week.

Observation:

Pot1 with 750 ml of water was observed that methane was formed after 10 days while the mixture has digested due to the presence of high amount of moisture content in the mixture. Pot 2 that was filed with 500 ml of water was observed that methane was formed after 7 days with digestion of the kitchen waste. Pot 3 that was initially given 250 ml of water had sustained its state undergoing complete digestion. Thus leading to the formation of pungent smelling gas (methane) in optimum conditions.

Result:

Thus indicating the optimal quantity of water required (250 ml or lesser) for the decomposition process to take place thus leading to the formation of methane over a long time period under constant stirring.

TABLE 4.2 OBSERVATION FOR EXPERIMENT 2

Pot No.	Kitchen Waste in Kg	Water in ml	Stir Per Day	Remark	Reason
1	1	750	Twice	Formation of methane after 10 days	Improper slurry formation
2	1	500	Twice	Formation of methane after 7 days	Improper slurry formation
3	1	250	Twice	Formation of methane within 5 days	Optimum slurry formation

****Slurry refers to the right consistency mixture of water and Kitchen waste.***

3. EXPERIMENT 3: (COMPOST)

Aim: To determine the influence of catalyst (COCOPEAT) in the composting process.

Materials Used: Pot 1,Pot 2, Pot 3,Pot 4, Pot 5, Pot 6, 3 Kg Kitchen Waste, Cocopeat.

Procedure:

The six pots were filled with 1 kg of kitchen waste. All the six pots were given fixed amount of water (250ml).

Pot 1 was filled with 500 g of cocopeat , Pot 2 was filled with 250 g of cocopeat and Pot 3 filled with 100 g of cocopeat.

Pot 1,2 and 3 are not agitated while Pots 4,5 and 6 are constantly agitated

FIG 4.3 POTS UNDER EXPERIMENT 3

Observation:

Pot No.	Kitchen Waste In Kg	Water in ml	Agitation	Cocopeat in gms	Remark	Reason
1	1	250	No	500	Improper compost	Lack of agitation
2	1	250	No	250	Improper compost	Lack of agitation
3	1	250	No	100	Improper compost	Lack of agitation
4	1	250	Yes	500	Proper compost	Good quality of manure
5	1	250	Yes	250	Proper compost	Good quality of manure
6	1	250	Yes	100	Proper compost	Moderate quality of manure

TABLE 4.3 *OBSERVATION FOR EXPERIMENT 3*

4. DESIGN

A. SOLID MODELING

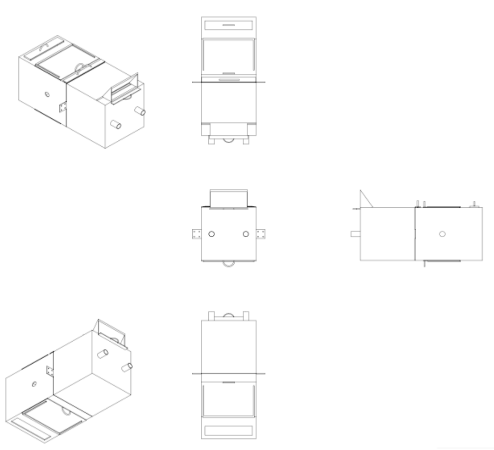


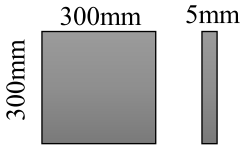
FIG 4.4 Combined Compartment 2D sketch

B. DESIGN SPECIFICATIONS

Compartment 1 Wall :

Material: **Acrylic Sheet**

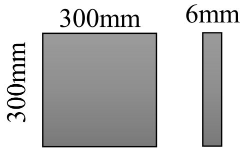
Thickness = 5mm



- **Compartment 2 Wall :**

  Material: **Acrylic Sheet**

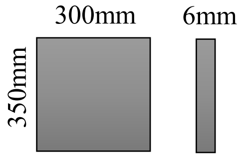
  Thickness = 6mm



- **Slab :**

  Material: **Acrylic Sheet**

  Thickness = 6mm



- **Stirrer :**

  Material: **Nylon**

  Outer Diameter = 12.7mm

- **Mixer Shaft :**

  Material: **Nylon**

  Outer Diameter =40mm

- **Bearings (Mixer blade) :**

  Inner Diameter = 12.7mm

- **Fittings**

  Material: Plastic

Blade Profile :

Material: **Acrylic Sheet**

Thickness: 5mm

Hose :

Material: Plastic

Pump

Voltage: 12V

Discharge: 500 L/min

C. FABRICATION

1. DIFFERENT PROCESSES INVOLVED

TABLE 4.4 COMPLETE FABRICATION PROCESS

S. No	Machining Process	Machine used	Tools Used	Explanation
1	Acrylic Sheet Cutting	Jig Saw Machine	Saw Blade	Proper fixture to cut in straight lines
2	Shafts	Lathe Machine	White bit tool	To have enough sharpness and less Heat Affected Zones (HAZ)
3	Slots on Mixer Blade	Milling Machine	Carbide tool	To cut straight and equally spaced
4	Slots on Agitator	Milling Machine	Carbide tool	To cut straight and equally spaced
5	Dowel pins	Tapping	Tapping tool	To pierce the sub screws into the shafts
6	Agitator Blades	Angle Grinder	Buff Tool and Cutting disc	To get sharpness to blade edges
7	Binding of two acrylic sheets	Anabond /Araldite		It should be applied carefully with usage of proper fixture and application of uniform pressure
8	Water Sealant	Silicone Paste	-	To make the edges water sealant
9	Air Sealant	Rubber Pading	-	To make the compartments air tight

Note : *Computerized machining by laser can also be used to cut acrylic sheets , but cost is high .*

D. MECHANISM INVOLVED

1. ENZYMATIC HYDROLYSIS

In the first phase, large polymer molecules that cannot be transported to cell membranes by microorganisms are broken down by hydrolases secreted by facultative or obligate anaerobic hydrolytic bacteria. Hydrolysis breaks down the polymers into oligomer or monomeric units. Polysaccharides are broken down into oligosaccharides and monosaccharides ; for example, represents production of glucose molecules by starch hydrolysis. Proteins are broken down into peptides and amino acids and lipids are converted into glycerol and fatty acid.

$$nC_6H_{10}O_5 + nH_2O \longrightarrow nC_6H_{12}O_6$$

In the anaerobic conditions, the hydrolysis rate is relatively slower than the rate of acid formation and depends on the nature of substrate, bacterial concentration, pH, and the temperature of the bioreactor. Other parameters such as size of the substrate particles, pH, production of enzymes, and adsorption of enzymes on the substrate particles also affect the hydrolysis rate. Streptococcus and Enterobacter are genera of anaerobes that are responsible for hydrolysis.

2. ACIDOGENESIS PHASE

In the second phase, acidogenesis takes place in which hydrolytic products are fermented to volatile fatty acids such as acetate, propionate, butyrate, valerate, and isobutyrate along with carbon dioxide, hydrogen, and ammonia. During acidification, facultative anaerobic bacteria utilize oxygen and carbon creating an anaerobic condition for methanogenesis. The monomers obtained in phase one become substrates for the microbes in phase two where the substrates are converted into organic acids by a group of bacteria.

Acetate, hydrogen, and carbon dioxide can be utilized directly for methane production. However, propionate, butyrate, valerate, and isobutyrate are introduced for further degradation by syntrophic acetogenic bacteria to form acetate and hydrogen.

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3. ACETOGENESIS

Acetogenic bacteria belonging to genera Syntrophomonas and Syntrophobacter convert the acid phase products into acetates and hydrogen. Few acetate molecules are also generated by reduction of carbon dioxide using hydrogen as an electron source. Acetates will further be utilized by methanogens in subsequent steps. However, hydrogen released in the process exerts inhibitory effect on microorganisms. Therefore, in anaerobic digesters, acetogenic bacteria live in syntrophic relationship with hydrogenotrophic methanogens that remove the hydrogen by utilizing it for methane formation. Also, acetogenesis is the phase, which depicts the efficiency of the biogas production because 70% of methane arises when acetate reduces. Simultaneously, 11% hydrogen is also formed during the process .

$$nC_6H_{12}O_6 \longrightarrow 3nCH_3COOH$$

4. METHANOGENESIS

In the last phase, methanogenesis takes place which is carried out by methanogens, belonging to Archaea. Methane can be produced either by fermentation of acetic acid or by reducing carbon dioxide. Therefore, the products of previous phase, that is, acetic acid, hydrogen, and carbon dioxide, act as a precursor for methane formation. Only 30% of methane produced in this process comes from carbon dioxide reduction carried out by methanogens .

$$CH_3COOH \longrightarrow CH_4 + CO_2$$

Methane can be generated in two ways by two types of methanogens
(a) acetoclastic methanogens that produce methane from acetic acid and

(b) hydrogenotrophic methanogens that utilize hydrogen to reduce carbon dioxide.

$$CO_2 + 4H_2 \longrightarrow CH_4 + 3H_2O$$

Co- digestion of waste activated sludge with food waste was reported to have highest gas production rate at 55°C which was 1.6 and 1.3 times higher than the gas production at 35°C and 45°C.

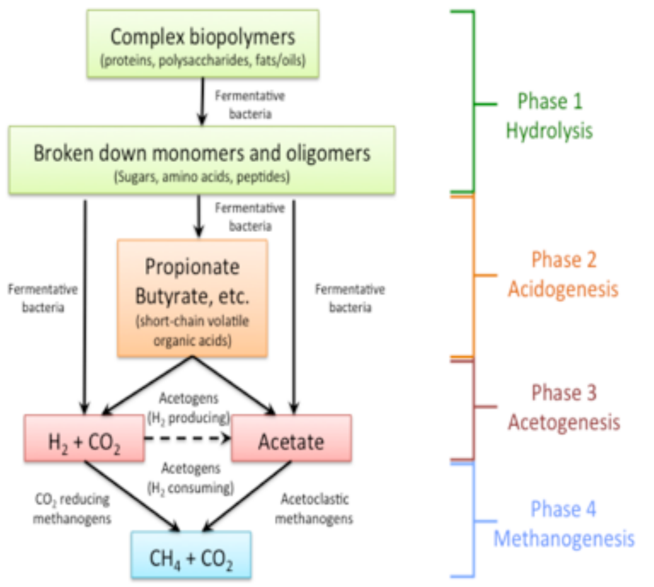

FIG 4.6 CHEMICAL REACTIONS

V . RESULTS AND DISCUSSIONS

The following were the findings of our experimentation analysis

- The generated gas was confirmed to be Bio-gas or Methane by using a gas sensor MQ4 is interfaced with an Arduino board that analyzes the composition of the gas that was collected.
- The produced gas composed of around 57% of Methane (CH4), 30% of Carbon dioxide (CO2), 3% of Hydrogen sulphide (H2S), 7% of Nitrogen (N2), 2% of Oxygen (O2) and 1% of Hydrogen (H2).
- For 1 Kg of waste around 0.45m3 of bio Gas should be generated. Our working prototype was able to produce 0.37 m3 for an input of 1 kg of kitchen organic waste. Indicating a loss of .08 m3 of biogas, which is due to the opening and closing of the doors.
- For 1 kg of organic kitchen waste that is given as input, only 0.3 to 0.5 kg of manure was obtained as end result in the analysis.
- This infers that the organic waste generated inside a household can be made into zero waste by optimally extracting the by-products.
- According to various that has been studied each household in India will produce about 1 to 1.5 kg of waste on a daily basis. Using KAD we can yield around 0.37 m3 to 0.55 m3 of bio gas and about 0.27 kg to 0.41 kg of manure .
- The working prototype (KAD) was able to hold around 4 kg to 5 kg of waste which will generate around 1.48 m3 to 1.85 m3 of biogas and the 4 to 5 kgs. of waste will be reduce to 1.12 kg to 1.35 kg of manure.

VI. CONCLUSION AND SCOPE

KAD proposes to be a reliable product where composter or digesters already available in the market will only be able to give any one of the byproducts (i.e. manure or Bio gas) but KAD gives both of these, with 1kg of Organic Kitchen waste it can generate around 0.37 m^3 of biogas and up to 0.25 kg of manure. It appears that conversion of food waste into energy via anaerobic processes in terms of methane is economically viable.

The working prototype can be automated fully so that the yield of biogas and the quality of manure can be increased and also reduce the human interaction to the maximum extent.

Proper disposal of food waste has posed a stern pecuniary and environmental concern. The potential of KAD is huge because no such product is available in the market .Once it is practically released , each household can keep this product under the already existing space under the sink. Which can segregate waste in the kitchen level itself ,at the same time producing by products like Bio gas and Manure ,thus obtaining Zero waste concept from the very kitchen itself .By increasing the capacity of KAD scope can be expended variably (hotels, supermarkets, food industries etc.)

However, difficulties accompanying the collection as well as transportation of food waste should also be considered. Nevertheless, the stumpy or no cost of food waste along with the environmental aids considering the waste discarding would balance the initial high investment costs of the bio refineries. Moreover, the efficacy and cost base of the generation could be upgraded by intensifying research and optimization studies on assimilating different value-added product manufacturing processes.

B. SCOPE OF THE PROJECT

A research team had conducted a survey in which the activities of the households and their disposal practices were observed, the results were of the questionnaire is as follows.

1. Spoiled vegetables and fruits as wastes were reported by 55 peoples; feed waste, poultry wastes including debris of birds, rotten eggs and feathers were disposed by 37 persons and food waste was reported by 8 persons.
2. Quantity of waste disposed by respondents: 51 persons stated that they dispose vegetable and fruit wastes of 30 kg/day, 42 persons dispose 50-60 kg/ day poultry waste and 7 persons dispose 100-200 kg/day of food waste.
3. Methods of waste disposal: There was no special method used other than dumping by many of the respondents (%) or; 100 persons reported that they handover the wastes to municipality or corporation.
4. The availability of dump yards in these study areas are minimal and only 7 persons are reported to put the wastes in dumping yard.
5. Means of garbage removal: 71 and 29 persons reported that they availed municipal service and private service respectively for waste disposal.
6. Waste collection center - Most of the people (89) reported that they had collection center while 11 people reported absence of such centers.
7. Awareness: Over less than 50 persons of the sample population are aware of the different types of wastes.
8. Awareness of disposal waste guided by government / private organization: There was no awareness as reported by 77 people and 23 people know about guidance of the government /private agencies.
9. Disposal waste: 93 persons did not dump the waste whereas 7 persons regularly disposed the waste by dumping it.
10. Proposal for waste management: All respondents agree that there was no proposal/scheme/plan for waste management.

From the survey, still ways of disposal of waste is still not clear in the minds of the people. This project is to educate and create awareness on the benefits of waste disposal. Disposal of organic waste in household would reduce the amount of waste reaching these dump yards, thereby reducing the amount of pollution it causes on a larger scale.

TABLE 1.2 AVERAGE MSW GENERATED DURING VARIOUS WEEKS OF THE STUDY PERIOD

Nature of Waste	Avg* (kg) Week 1	Avg* (kg) Week 2	Avg* (kg) Week 3	Avg* (kg) Week 4	Avg* (kg) Week 5	Avg* (kg) Week 6	Avg* (kg) Week 7	Avg* (kg) Week 8	Avg* (kg) Week 9
Organic food	105.4	92.38	104.9	84.75	100.7	88.5	108.2	88.63	110.4
Paper	15.3	16	15.55	19.38	170.8	18.25	18.6	17.63	26
Plastic	18.15	20.25	19.45	24.38	20.1	24.75	21.55	19.88	22.5
Glass	2.35	2.5	2.3	4.13	2.25	4.75	3.1	3.13	3.13
Cloth	0	1.75	0	5.13	0.3	4.1	4.7	10.63	6.5
Metals	0.3	0.63	0.15	1.38	0.3	1	0.4	1.38	1
Footwear	1.1	0.75	0.4	2.5	1.15	2	1.85	4.5	3.75
Miscella-neous	36.3	34	33.9	39.63	33.75	34.13	38.1	30.38	26.63
Total weight	178.9	168.3	176.6	181.3	176.4	177.5	196.5	176.1	199.8 8

*Avg = Average

The study was done by Kancheepuram municipality, Tamil Nadu[34]

C. AVERAGE MUNICIPAL SOLID WASTE.

A report on Delhi says "Delhi's garbage problem can be substantially reduced if residential societies locally process their biodegradable waste, which includes kitchen and horticultural waste. What's more, communities can make money out of biodegradable waste. Here is how: 40 per cent of Delhi's waste is biodegradable which, if processed properly, can be turned into high-quality manure.

An article about Chennai being the highest per capita waste level [35] in India was published on Hindu newspaper which states as follows:

"Big buildings in Chennai will have to manage their own food waste. They will have to put in place a system to convert waste into bio-gas or compost.

The various environmental bodies in the State are also focusing on handling food waste, since it forms 16 per cent of the municipal solid waste and also leads to formation of landfill gas and leachate.
Over the last decade with the growth of cities, the amount of municipal solid waste being dumped in landfill sites too has increased. For instance, seven years ago Chennai used to generate 3,400 tonnes of waste a day and now it is 4,700 tonnes. All of this, including the food waste that can be used to power lights or converted as compost, is dumped in the landfill [36]. "It would help reduce the load on the landfill sites, reduce transportation costs and manure costs for parks. Biogas plants would produce electricity that can be used by the community and provide employment," explained a source in the Tamil Nadu Pollution Control Board.

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