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OPTIMISATION OF ALTERNATE FEEDSTOCKS FOR BIOGENESIS OF METHANE

P-1831

A PROJECT REPORT

Submitted by

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in partial fulfillment for the award of the degree

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in

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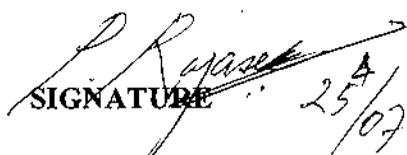
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BONAFIDE CERTIFICATE

Certified that this project report “**OPTIMISATION OF ALTERNATE FEEDSTOCKS FOR BIOGENESIS OF METHANE**” is the bonafide work of **GOKULAPRIYA.N.A**, **NITHYA.S** and **PRIYADHARSHINI.M**, who carried out the project work under my supervision.


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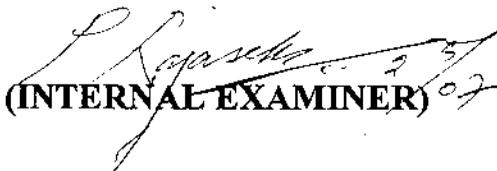
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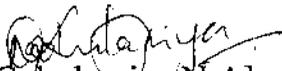
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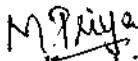
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ABSTRACT

Biogas technology provides an alternate source of energy in rural India and is considered as an archetypal appropriate technology that meets the basic need for cooking fuel in rural areas. Cattle dung has been hitherto employed as a feedstock for biogenesis of methane. However its availability in sufficient quantity limits its continuous application. The locally available resources like silkworm larval waste, piggery waste, mushroom spent waste and other organic wastes could be exploited for biogas generation. Microbial conversion of organic matter to methane has become attractive as a method of waste treatment and resource recovery.

Our project work dealt with utilization of silkworm larval litter and mushroom spent waste along with cattle dung and optimizing these feed stocks and their different ratios for maximum gas generation. The gas output of various treatments was recorded over a period of 8 weeks. The maximum gas output of 9948 ml was recorded in silkworm larval litter followed by 8960 ml in mushroom spent waste and 6238 ml in cattle dung. The physical and chemical properties of the raw materials and bio- digested slurry were analyzed. The total solids destroyed was maximum for silkworm larval litter (56.18 %), followed by mushroom spent waste (49.39 %) and cattle dung (46.79 %). The volatile solids destroyed was maximum for silkworm larval litter (81.99 %), followed by mushroom spent waste (74.87 %) and cattle dung (60.85 %). The methane content was highest in silkworm larval litter with a value of 65.6 %. These wastes were found to have high manurial value. The maximum amount of N, P, K was recorded as 2.13, 0.86 and 0.82 in silkworm larval litter. Thus this study reveals that silkworm larval waste, and mushroom spent waste can be used as a supplement with cattle dung for augmenting the gas output.

TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	CERTIFICATE	ii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	TABLE OF CONTENTS	vi
	LIST OF TABLES	ix
	LIST OF FIGURES	x
	LIST OF ABBREVIATIONS	xi
1.	INTRODUCTION	
	1.1 Biogas Technology	1
	1.2 Microbes in conversion	3
	1.3 Objectives	5
2.	LITERATURE REVIEW	
	2.1 Different waste utilization and biogas production	6
	2.2 Volatile solids destruction, retention time and gas production	9
	2.3 Effect of temperature in gas generation	11
	2.4 Microbes involved in bio digestion	14
	2.5 Factors affecting biogas generation	15
	2.6 Manurial values of the biodigested slurry	15

3.	MATERIALS AND METHODS	
3.1	Collection of waste materials	17
3.2	Utilization of wastes as various treatments for biogas generation	18
3.3	Gas Collection	20
3.4	Analysis of waste materials and slurry specimens of various treatments	21
3.4.1	Physical properties	21
	3.4.1.1 Moisture Content	21
	3.4.1.2 Total Solids	22
	3.4.1.3 Volatile Solids	22
3.4.2	Chemical Properties	23
	3.4.2.1 Total Organic Carbon	23
	3.4.2.2 Total Nitrogen	24
	3.4.2.3 Phosphorous	25
	3.4.2.4 Potassium	26
3.5	Carbon dioxide estimation of the gas generated in the wastes incorporated treatments	27
3.6	Methane estimation of the gas generated in the wastes incorporated treatments	28
4.	RESULTS AND DISCUSSION	
4.1	Physical properties	29
	4.1.1 Moisture content	29
	4.1.2 Total solids	29

4.1.3	Volatile solids	29
4.1.4	Percentage of volatile solids to total solids	30
4.2	Chemical properties	31
4.2.1	Total nitrogen	31
4.2.2	Organic carbon	31
4.2.3	C: N Ratio	31
4.2.4	Potassium	31
4.3	Gas production	33
4.4	Analysis of slurry samples of various wastes incorporated treatments	43
4.5	Analysis of carbon-di-oxide content	50
4.6	Estimation of Methane	52
4.7	Manurial value of biodigested slurry sample	55
4.8	Discussion on physical properties	57
4.9	Discussion on chemical properties	57
4.10	Discussion on gas production	58
4.11	Discussion on physico-chemical analysis of bio-digested slurry.	60
4.12	Discussion on analysis of biogas for its carbon dioxide content	62
4.13	Discussion on analysis of biogas for its methane content	62
4.14	Discussion on manurial values of bio-digested slurry samples	63
5.	CONCLUSION	64
6.	REFERENCES	65

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
4.1.	Physical properties of raw materials.	30
4.2.	Chemical properties of raw materials.	32
4.3.	Maximum amount of Bio-gas produced for silkworm larval litter Co-digested with cattle dung.	34
4.4.	Maximum amount of Bio-gas produced for mushroom spent wastes co-digested with cattle dung.	35
4.5.	a) Bio-gas produced for silkworm larval litter co-digested with cattle dung (Replication1).	36
	b) Bio-gas produced for mushroom spent waste co-digested with cattle dung (Replication 1).	37
4.6.	a) Bio-gas produced for silkworm larval litter co-digested with cattle dung (Replication2).	38
	b) Bio-gas produced for mushroom spent waste co-digested with cattle dung (Replication 2).	39
4.7.	Physical properties of various wastes incorporated treatments.	45
4.8.	Gas output per gram of total solids destroyed.	48
4.9.	Gas output per gram of volatile solids destroyed.	49
4.10.	Estimation of carbondioxide content in various treatments.	50
4.11.	Estimation of methane content in various treatments.	53
4.12.	Manurial values of biodigested slurry samples of various treatments.	56

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1.1.	Pathway of methane biogenesis	4
3.1.	Substrates Co-digested with cattle dung	17
	(a) Silkworm larval litter	
	(b) Mushroom spent waste	
3.2.	Liquid displacement assembly	20
3.3.	Testrestyrit instrument (CO ₂ estimation)	28
4.1.	Different sets of bottle for each replica and ratio	33
4.2.	Maximum weekly gas output for silkworm larval litter co-digested with cattle dung (T1-T5)	40
4.3.	Maximum weekly gas output for mushroom spent waste co-digested with cattle dung (T6-T10)	41
4.4.	Maximum gas output in various waste incorporated treatments	42
4.5.	Total solid content % (initial and final) of various waste incorporated treatments	46
4.6.	Volatile solid content % (initial and final) of various waste incorporated treatments	47
4.7.	Carbondioxide content of biogas at three different stages	51
4.8.	Observation of blue colored flame	52
4.9.	Methane content of biogas at three different stages	54
4.10.	Comparison of maximum gas output over 8 weeks for cattle dung, silkworm larval litter and mushroom spent waste	59

LIST OF ABBREVIATIONS

- CD - Cattle dung
- SLL - Silkworm larval litter
- MS - Mushroom spent waste
- TS - Total solids
- VS - Volatile solids
- TOC - Total organic carbon
- N - Nitrogen
- P - Phosphorous
- K - Potassium

INTRODUCTION

1. INTRODUCTION

1.1 BIOGAS TECHNOLOGY

Biogas technology provides an alternate source of energy in rural India, and is hailed as an archetypal appropriate technology that meets the basic need for cooking fuel in rural areas. Using local resources, viz. cattle waste and other organic wastes, energy and manure are derived. Realization of this potential and the fact that India supports the largest cattle wealth led to the promotion of National Biogas Programme in a major way in the late 1970s as an answer to the growing fuel crisis. Biogas is produced from organic wastes by concerted action of various groups of anaerobic bacteria. Methane fermentation is a process which is capable of converting almost all types of organic polymeric materials into methane and carbon dioxide. Some of the natural sources of methane emissions are wetland soils, oceans, rumen of ruminant animals, the lower intestinal tracts of humans, land fills, and sewage digesters.

Microbial conversion of organic matter to methane has become attractive as a method of waste treatment and resource recovery. This process is anaerobic and is carried out by action of various groups of anaerobic bacteria.

Three basic points about this process are:

- (i) That most of the important bacteria involved in biogas production process are anaerobes and slow growing;
- (ii) That a greater degree of metabolic specialization is observed in these anaerobic microorganisms and

(iii) That most of the free energy present in the substrate is found in the terminal product methane. Since less energy is available for the growth of organism, less microbial biomass is produced and, consequently, disposal of sludge after the digestion may not be a major problem.

The methanogenic decomposition of organic matter requires microbial consortia composed of at least three interacting metabolic groups of anaerobes. Anaerobes play important roles in establishing a stable environment at various stages of methanogenesis. A variety of microorganisms are involved in the methane fermentation which include the fermentative bacteria, which ferment complex polymers to H_2 , CO_2 , and various volatile carboxylic acids. The second group is acetogens, which then oxidize the higher acids to acetate and to either H_2 or formate. The strictly anaerobic methane-producing microorganisms are the final group in the consortium and they utilize H_2 , formate and acetate as substrate for growth. Methanogens represent the large and the most diverse group within the Archaea domain.

Methane fermentation offers an effective means of pollution reduction, which is superior to that achieved via conventional aerobic process. Methane produced by anaerobic fermentation of biomass is a clean, renewable fuel. In addition, during anaerobic digestion adequate sanitation of the treated material is guaranteed. Recent studies have shown that the most important agricultural pests and parasites are effectively deactivated during thermophilic anaerobic digestion. Although practiced for several years, interest in anaerobic digestion has recently focused on the economic

recovery of fuel gas from cattle, industrial and kitchen wastes and agricultural surpluses.

1.2 MICROBES IN CONVERSION

The model of microbial groups involved in the flow of carbon from complex polymers to methane consists of five groups:

- Group 1 - Fermentative bacteria
- Group 2 - Obligate hydrogen producing acetogenic bacteria
- Group 3 - Hydrogen oxidizing acetogenic bacteria
- Group 4 - Carbon dioxide reducing methanogens and
- Group 5 - Aceticlastic Methanogens

During the process of biomethanation (Fig.1.1), complex polymers are broken into soluble products by enzymes produced by fermentative bacteria (Group – 1) which ferment the substrate to short chain fatty acids, hydrogen and carbon dioxide. Fatty acids, longer than acetate are metabolized to acetate by obligate hydrogen producing acetogenic bacteria (Group – 2). The major products after digestion of the substrate by these two groups are hydrogen, carbon dioxide and acetate. Hydrogen and carbon dioxide can be converted into acetate by hydrogen oxidizing acetogens (Group – 3) or methane by carbon dioxide reducing, hydrogen oxidizing methanogens (Group – 4). Acetate is also converted into methane by aceticlastic methanogens (Group – 5).

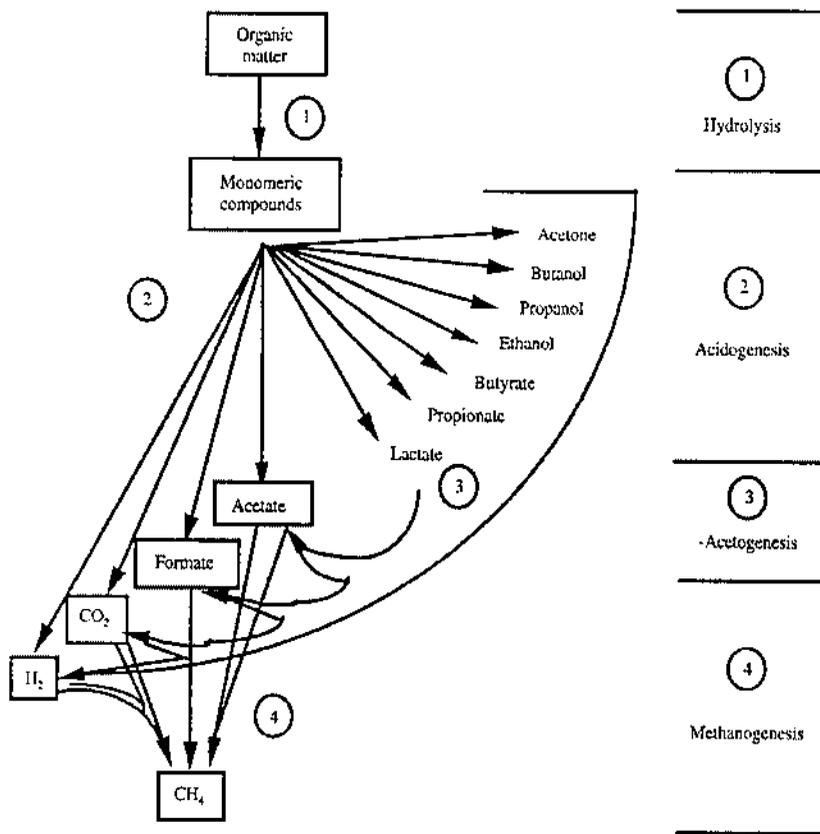


Fig.1.1: PATHWAY OF METHANE BIOGENESIS

Being a labor intensive and highly remunerative agro-based industry, sericulture is fast expanding in the rural sector. This industry generates large quantities of wastes in the form of silkworm larval liter which at present is indirectly applied to the mulberry gardens. This nitrogen rich waste is a possible supplement to the nitrogen deficient agricultural wastes that are incorporated into the biogas plant for biogas generation. In addition, the spent slurry, after digestion, is of high manurial value than the components incorporated into this plant earlier.

An attempt has been made in the research laboratory of sericulture unit to supplement the silkworm larval litter with cow dung for increased biogas generation and also to obtain nutrient rich manure after biodigestion.

1.3 OBJECTIVES

The objective of this project is to optimize the various feedstocks (ie., coddung + mushroom spent waste and coddung + silkworm larval litter) for biogenesis of methane.

These samples are then analysed for

- ❖ Moisture content
- ❖ Total solids (TS)
- ❖ Volatile solids (VS)
- ❖ Total organic carbon

To compare the different ratios of both wastes and their effects in the production of methane gas.

In addition to that the constituents of the gas are to be analysed using gas chromatography.

Finally to determine the manurial values ie.N,P and K contents of the samples

LITERATURE REVIEW

2. LITERATURE REVIEW

The anaerobic digestion of different types of wastes has attracted the attention of researchers in various parts of the world. A review of literature concerned with the above is detailed below:

2.1 DIFFERENT WASTE UTILIZATION AND BIOGAS PRODUCTION

Bousfield *et al.*, (1979) while studying the anaerobic digestion of cattle and poultry wastes reported that the methane content was lower in poultry wastes than from cattle wastes.

Summers and Bousfield (1980) reported that during piggery waste anaerobic digestion, the gas production was $0.30 \text{ m}^3 / \text{kg}$ of total solids which contained 69 percent methane.

Rajasekaran and Oblisami (1980) reported the possibility of recycling of sericulture wastes along with cowdung and old slurry for biogas generation. Maximum quantity of 1524 cc/day was observed on an average over a period of 12 weeks in silkworm larval litter incorporated treatments which also recorded the maximum number of methanogenic bacteria ($25.8 \times 10^4/\text{g}$).

Sharma *et al.*, (1980) while reporting the recycling of waste materials recorded the maximum production of methane (74 liters/kg and 147 liters/kg) from poultry and piggery wastes.

Hashimoto *et al.*, (1981) stated that the ultimate methane yield obtained from the digestion of cattle manure was 0.210 liter /g of volatile solids.

Singh *et al.*, (1982) reported that 75 percent of the biogas production was obtained during the digestion of cattle waste at the retention time of forty days.

Hills and Roberts (1982) indicated that the gas production were 0.43, 2.45 and 1.5 liters /digester vol/day during the digestion of tomato, peach and honey dew solid wastes respectively.

Varreier *et al.*, (1982) while reporting the French programme on the methane production recorded the maximum production of methane from different animal wastes.

Hills (1982) stated that the production of methane were 4.23 litre CH₄/day, 1.36 litre CH₄/day, 0.77 litre CH₄/day and 1.26 litre CH₄/day for beef, swine ,poultry and dairy wastes respectively When the wastes are digested in a comprehensive dynamic model.

Hills and Prince (1983) reported that the methane production was 150 m³ /day, 69 m³ /day and 160 m³ /day for swine, beef and poultry wastes respectively.

Hills (1983) reported that the gas production of 1.72 gas vol/digester vol/day at the 32.3 percent volatile solid was obtained from the intermittently and plug flow digestion of beef feed lot manure.

Roy Holmberg *et al.*, (1983) recorded the flow rates of 75 litres /min in 60 mesh screening size, while reporting the solid liquid separation of swine wastes.

Sleat and Robinson (1984) stated that range of aromatics could be metabolized to methane and carbon dioxide with a greater than 90 percent conversion of substrate in to these gases.

Pathak *et al.*, (1985) obtained a maximum gas production when cattle dung and rice-straw mixture were allowed for bio gasification. The mixture of cattle dung and rice straw was at the ratio of 1:2 and it contained 1.2 percent solids.

Olezzkiewick (1985) while studying the aerated lagoon treatment of piggery wastes, reported that the substrate removal rate was $K=0.0014$ litre day⁻¹ mg⁻¹ biomass yield $Y=0.5$ and decay coefficient $K_d=0.02$ day⁻¹. a load removal kinetic expression of the type $S/S_0 = \exp (-K/L)$ was also proposed.

Vaidyanathan *et al.*, (1985) stated that the gas production may reach 0.16 nm³ kg⁻¹ VS added when water hyacinth was allowed for digestion.

Gunnarson *et al.*, (1985) reported that the utilization of above ground part of Jerusalem artichoke (*Helianthus tuberosus.L.*) for biogas production. The biogas production estimated ranged from 480-680 liters.

Lo and Liao (1986) stated that the maximum methane production of 8.14 liter (CH_4 litre⁻¹ day at a loading rate of 7.78 gas litre⁻¹ day⁻¹) from winery wastes.

Prema Viswanath and Krishna Nand (1994) estimated that methane content was high as 70 % for sericultural waste in anaerobic digestion.

Hansen *et al.*, (1998) reported that high levels of ammonia can inhibit the anaerobic digestion of swine manure.

Nagamani and Ramasamy (1999) described that the use of different feedstocks in biogas production proves to meet the basic need for cooking fuel in rural areas.

Ruihong Zhang *et al.*, (2007) stated that various food waste can be used as an effective feedstock for anaerobic digestion.

2.2 VOLATILE SOLIDS DESTRUCTION, RETENTION TIME AND GAS PRODUCTION

Fischer *et al.*, (1975) stated that during anaerobic digestion of swine manure the biogas production begin at a loading rate of 0.8g VS litre day⁻¹

Varel *et al.*, (1977) recorded the maximum methane production rates of about 0.16, 0.18, 0.2. and 0.22 litre/day per g of VS in the feed from cattle waste. The gas contained 52 to 57 percent methane.

Hashimoto *et al.*, (1981) reported that the ultimate methane yield from beef cattle manure was 0.210 litre CH₄/g of volatile solids.

Hills *et al.*, (1981) while reporting on the design of digestion systems recorded the gas production of the digester as 43, 74, 60 and 56 percent and volatile solids reduction was 75, 65, 62 and 30 percent for swine, beef, poultry and dairy wastes respectively.

Fischer *et al.*, (1983) reported that the wheat straw addition reduced the biogas production except for one treatment where alkali treated straw was substituted at 4g VS litre/ day⁻¹

Walker *et al.*, (1985) while studying the experiment anaerobic digestion on a dairy farm recorded the maximum gas out flow of 400-495 m³ day.

Lo and Liao (1985) attained the maximum methane production at 4.2 percent volatile solids feed. The experimented volatile solids rates were 3.4, 4.2 and 5.2 percent over a HRT from 1.1-15 days.

According to Lo and Liao (1986) the maximum methane production rates of 1.29 and 1.19 litres of CH₄ /litre/day at one day HRT

were achieved with the volatile solids feeds of 5.2 and 4.2 percent respectively.

Stephenson and Loster (1986) while studying the evaluation of starting and operation of 4 anaerobic processes treating a synthetic meat waste, reported that the proportion of methane in the effluent gases increased as the influent COD concentrations was increased. The two stage reactor which contained to metals cobalt and nickel removed upto 85 percent of the influent COD concentration of 5000 mg/l.

Prince *et al.*, (1999) reported that the performance of each system depends on the HRT and the VS loading rate. The HRT was 20 days for anaerobic digestion.

David Bolzonella *et al.*, (2004) studied that the specific gas production per kilogram of volatile solids destroyed was in the range 0.5–0.9 m³/kg, VS destroyed and the reduction of the volatile solids concentration was in the range 13–27% (average 18%).

Batzias *et al.*, (2005) reported that the amount of volatile solids destroyed is proportional to the the gas liberated.

2.3 EFFECT OF TEMPERATURE IN GAS GENERATION

Converse *et al.*, (1977) made their research on anaerobic degradation of dairy manure under mesophilic and thermophilic temperatures, recorded that

the digester operated at 60°C instead of 35°C showed higher rates of gas production.

Varel *et al.*, (1977) stated that thermophilic methane production from cattle waste obtained maximum efficiency at 60°C for 8 days. While an increase from 60 to 65°C lowered the efficiency of gas production.

Van Velsen *et al.*, (1979) stated that at a digestion temperature of 13 °C no methane was produced while in mesophilic range (20 to 40 °C) methane production increased with temperature and under thermophilic condition (55 °C) it decreased by 25 percent.

Jain *et al.*, (1981) while studying the diurnal variations in gas production in a biogas plant reported that the gas production varied in all the seasons at different hours of the day depending upon the variation in the environmental temperatures.

Hills *et al.*, (1981) while reporting the continuously expanding anaerobic digestion recorded the production of methane gas averaging 58 to 60 percent at temperature 20 to 30 °C.

Lo *et al.*, (1985) while studying the mesophilic digestion of screened dairy manure, recorded the maximum biogas production of 1.89 litres of CH₄/litre day⁻¹

Madamwar and Mittal (1986) expressed that the effect of pectin on anaerobic digestion increases the production of gas with the increased methane content at controlled temperature of 38 ± 1 °C.

Saraswath and Khanna (1986) while studying a diphasic system with alkali treatment design with an alkali pretreatment step (3.6% Na_2CO_3 + 2.5% $\text{Ca}(\text{OH})_2$ (w/w) of water hyacinth, 24 hours duration followed by an open acid phase (2-1 days HRT) and closed methane reactor with sludge recycling (5-7 days HRT, 7-7 days MCRT) recorded the gas yield of 501/kg WH /d at 35-37 °C.

Prema Viswanath and Krishna Nand (1994) stated the optimal temperature for sericultural anaerobic digestion is $33^\circ\text{C} \pm 2$.

Yue Han *et al.*, (1997) stated that the purpose of laboratory study was to compare the performance of the temperature-phased system with the conventional single-stage mesophilic (35°C) system for treating mixtures of primary and waste activated sludge.

Birgitte *et al.*, (2001) reported that thermophilic anaerobic digestion of manure at temperatures ranging from 50 to 55C is a waste treatment technology successfully applied in many full-scale plants.

Gavala *et al.*, (2003) studied the effect of pretreatment on the anaerobic mesophilic biodigestion.

2.3.1 Energy inputs of biogas plants

Fischer, *et al.*, (1983) stated that the daily requirement for a mesophilic farm scale anaerobic digester ranging from 16.9 MJ/M³d.

2.4 MICROBES INVOLVED IN BIO DIGESTION

Smith and Hungate (1952) described that methods for the isolation and culturing of methanogenic bacteria from the rumen of cattle and studied the technique of transfer.

Rajasekaran (1984) studied the microbiological changes accompanying degradation of water hyacinth in an anaerobic digester. The cellulytic population of 375×10^3 /g was recorded in the digester containing cowdung, old slurry and water hyacinth.

Rajasekaran (1980a) stated that the total bacterial population was found to be more in the slurry specimen ranging from 101.3×10^6 to 367.7×10^6 /g of oven dry samples.

Rajasekaran (1984) studied about the addition of various sources of microbial inoculation on the biogasification of water hyacinth incorporated cowdung treatment.

Matt (2000) stated that *Methanosaeta* species were the most abundant methanogens in the inoculum, but their levels decreased rapidly as acetate built up

Dimitar Karakashev *et al.*, (2005) stated that the methanogenic diversity like *Methanosaetaceae*, *Methanosarcinaceae etc* was greater in reactors operating under mesophilic temperatures.

2.5 FACTORS AFFECTING BIOGAS GENERATION

Vandenberg *et al.*, (1976) while reporting the conversion of acetic acid into methane gas recorded the maximum gas production was at the acetic acid concentration of 0.2 and 100 mm at the temperature of 40-45 °C at the pH 6.5-7.1.

Dennis *et al.*, (1978) reported that the maximum rate of gas production 690ml CH₄ /g occurred at C/N ratio of 19.1.

Hills and Roberts (1979) reported that the effects of C/N ratio on anaerobic digestion of dairy manure screened dairy manure which had a C: N ratio of the feed at 25.

David Bolzonellaa *et al.*, (2004) studied that the waste activated sludge is stabilised by means of the mesophilic (35–37°C) anaerobic digestion process. Moreover, it was observed that the higher the applied solid retention time in the activated sludge process for wastewater treatment, the lower the gas production

2.6 MANURIAL VALUES OF THE BIODIGESTED SLURRY

Acharya (1958) stated that the digested slurry contained about 1.8 to 1.9 percent nitrogen on dry basis than farm yard manure.

Fry (1974) reported that the anaerobic digestion of cow dung produced better quality manure rich in humus content.

Barnett *et al.*, (1978) stated that the nitrogen content of cow manure, chicken manure, bagasse, sawdust and poultry litter was 1.7, 6.2, 0.3, 0.1 and 6.7 percent respectively and urine contained about 40 to 70 percent of the fertilizer value of the manure.

Gupta *et al.*, (1986) reported that the losses of plant nutrients by biogas slurry was 36.5, 25.0, 21.5, 14.8, 5.9, 4.9 and 2.7 percent for K, Zn, N, Cu, Mn, Fe and P respectively.

Dohia and Vasudevan (1986) reported that the biogas plant slurry and it may be used as an alternative to chemical fertilizers.

Beckwith and Parsons (2005) studied that the rate of decomposition was at a maximum over the first twenty days and was not influenced by the level of added nitrogen.

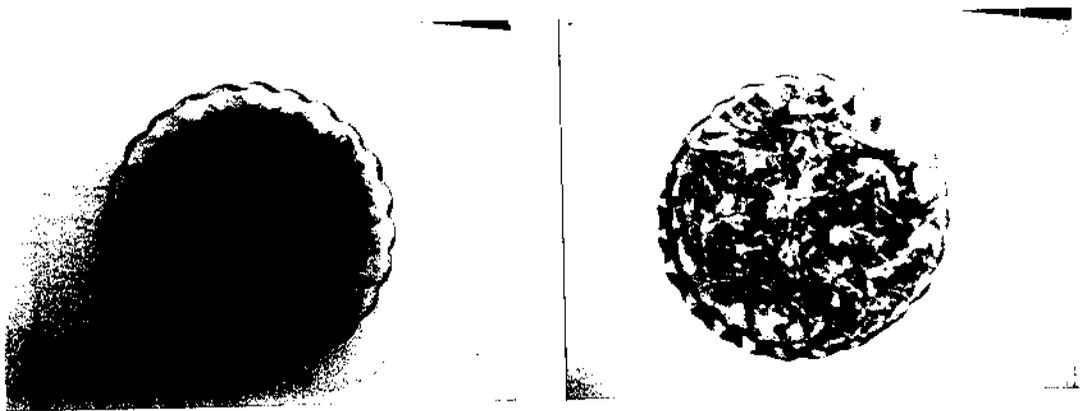
Warman *et al.*, (2005) stated that compared to the conventional fertilizer, the nutrient availability from the organic amendments (especially N and P) was considerably lower than the 50% assumed at the start of the experiment.

MATERIALS AND METHODS

The various waste materials like silkworm larval litter, cattle dung, mushroom waste and biodigested slurry utilized in this study were collected from various places in and around Coimbatore. The wastes thus obtained were analyzed for their physical and chemical properties such as moisture, total solids, volatile solids, nitrogen, phosphorous and potassium.

3.1 COLLECTION OF WASTE MATERIALS

Silkworm larval litter was collected from sericulture farm in Aalandurai located 20 km away from Coimbatore. The cattle dung was collected from Kulathupalayam located 10 km away from Coimbatore. The bedding waste materials used for the cultivation of mushrooms was collected from mushroom cottage in Saravanampatty near Kumaraguru College of Technology. The substrates collected are shown in Fig (3.1).



(a) Silkworm larval litter

(b) Mushroom spent waste

Fig. 3.1: SUBSTRATES CO-DIGESTED WITH CATTLE DUNG

3.2 UTILIZATION OF WASTES AS VARIOUS TREATMENTS FOR BIOGAS GENERATION

There were thirteen treatments with three replications. The details of various treatments employed were given as under:

3.2.1 Cattle dung alone (Control-C_{CD})

The cattle dung slurry was prepared by mixing the cattle dung with equal amount of tap water (wt/wt basis). A total quantity of 400 g of cattle dung slurry was prepared by mixing 200 g of cattle dung with equal amount of tap water (1: 1 wt/wt). The slurry thus prepared was in 2.5 litre amber colored bottles which were tightly stoppered. The contents were allowed to undergo anaerobic biodigestion.

3.2.2 Silkworm larval litter alone (Control-C_{SLL})

The silkworm slurry was prepared by mixing 200 g of silkworm larval litter with equal amount of tap water (1: 1 wt/wt).

3.2.3 Mushroom spent waste (Control-C_{MS})

200 g of mushroom spent waste was chopped into bits and mixed with equal amount of tap water (1: 1 wt/wt).

3.2.4 Cattle dung + Silkworm larval litter (Treatment No.1)

200 g of silkworm larval litter was mixed with equal amount of cattle dung (1: 1 wt/wt) and a total volume of 400ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

3.2.5 Cattle dung + Silkworm larval litter (Treatment No.2)

100 g of silkworm larval litter was mixed with 200 g of cattle dung (1: 2 wt/wt) and a total volume of 300ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

3.2.6 Cattle dung + Silkworm larval litter (Treatment No.3)

50 g of silkworm larval litter was mixed with 200 g of cattle dung (1: 4 wt/wt) and a total volume of 250 ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

3.2.7 Cattle dung + Silkworm larval litter (Treatment No.4)

25 g of silkworm larval litter was mixed with 200 g of cattle dung (1: 6 wt/wt) and a total volume of 225 ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

3.2.8 Cattle dung + Silkworm larval litter (Treatment No.5)

12.5 g of silkworm larval litter was mixed with 200 g of cattle dung (1: 8 wt/wt) and a total volume of 212.5 ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

3.2.9 Cattle dung + mushroom spent waste (Treatment No.6)

200 g of mushroom spent waste was mixed with equal amount of cattle dung (1: 1 wt/wt) and a total volume of 400ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

3.2.10 Cattle dung + mushroom spent waste (Treatment No.7)

100 g of mushroom spent waste was mixed with 200 g of cattle dung (1: 2 wt/wt) and a total volume of 300ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

3.2.11 Cattle dung + mushroom spent waste (Treatment No.8)

50 g of mushroom spent waste was mixed with 200 g of cattle dung (1: 4 wt/wt) and a total volume of 250 ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

25 g of mushroom spent waste was mixed with 200 g of cattle dung (1: 6 wt/wt) and a total volume of 225 ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

3.2.13 Cattle dung + mushroom spent waste (Treatment No.10)

12.5 g of mushroom spent waste was mixed with 200 g of cattle dung (1: 8 wt/wt) and a total volume of 212.5 ml of tap water was added. The contents were allowed to undergo anaerobic biodigestion.

3.3 GAS COLLECTION

Biogas production in each treatment was measured by liquid displacement method on daily basis as shown in Fig (3.2).



Fig. 3.2 :LIQUID DISPLACEMENT ASSEMBLY

3.4 ANALYSIS OF WASTE MATERIALS AND SLURRY SPECIMENS OF VARIOUS TREATMENTS

Physical properties like moisture content, total solids and volatile solids, chemical properties like total organic carbon, total nitrogen, phosphorus and potassium contents of raw materials as well as slurry samples of various wastes incorporated treatments were initially determined.

The biodigested slurry samples of various wastes incorporated treatments were also obtained after the completion of the experiments and analyzed for the moisture, total solids, volatile solids, total organic carbon, total nitrogen, phosphorous and potassium contents.

3.4.1 Physical properties

3.4.1.1 Moisture content

The moisture content of the various materials used in this study was estimated following the method described by Johnson and Ulrich (1980).

About 10 g of freshly collected samples were placed in weighing bottles and dried in hot air oven at 105° C for 12-16 hours. The bottles were cooled in a desiccator and weighed in a “Melter chemical balance”. This procedure was repeated until the concordant values were obtained. The difference in weight was expressed as percentage of moisture on oven dry basis.

Weight of samples before drying in hot air oven	=	A
Weight of samples after drying in hot air oven	=	B
Loss in weight of samples	=	A-B
Moisture percentage	=	$\frac{A-B \times 100}{A}$

3.4.1.2 Total solids

Total solids of the waste materials were determined by deducing the moisture content from 100. Total solids (T.S.) = 100 - moisture content.

3.4.1.3 Volatile solids

After determining the moisture content and total solids, the contents in the moisture bottles were completely transferred to already weighted silica crucibles. The silica crucibles were kept at 645° C for 2-3 hours in a muffle furnace. Weights were taken in a Melter chemical balance after cooling to room temperature.

Weight of the moisture bottle	=	A g
Weight of moisture bottle+ sample	=	B g
Sample weight	=	B-A g
Weight of sample after heating in hot air oven	=	C g
Weight of silica crucible	=	D g
Weight of silica crucible +sample	=	E g
Weight of the sample after keeping in muffle furnace	=	E-D g
Volatile solids percentage	=	$\frac{C - (E - D) * 100}{B - A}$

3.4.2 Chemical properties

3.4.2.1 Total organic carbon

The total carbon content of the samples was estimated as follows:

Reagents

1. Ferrous ammonium sulphate = 0.5 N
2. Potassium dichromate solution = 1.0 N
3. Diphenylamine indicator

1.5 g of diphenylamine was dissolved in 20 ml of distilled water and 100 ml sulphuric acid.

4. Concentrated sulphuric acid 96 percent.
5. Orthophosphoric acid 85 percent.

Procedure

Samples containing not more than 0.1 g of solid material (1g of wet material) weighed and transferred to 500ml conical flask. Twenty ml of 1N potassium dichromate and 20 ml of concentrated sulphuric acid were added and gently the contents were mixed. The mixture was allowed to stand for 20-30 minutes at room temperature.

Standardization blank was also run in the same manner. Then the solution was diluted by adding 200ml of distilled water and 10 ml of 85% orthophosphoric acid. Three drop of diphenylamine indicator was then added. After the contents were titrated against 0.5 N Ferrous ammonium sulphate solution the change of color from blue to brilliant green was taken as the end point.

Calculation

1 ml of 1N KCr_2O_7 : 0.003 g of carbon

Volume of potassium dichromate -20ml

Blank titre value -BTV

Titre value -TV

Moisture content -M

Percent of organic carbon = $\frac{20-20 \times \text{TV} \times 0.003}{\text{BTV} \times \text{WS}} \times \frac{100 \times 100}{10-M}$

where WS is the weight of sample

3.4.2.2 Total nitrogen

The total nitrogen content of the wastes were estimated as per the method described by Humphries (1956).

Reagents

1. Sulphuric acid + Salicylic acid mixture

(5 g of salicylic acid in 100 ml of concentrated sulphuric acid).

2. Sodium thiosulphate

3. Catalyst mixture (1g of cupric sulphate)

8 g of potassium sulphate and 1 g of selenium dioxide 1:8:1.

4. 49 percent sodium hydroxide.

5. 2 percent boric acid.

6. Double indicator solution (83.3 mg of bromocresal green + 16.6 mg of methyl red dissolved in 100ml of 95% ethanol).

Procedure

About 0.1 g of the dried waste material was taken in microkjeldhal digestion flask. 2ml of sulphuric acid +salicylic acid mixture was added and mixed well. After 20 minutes approximately 0.3 g of sodium thiosulphate was added and heated gently. Then the flask was cooled and 0.06 g of the catalyst mixture was added. The contents were digested vigorously and color was observed. The flask was cooled and the content of each flask was made up to 100 ml distilled water.

From the stock solution 10 ml was pipetted out into a microkjeldhal flask to which 100 ml of 40% sodium hydroxide was added. The liberated ammonia was collected in 2% boric acid (20ml) containing a drop at the double indicator which was then back titrated against N/50 sulphuric acid. The suitable blank was simultaneously run and the value was deducted from the sample before calculation.

Calculation

1 ml of 0.1 N H_2SO_4 contain 0.00014 g of N, 1 ml of N/50 sulphuric acid contains 0.00028 g of N, X ml of N/50 sulphuric acid contains 0.00028 x Xg. This is present in 10 ml of the aliquot. Therefore, 100ml of the aliquot will contain =0.00028 x100/10 x Xg of N.

Therefore, 0.1 of the substance will contain

$$=0.00028 \times 100/0.1 \times X \text{ g of N.}$$

3.4.2.3 Phosphorous

To this 1.25 ml of ammonium molybdate and 0.25 percent of ammonium metavanadate were added. The absorbance of the color thus developed was read in Bausch and Lomb spectronic-20 colorimeter at 540

nm against a reagent blank. The amount of phosphorus was calculated by referring to a calibration curve with potassium dihydrogen phosphate and expressed on percentage basis.

In 100 ml of distilled water 0.043 g of potassium dihydrogen phosphate was dissolved so as to get concentration equivalent to 100 ppm. A standard curve complying 10, 20, 30, 40, 50 upto 100 ppm concentrations was prepared and from this the unknown concentration was calculated.

Calculation

$$\% \text{ of phosphorous} = \frac{X \text{ ppm} \times 50 \times 100 \times 100}{1000000 \times 5 \times 0.5}$$

where X is the sample reading.

3.4.2.4 Potassium

The potassium content of the sample was estimated by flame photometry method described by Jackson (1962).

Standard potassium solution

The standard potassium solution was prepared by dissolving 1.907 g of potassium chloride in distilled water and making up to 100 ml, 10 ml of the solution was diluted to 1000 ml to get a solution containing 1 mg of potassium per ml.

Procedure

A known quantity of sample was taken in a flask to which the triacid mixture (15ml) was added and the digestion was until a white mixture was

obtained. The flask was cooled and the contents made up to 50 ml with distilled water.

Different concentration of the standard potassium chloride of the standard potassium chloride was fed into EEL flame photometer to prepare a standard curve and the transmittance was recorded using potassium filter. The sample was also treated in the same manner and from the calibration curve; the amount of potassium in the unknown was calculated

3.5 CARBON DIOXIDE ESTIMATION OF THE GAS GENERATED IN THE WASTES INCORPORATED TREATMENTS

Carbon dioxide content of the biogas produced was estimated during III week in the various treatments using testestyril instruments (Fig.3.3). This instrument contained 5% potassium hydroxide in its stem calibrated with percentage marking. The biogas was first drawn in the separately attached horn shaped thick rubber bladder and by pressing, the gas was injected into the stem of the testestyril instruments.

The pressing and relaxing was repeated at least 10 times which facilitated the maximum absorption of CO₂ by 5% potassium hydroxide. The liquid was mixed with the gas injected by proper shaking before raking. The reading on the calibrated scale attached to the stem. The result was expressed in terms of percent of carbon dioxide contained on the injected gas mixture.

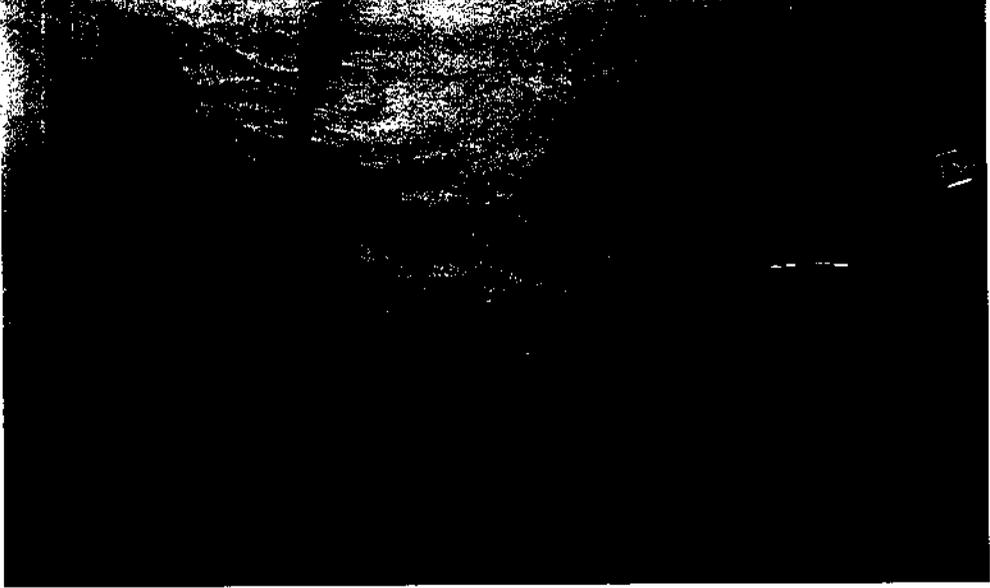


Fig.3.3: TESTRESTYRIT INSTRUMENT

3.6 METHANE ESTIMATION OF THE GAS GENERATED IN THE WASTES INCORPORATED TREATMENTS

The gas constituents were analyzed for methane content. The gas generated from various treatments were collected in a sterilized, air tight vials and the quality of methane was ascertained by employing Thermal Conductivity Detector(TCD) in a Perkin Elmer Gas Chromatograph. The quantity of methane gas was obtained by calculation. The methane content was estimated by deducing the CO₂ content from 100% and also giving an allowance of 2% for moisture content and other gases.

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results obtained from the experiments carried out are detailed below:

Effect of incorporation of silkworm larval litter and mushroom spent waste along with cattle dung in relation to biogas generation.

The various types of wastes used were silkworm larval litter and mushroom spent waste along with cattle dung. These organic wastes were analyzed for their physical and chemical properties such as moisture, total solids, volatile solids, percentage of volatile solids to total solids, total organic carbon, total nitrogen, C: N ratio, phosphorus and potassium.

4.1 PHYSICAL PROPERTIES

The results of physical properties of various wastes are presented in Table 4.1.

4.1.1 Moisture content

The moisture percentage of various waste materials ranged from 35.1 (mushroom spent waste) to 86.12 (cattle dung). The estimated moisture contents were 86.12, 38.46 and 35.1 percent for cattle dung (CD), silk worm larval litter (SLL) and mushroom spent waste (MS) respectively.

4.1.2 Total solids

The total solids varied with different waste materials examined. The total solids estimated were 13.88 (CD), 61.54 (SLL) and 94.9 (MS) percent respectively.

4.1.3 Volatile solids

The volatile solids estimated were 12.12, 58.61 and 69.34 percent for cattle dung (CD), silk worm larval litter (SLL) and mushroom spent waste (MS) respectively.

4.1.4 Percentage of volatile solids to total solids

The percentage of volatile solids to total solids for cattle dung (CD), silk worm larval litter (SLL) and mushroom spent waste (MS) were 87.31, 95.23 and 73.04 percent respectively.

Waste Materials	Moisture Content (%)	Total Solids (%)	Volatile Solids (%)	% VS/TS
CD	86.12	13.88	12.12	87.31
SLL	38.46	61.54	58.61	95.23
MS	35.1	94.9	69.34	73.04

Table 4.1: Physical properties of raw materials

CD - Cattle Dung

SLL - Silkworm larval litter

MS - Mushroom spent waste

4.2 CHEMICAL PROPERTIES

Various chemical properties analyzed in the different wastes used are presented in Table 4.2.

4.2.1 Total nitrogen

The total nitrogen content of various wastes was different and the percentage value for cattle dung, silkworm larval litter and mushroom spent waste were 1.24, 3.21 and 1.29 respectively.

4.2.2 Organic carbon

The organic carbon content of the various wastes analyzed ranged from 32.18(CD) to 33.46(SLL) percent. The organic carbon content of the cattle dung, silkworm larval litter and mushroom spent waste were 32.18, 33.46 and 33.23 respectively.

4.2.3 C: N Ratio

C:N ratio estimated were 22.66, 10.42 and 25.75 percentage for cattle dung, silkworm larval litter and mushroom spent waste respectively.

4.2.4 Phosphorous

The phosphorous content was 0.64, 0.78 and 0.21 percent for cattle dung, silkworm larval litter and mushroom spent waste respectively.

4.2.5 Potassium

The potassium content was 0.75, 1.68 and 0.86 percent for cattle dung, silkworm larval litter and mushroom spent waste respectively.

Waste Materials	Nitrogen (%)	Carbon (%)	C/N Ratio	Phosphorus (%)	Potassium (%)
CD	1.24	32.18	22.66	0.64	0.75
SLL	3.21	33.46	10.42	0.78	1.68
MS	1.29	33.23	25.75	0.21	0.86

Table 4.2: Chemical properties of raw materials

CD - Cattle Dung

SLL - Silkworm larval litter

MS - Mushroom spent waste

The various waste incorporated treatments were allowed to undergo batch digestion in 2.5 litre capacity amber colored bottles as depicted in Fig.4.1. The maximum gas output recorded for the various thirteen treatments are given in Table 4.3 and 4.4, Fig.4.2, 4.3 & 4.4. The gas output for the other replications is given in Table 4.5 & 4.6.

The maximum gas output of 9948 ml was recorded in the silk worm larval litter and cattle dung incorporated treatments (T1). Among the other treatments, mushroom spent waste and cattle dung incorporated treatment (T6) recorded 8960 ml. The control cattle dung alone treatment (C_{CD}) however recorded 6238 ml only over five weeks period. An increase in gas production over the cattle dung control was observed in all the silkworm larval litter and mushroom spent waste mixed treatments.

The quantity of gas production in ml per gram of total solid destroyed was observed maximum in CD+SLL (3318.51) followed by CD+MS (2925.88). The cattle dung control (CD) recorded 1718.4 ml per gram of TS destroyed

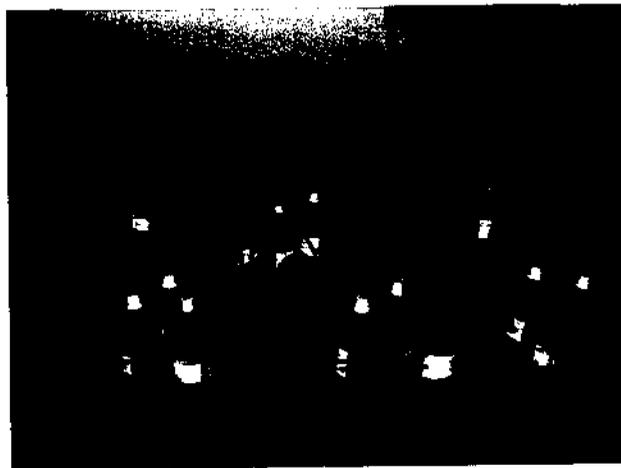


Fig. 4.1: DIFFERENT SETS OF BOTTLE FOR EACH REPLICA AND RATIO

Treatments	Weekly maximum total gas output (in ml)								Total gas output over 8 weeks (ml)	Weekly average gas output (ml)	Percentage increase over control
	I	II	III	IV	V	VI	VII	VIII			
	C _{CD} CD : H ₂ O 200 : 200	383	1040	1330	1120	730	370	690			
C _{SLL} SLL : H ₂ O 200 : 200	2220	1613	563	890	370	950	370	660	7636	954	-
CD : SLL : H ₂ O											
T ₁ 200:200:400	800	1050	2793	1000	980	800	570	435	9948	1243	59.35
T ₂ 200:100:300	1280	1510	2240	1088	976	856	610	540	9034	1138	45.89
T ₃ 200:50:250	1000	1350	2400	920	725	560	480	445	7880	985	20.28
T ₄ 200:25:225	1100	1450	1890	1100	1000	730	460	380	8845	1014	30
T ₅ 200:12.5:212.5	910	1740	2060	850	780	690	560	490	7516	938	20.25

Table 4.3: Maximum amount of Bio-gas produced for silkworm larval litter co-digested with cattle dung

CD = Cattle Dung
SLL = Silkworm larval litter

Treatments	Weekly maximum total gas output (in ml)								Total gas output over 8 weeks (ml)	Weekly average gas output (ml)	Percentage increase over control
	I	II	III	IV	V	VI	VII	VIII			
C_{CD} CD : H ₂ O 200 : 200	383	1040	1330	1120	730	370	690	575	6238	780	-
C_{MS} MS : H ₂ O 200 : 200	547	387	207	430	910	700	1453	1153	5787	723	-
CD : MS : H ₂ O											
T_6 200:200:400	440	610	740	990	1120	1560	1710	1790	8960	1120	43.59
T_7 200:100:300	580	760	920	1070	1600	1720	1210	990	8850	1106	41.79
T_8 200: 50:250	640	800	990	1790	1210	940	770	620	7760	970	24.36
T_9 200: 25:225	560	1010	1180	1690	1090	890	720	540	7680	960	23.07
T_{10} 200:12.5:212.5	620	1090	860	1250	1140	920	760	690	8330	1041	33.46

Table 4.4: Maximum amount of Bio-gas produced for mushroom spent wastes co-digested with cattle dung

CD = Cattle Dung
MS = Mushroom spent waste

Treatments	Weekly gas output (in ml)								Total gas output over 8 weeks (ml)	Weekly average gas output (ml)
	I	II	III	IV	V	VI	VII	VIII		
C_{CD} CD : H₂O 200 : 200	383	1035	1310	1115	730	370	680	565	6188	773.5
C_{SLL} SLL : H₂O 200 : 200	2220	1600	563	880	300	950	350	660	7523	940.3
CD : SLL : H₂O										
T₁ 200:200:400	800	1050	2780	985	980	800	550	415	8360	1045
T₂ 200:100:300	900	1250	2380	920	710	560	460	445	7625	953.1
T₃ 200: 50:250	810	1650	2050	850	780	680	555	460	7835	979.3
T₄ 200: 25:225	1180	1410	2230	950	960	850	610	540	8730	1091.2
T₅ 200:12.5:212.5	1000	1200	1790	850	985	690	455	360	7330	916.25

Table 4.5(a): Bio-gas produced for silkworm larval litter co-digested with cattle dung (Replication 1)

CD = Cattle Dung
SLL = Silkworm larval litter

Treatments	Weekly gas output (in ml)								Total gas output over 8 weeks (ml)	Weekly average gas output (ml)
	I	II	III	IV	V	VI	VII	VIII		
C_{CD} CD : H₂O 200 : 200	360	1020	1310	1100	710	350	670	575	6095	760
C_{MS} MS : H₂O 200 : 200	547	387	200	410	890	680	1430	1153	5697	712
CD : MS : H₂O										
T₆ 200:200:400	440	400	710	800	1060	1710	1500	1200	7820	977.5
T₇ 200:100:300	570	760	800	1005	1200	1590	1000	990	7915	989.3
T₈ 200:50:250	600	700	990	1200	1000	910	770	610	6780	847.5
T₉ 200:25:225	555	1000	1170	1690	1070	890	700	510	7585	948.1
T₁₀ 200:12.5:212.5	610	990	800	1240	1140	910	650	610	6950	868.7

Table 4.5(b): Bio-gas produced for mushroom spent waste co-digested with cattle dung (Replication 1)

CD = Cattle Dung
MS = Mushroom spent waste

Treatments	Weekly gas output (in ml)								Total gas output over 8 weeks (ml)	Weekly average gas output (ml)
	I	II	III	IV	V	VI	VII	VIII		
C_{CD} CD : H₂O 200 : 200	340	1020	1210	1110	610	310	570	515	5685	711
C_{SLL} SLL : H₂O 200 : 200	2080	1000	400	680	100	870	270	600	6000	750
CD : SLL : H₂O										
T₁ 200:200:400	565	900	2007	650	400	500	310	410	5742	718
T₂ 200:100:300	675	1050	1986	500	555	460	210	400	5856	732
T₃ 200: 50:250	600	1100	1995	600	685	550	100	310	5940	743
T₄ 200: 25:225	675	1325	1805	500	425	299	255	225	5509	688.6
T₅ 200:12.5:212.5	500	985	1090	320	330	350	210	120	3905	488.1

Table 4.6(a): Bio-gas produced for silkworm larval litter co-digested with cattle dung (Replication 2)

CD = Cattle Dung
SLL = Silkworm larval litter

Treatments	Weekly gas output (in ml)								Total gas output over 8 weeks (ml)	Weekly average gas output (ml)
	I	II	III	IV	V	VI	VII	VIII		
C _{CD} CD : H ₂ O 200 : 200	300	980	1100	950	680	300	470	470	5250	656
C _{MS} MS : H ₂ O 200 : 200	400	320	160	210	445	550	1210	1000	4295	537
CD : MS : H ₂ O										
T ₆ 200:200:400	310	300	630	775	850	1510	1300	1150	6825	853
T ₇ 200:100:300	520	700	770	940	1100	1390	700	940	7060	883
T ₈ 200: 50:250	430	505	980	850	900	710	470	560	5405	676
T ₉ 200: 25:225	335	895	1010	1125	970	690	400	470	5895	737
T ₁₀ 200:12.5:212.5	305	885	705	1060	1040	710	350	520	5575	697

Table 4.6(b): Bio-gas produced for mushroom spent waste co-digested with cattle dung (Replication 2)

CD = Cattle Dung
MS = Mushroom spent waste

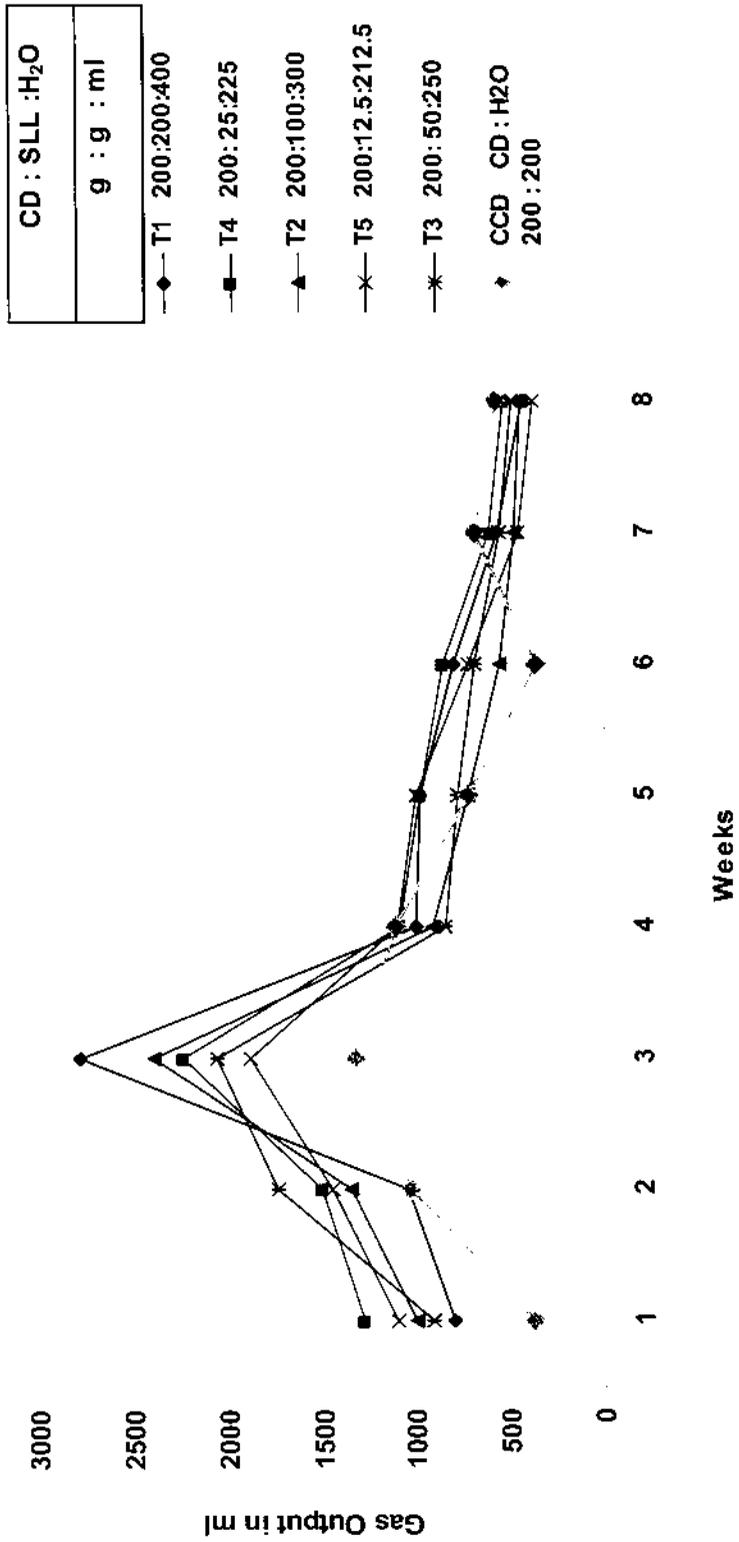


FIG.4.2 :MAXIMUM WEEKLY GAS OUTPUT FOR SILKWORM LARVAL LITTER CO-DIGESTION WITH CATTLE DUNG [T1 - T5]

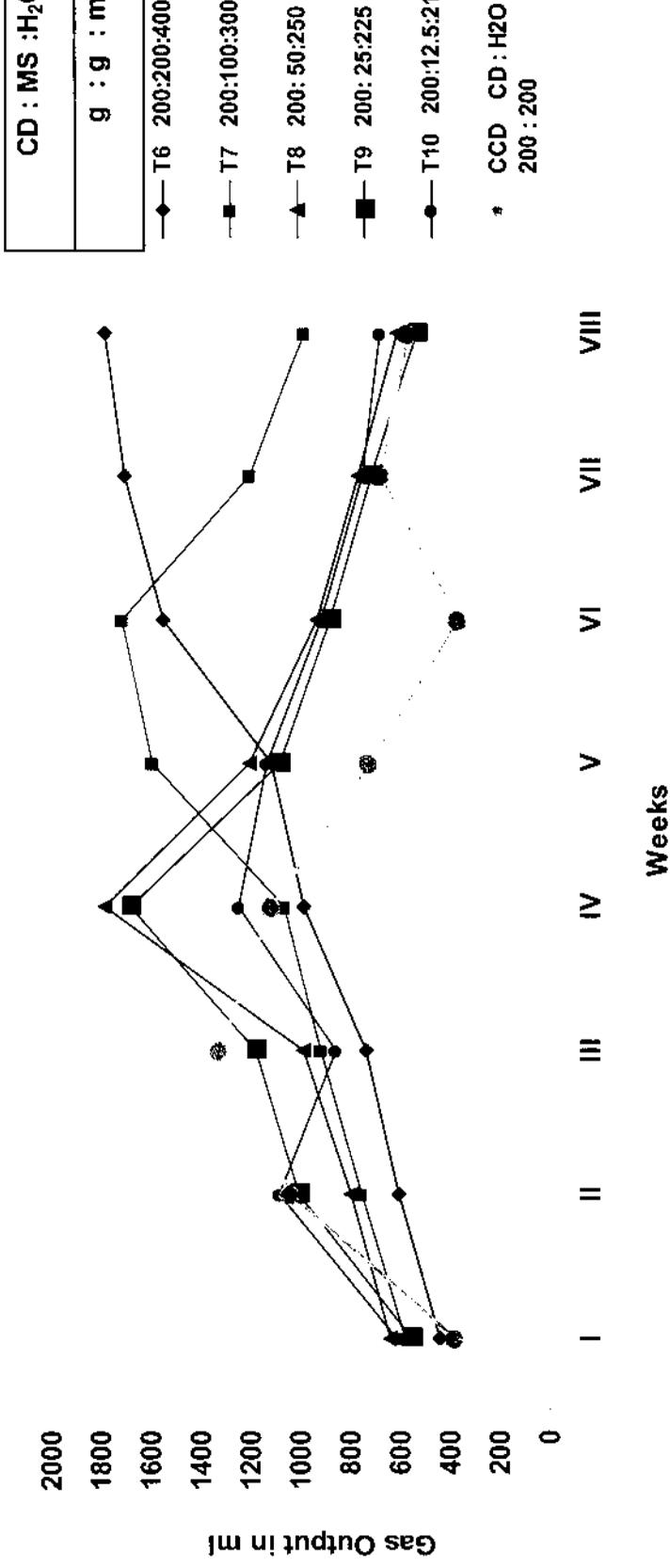


FIG.4.3: MAXIMUM WEEKLY GAS OUTPUT FOR MUSHROOM SPENT WASTES CO-DIGES WITH CATTLE DUNG [T6 - T10]

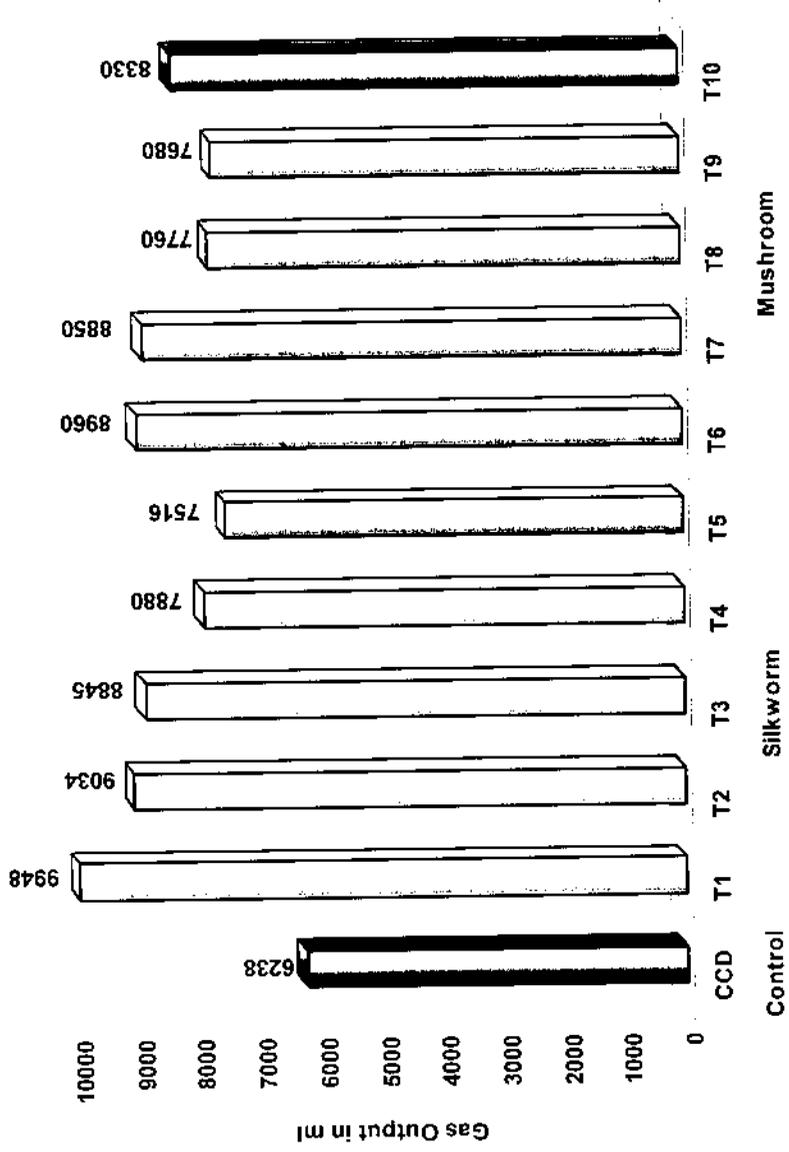


FIG.4.4: MAXIMUM GAS OUTPUT (ml) IN VARIOUS WASTE INCORPORATED TREATMENTS

4.4 ANALYSIS OF SLURRY SAMPLES OF VARIOUS WASTES INCORPORATED TREATMENTS

Initial and final analysis of moisture content, total solids and volatile solids of the composite samples of biodigested slurry of the different treatments are presented in Table 4.7.

4.4.1 Moisture content

The initial moisture content of the various wastes incorporated treatments were analyzed and the highest percentage of moisture content, 93.13 percent was observed in cattle dung control and the lowest 91.98 percent in mushroom spent waste. The final moisture content of the various treatments ranged from 95.21 to 96.85.

4.4.2 Total solids

The initial solids content of the various treatments varied from 7.19(MS) to 8.97(CD+SLL) percent. The total solids at the end of the experiment ranged from 3.15(SLL) to 4.19 (CD) percent.

4.4.3 Volatile solids

The initial volatile solid content of the various treatments ranged from 6.21 to 8.45 percent. The lowest volatile solids content was observed in MS and the highest in CD+SLL. The final volatile solid content ranged from 1.95(CD+MS) to 3.04(CD+SLL) percent.

4.4.4 Percentage degradation of total solids

The percentage degradation of total solids of the various treatments were estimated at the end of the experiment and ranged from 45.06 to 56.18 percent. The percentage degradation of total solids were lowest in the treatment (MS) and highest in the treatment (CD+SLL). The initial and final total solids of various wastes incorporated treatments are presented in Fig.4.5.

4.4.5 Percentage degradation of volatile solids

At the end of the experiment, the percentage degradation of the volatile solids were obtained and the highest being in the treatment CD+SLL (81.99) and the lowest in the treatment CD (60.85). The initial and final volatile solids estimated in the treatments are presented in Fig.4.6.

Treatments	Moisture Content (%)		Total Solids (TS) %				Volatile Solids (VS) %			
	Initial	Final	Initial	Final	Difference	%Degradation of TS	Initial	Final	Difference	%Degradation of VS
CD	93.13	95.81	7.49	4.19	3.30	46.79	6.61	2.43	3.78	60.85
SLL	92.81	96.21	7.88	3.15	4.73	48.01	6.98	2.83	4.5	72.06
MS	91.98	96.85	7.19	3.79	3.30	45.06	6.21	2.95	3.66	64.02
CD+SLL	92.15	95.55	8.97	4.19	4.92	56.18	8.45	3.04	5.41	81.99
CD+MS	92.51	95.21	8.56	4.45	4.84	49.39	7.23	1.95	5.08	74.87

Table 4.7: Physical properties of various wastes incorporated treatments

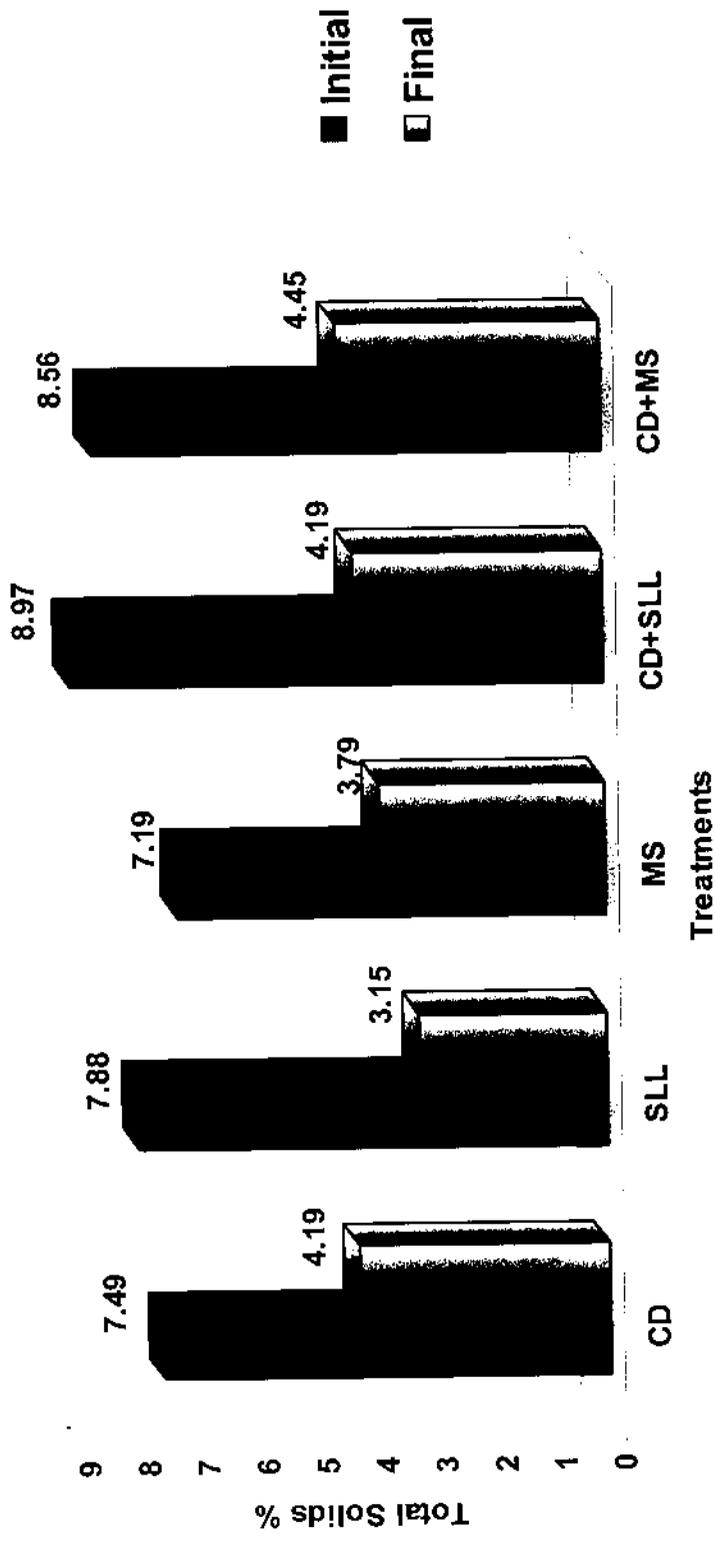


FIG.4.5: TOTAL SOLID CONTENT % [INITIAL AND FINAL] OF VARIOUS WASTES INCORPORATED TREATMENTS

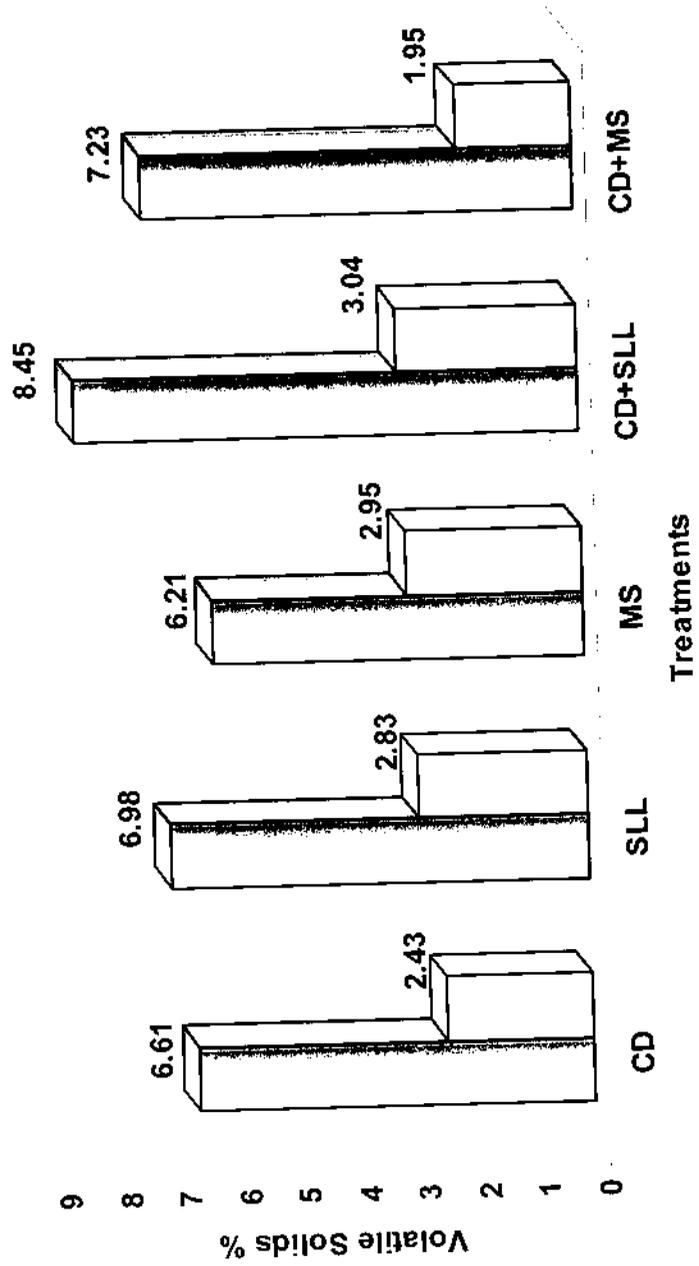


FIG.4.6: VOLATILE SOLID CONTENT % [INITIAL AND FINAL] OF VARIOUS WASTES INCORPORATE TREATMENTS

No.	Treatments	Total gas output over 8 weeks	Total solids Destroyed	Gas output per g of TS destroyed
1.	CD	6238	3.30	1718.4
2.	SLL	7636	4.73	2245.8
3.	MS	5787	3.30	1188.29
4.	CD+SLL	9948	4.92	3318.51
5.	CD+MS	8960	4.84	2925.88

Table 4.8: Gas output per gram of total solids destroyed

CD - Cattle Dung

SLL - Silkworm larval litter

MS - Mushroom spent waste

No.	Treatments	Total gas output over 8 weeks	Volatile solids destroyed	Gas output per g of VS destroyed
1.	CD	6238	3.78	1273.06
2.	SLL	7636	4.5	1521.11
3.	MS	5787	3.66	980.84
4.	CD+SLL	9948	5.41	2420.43
5.	CD+MS	8960	5.08	2309.2

Table 4.9: Gas output per gram of volatile solids destroyed

CD - Cattle Dung

SLL - Silkworm larval litter

MS - Mushroom spent waste

4.5 ANALYSIS OF CARBON DIOXIDE CONTENT

The carbon dioxide content of the biogas generated was estimated in the III, V and VIII weeks. The results are presented in Table 4.10 and Fig.4.7

The carbon dioxide content of the biogas was observed to decrease gradually with the increase in time. The initial CO₂ content was high in treatment MS (74.2 percent) and lowest in treatment CD+SLL (60.8 percent). The carbon dioxide content estimated at the final stage of digestion ranged from 35.8 to 40.0 percent in treatments CD and CD+MS respectively.

No.	Treatments	Week 3 (%)	Week 5 (%)	Week 8(%)
1.	CD	62	48	35.8
2.	SLL	64.3	38.6	36.9
3.	MS	74.2	56.6	38.2
4.	CD+SLL	60.8	40	33.9
5.	CD+MS	71.4	51.3	37.5

Table 4.10: Estimation of carbon dioxide content in various treatments

CD - Cattle Dung

SLL - Silkworm larval litter

MS - Mushroom spent waste

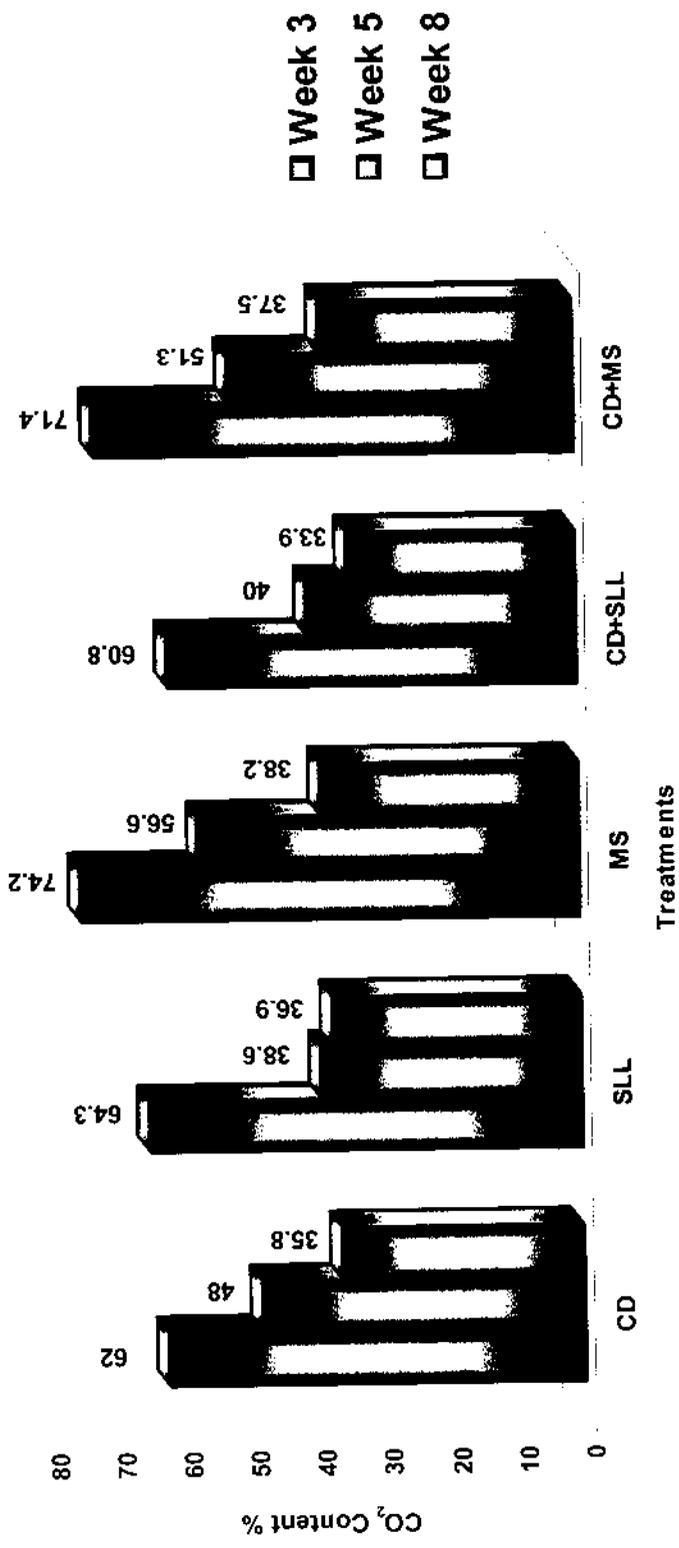


FIG.4.7: CARBONDIOXIDE CONTENT OF BIOGAS AT THREE DIFFERENT STAGES

The methane content of the biogas generated was estimated in the III, V and VIII weeks. The results are presented in Table 4.11 and Fig. 4.8.

The methane content of the biogas was observed to increase gradually with the increase in time and leveled off around 60-65% during the end of digestion. The final methane content was high in treatment CD+SLL (65.6 percent) and lowest in treatment MS (59.8 percent). The qualitative presence of methane can be confirmed, when a match stick is lit at the mouth of the measuring cylinder of the liquid displacement assembly. A blue colored flame is observed as in Fig.4.8.

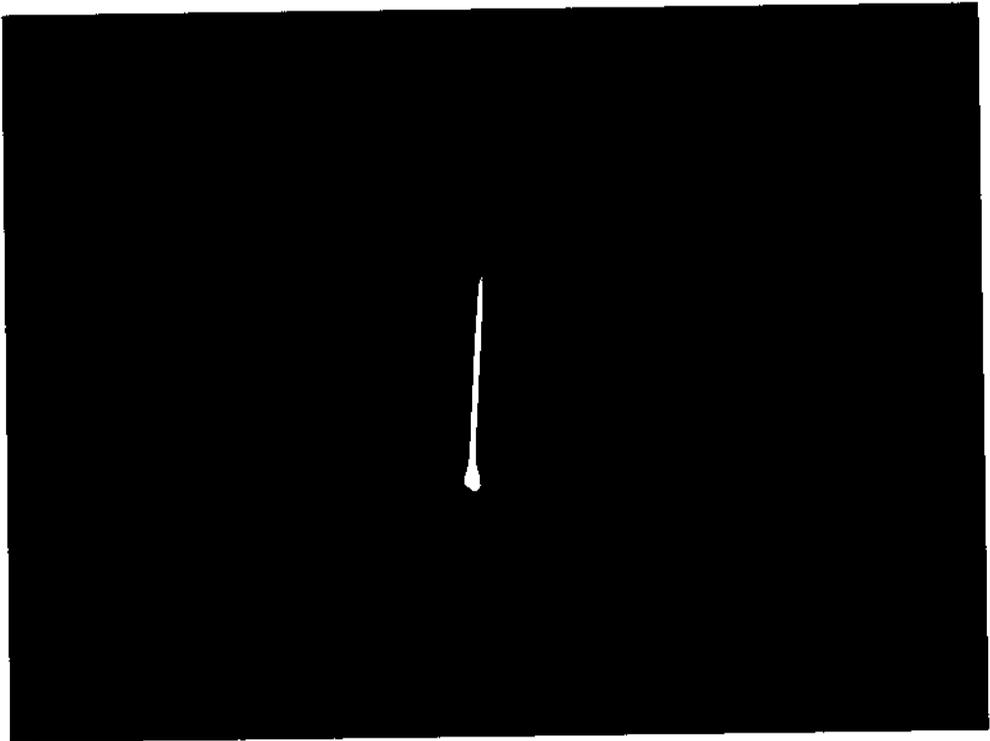


Fig.4.8: OBSERVATION OF BLUE COLORED FLAME

No.	Treatments	Week 3(%)	Week 5(%)	Week 8(%)
1.	CD	36	48.9	62.2
2.	SLL	33.7	54.7	61.1
3.	MS	23.8	41.4	59.8
4.	CD+SLL	37.2	61.8	65.6
5.	CD+MS	26.6	57.6	63.9

Table 4.11: Estimation of methane content in various treatments

CD - Cattle Dung

SLL - Silkworm larval litter

MS - Mushroom spent waste

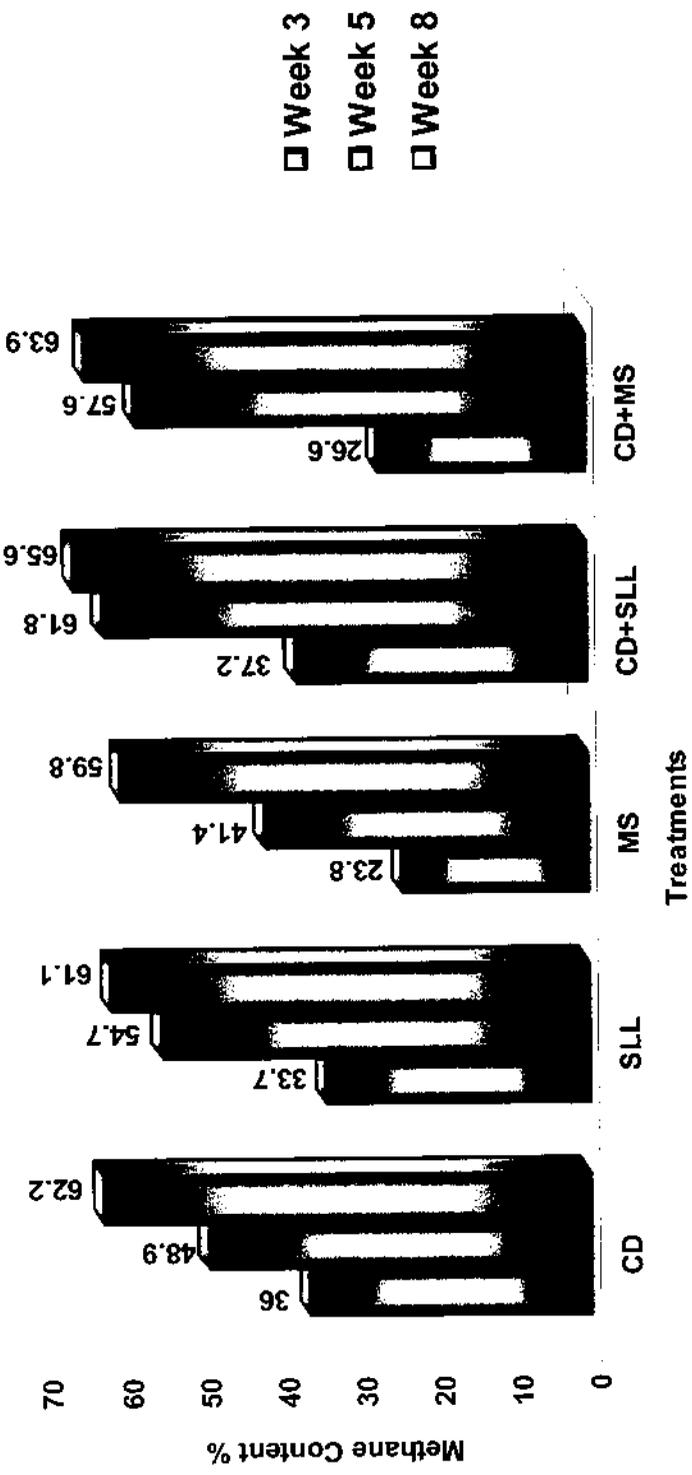


FIG.4.9: METHANE CONTENT OF BIOGAS AT THREE DIFFERENT STAGES

4.7 MANURIAL VALUE OF BIODIGESTED SLURRY SAMPLE

The manorial values of biodigested slurry samples of various treatments are presented in Table 4.12.

4.7.1 Total nitrogen

The nitrogen contents of various slurry samples ranged from 1.16 to 2.56 percent in treatments MS and SLL respectively. The next best treatment was CD+SLL (2.13 percent) followed by CD (1.46 percent) and CD+MS (1.26) respectively.

4.7.2 Phosphorous

The highest phosphorous content of 0.86 percent was estimated in the treatment CD+SLL. The next best treatment was SLL (0.75 percent), CD (0.59 percent) and CD+MS (0.48 percent). The least phosphorous content of 0.26 percent was estimated in MS.

4.7.3 Potassium

The potassium content varied with various treatments. The potassium content ranged from 0.62 (CD) to 0.82 (CD+SLL) percent.

No.	Treatments	Nitrogen (%)	Phosphorous (%)	Potassium (%)
1.	CD	1.46	0.59	0.62
2.	SLL	2.56	0.75	0.8
3.	MS	1.16	0.26	0.79
4.	CD:SLL	2.13	0.86	0.82
5.	CD:MS	1.26	0.48	0.72

Table 4.12: Manurial values of biodigested slurry samples of various treatments

CD - Cattle Dung

SLL - Silkworm larval litter

MS - Mushroom spent waste

No.	Treatments	Nitrogen (%)	Phosphorous (%)	Potassium (%)
1.	CD	1.46	0.59	0.62
2.	SLL	2.56	0.75	0.8
3.	MS	1.16	0.26	0.79
4.	CD:SLL	2.13	0.86	0.82
5.	CD:MS	1.26	0.48	0.72

Table 4.12: Manurial values of biodigested slurry samples of various treatments

CD - Cattle Dung

SLL - Silkworm larval litter

MS - Mushroom spent waste

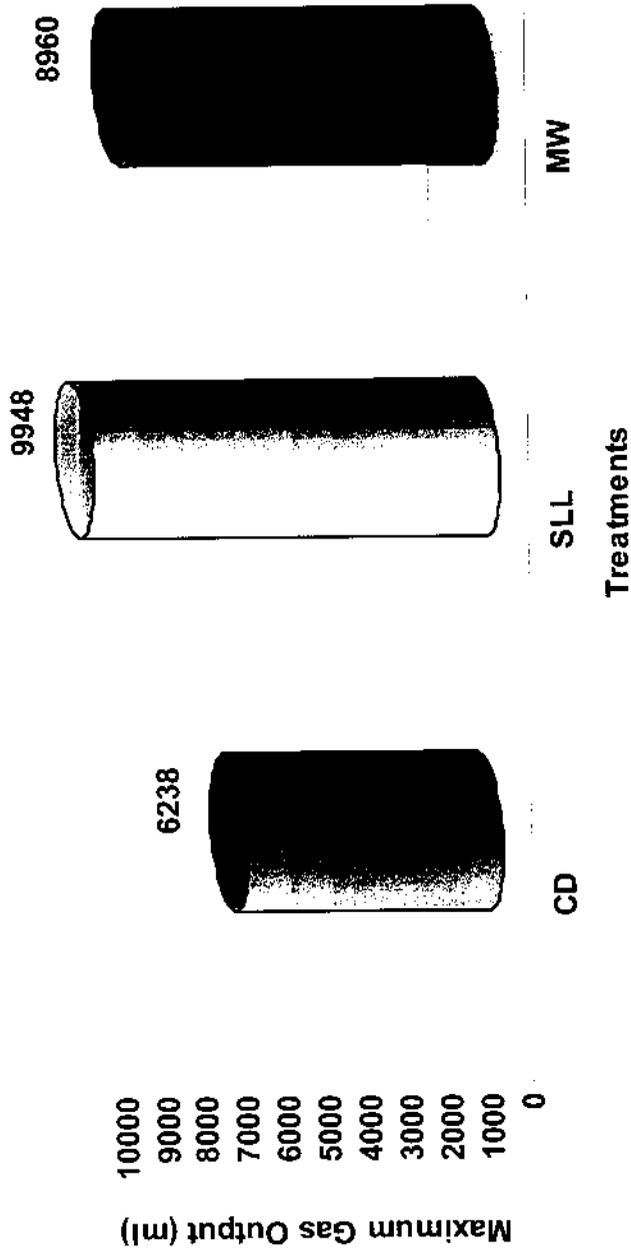
mushroom spent waste and silk worm larval litter respectively. The potassium content varied from 0.75 to 1.68 percent for cattledung and silk worm larval litter respectively.

In general the silkworm larval litter recorded a higher nitrogen, carbon, phosphorous and potassium when compared to the other wastes like cattledung and mushroom spent waste. This was supported by the similar findings of Shivappa shetty *et al.*, (1978).

4.10 DISCUSSION ON GAS PRODUCTION

Variations in the gas output were recorded with the various treatments. The maximum weekly gas output of 9948 ml was recorded in the treatment T1 and the minimum of 6238 ml in the control of cattle dung alone. In general the silkworm larval litter incorporated treatments gave comparatively higher gas output than that of cattledung alone. Shivappa shetty *et al.*, (1978) in their study on silkworm waste as substrate for biogas production reiterated the biogas production potential of silkworm wastes compared to cattle dung. They have also recorded that the fermentation proceeded rather rapidly causing quicker generation of biogas.

The maximum gas output from the silkworm litter incorporated with cattle dung treatments is supported by Rajasekaran and Oblisami (1980). They observed the maximum quantity of 1524 ml/day on an average over a period of 12 weeks in silkworm larval litter incorporated treatment. The desired type of microbial population which was favored by easy biodigestability in the optimal C: N ratio might be the possible cause for the silkworm larval litter treatment to produce higher gas output.



**FIG.4.10: COMPARISON OF MAXIMUM GAS OUTPUT OVER 8 WEEKS FOR CATTLE DUNG, SIL
LARVAL LITTER AND MUSHROOM SPENT WASTE**

The mushroom spent waste generally records lesser gas output. This may be due to higher polymeric substrates present in this waste, requiring more time for degradation.

4.11 DISCUSSION ON PHYSICO-CHEMICAL ANALYSIS OF BIODIGESTED SLURRY

4.11.1 Moisture content

The initial moisture content of the various slurry samples analyzed ranged from 91.98 (MS) to 92.81 (SLL) percent. The final moisture content of slurry samples of the various treatments varied from 95.21 (CD+MS) to 96.85 (MS) percent. The apparent increase in moisture content of the biodigested slurry might be due to the accumulation of excess water liberated during degradation of various organic wastes in the digester. In other words about one third of the material added is utilized by the microorganisms for the liberation of biogas. So, the remaining water that was not utilized resulted in the increase in the moisture content (Murugesan 1982).

4.11.2 Total Solids

The initial total solids percentage of the various treatments range from 7.19 (MS) to 8.97 (CD+SLL) percent. The final total solids percentage ranged from 3.15 (SLL) to 4.19(CD) percent. The decrease in total solid content of the fermented slurry was observed maximum to 4.92 percent in silkworm larval litter co-digested with cattledung.

The silkworm larval litter incorporated treatments showed relatively increased degradation of total solids. The gas generation as well as maximum total solid destruction were reported earlier by several workers (Acharya

(1958), Kirsh and Sykes (1971), Singh (1974), Mohan Rao (1974) and Summer and Bouseflied (1980)).

4.11.3 Volatile solids

The initial volatile solids content ranged from 6.21 to 8.45 percent. The cattledung alone treatment recorded 6.61 and the silkworm larval litter co-digested with cattledung gave 8.45percent. The gas generation is not only induced by the quantity but also the quality. This is supported by the findings of Varel *et al.*, (1977).

4.11.4 Percentage of degradation of total solids

The percentage degradation of TS of various slurry samples were analyzed and found to ranged from 45.06 to 56.18 percent. The percentage degradation of total solids were highest in the treatment (CD+SLL) and lowest in the treatment (MS).

4.11.5 Percentage degradation of volatile solids

At the end of the experiment, the percentage degradation of the volatile solids were obtained and the highest being in the treatment CD+SLL (81.99%) and the lowest in the treatment MS (60.85%).

4.11.6 Gas output per gram of TS destroyed

The gas output and the total solids destroyed are correlated. The gas output is maximum (9948ml) in CD+SLL. The total solids destroyed was also found highest in CD+SLL (4.92). Thus the treatment in which the the TS destroyed was maximum, the gas output was also maximum.

4.11.7 Gas output per gram of VS destroyed

The gas output and the volatile solids destroyed are correlated. The gas output is maximum (9948ml) in CD+SLL. The volatile solids destroyed was also found highest in CD+SLL (5.41). Thus the treatment in which the the VS destroyed was maximum, the gas output was also maximum.

4.12 DISCUSSION ON ANALYSIS OF BIOGAS FOR ITS CARBON DIOXIDE CONTENT

The percentage of carbon dioxide was analyzed in the biogas generated from the various treatments. The trend of the data revealed higher content of carbon dioxide in the initial stages of digestion. This may be due to anaerobic predigestion of wastes resulting in the release of higher carbon dioxide in the initial stage of digestion. The highest CO₂ content was observed in MS in the initial (74.2) and final (38.2) weeks.

4.13 DISCUSSION ON ANALYSIS OF BIOGAS FOR ITS METHANE CONTENT

The percentage of methane was analyzed in the biogas generated from the various treatments. The trend of the data revealed higher content of methane in the final stages of digestion. This may be due to the different microorganisms that help in the digestion of wastes and since it is a slower process, the methane content is increased in the final stages of digestion. The highest methane content was observed in CD + SLL in the initial (37.2) and final (65.6) weeks.

4.14 DISCUSSION ON MANURIAL VALUES OF BIODIGESTED SLURRY SAMPLES

The biodigested slurry samples from the various wastes incorporated treatments were analyzed for their manurial values.

4.14.1 Nitrogen content

The treatment SLL possessed the highest nitrogen content (2.56 percent). In general, all the treatments possessed higher nitrogen content than the control (CD-1.46 percent) except MS and CD+MS treatment. The increase in the nitrogen content of the treatments might be attributed to high initial nitrogen content of the wastes in addition to the build up of microbial biomass, conversion of ammoniacal nitrogen to nitrates in an anaerobic environment. A relatively high nutrient content in the slurry was also reported earlier by several workers. (Anonymous (1981), Palanisamy (1980), Murugesan (1982)).

4.14.2 Phosphorous

The phosphorous contents of the slurry samples varied with wastes. The maximum phosphorous content of 0.86 percent was estimated in the treatment, CD+SLL. All the treatments possessed higher phosphorous content than the control except MS. The results obtained are in agreement with that of Singh (1974) and Rajasekaran (1980 a).

4.14.3 Potassium

The potassium content of the biodigested slurry samples varied with the treatments. The higher potassium content was estimated in the treatment CD+SLL (0.82 percent). The least potassium content was observed in treatments CD (0.62 percent). Similar findings reported by Palanisamy (1980) and Murugesan (1982) lend support to the results obtained in the present study.

CONCLUSION

5. CONCLUSION

The waste emanating from sericulture industry such as silkworm larval litter could thus be profitably utilized for bio gas generation as a supplementary feedstock along with cattle dung. The mushroom bedding waste such as rice straw waste employed as a bedding material for the cultivation of mushrooms seems to contain cellulose to the extent of 37.25 percent (Sivaprakasam 1980). The carbon content of this waste and the nitrogen rich waste like silkworm larval litter could thus form a better feedstock for exploitation towards biogas production.

In Tamilnadu a huge quantity of about 50,000 tones of silkworm larval litter goes as waste. By utilizing such a huge amount of silkworm larval litter for biogas generation, we can solve the energy crisis which is on the increase day by day. This will also help in making our environmental clean and healthy. This will avoid pollution problem faced by mankind. Thus wealth from wastes such as silkworm larval litter and mushroom waste in the form of biogas could be possible. This has to be exploited in a big way. Besides the methane rich biogas the biodigested slurry obtained serves as a potential source of organic manure rich in plant food nutrients like N, P, K for application to the farmer's fields for improving crop productivity.

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