

**BIOGAS PRODUCTION FROM POULTRY
DROPPINGS AND INFLUENCE OF FERMENTED
SLURRY ON SOIL MICROFLORA**

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**DEPARTMENT OF AGRICULTURAL MICROBIOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE
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**BIOGAS PRODUCTION FROM POULTRY
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SLURRY ON SOIL MICROFLORA**

K. RAMANAND, B.Sc. (Agri.)

Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
for the award of the Degree of

Master of Science (Agriculture)

in

AGRICULTURAL MICROBIOLOGY

BANGALORE

OCTOBER, 1984

Dedicated
To My Beloved Parents

Department of Agricultural Microbiology
UNIVERSITY OF AGRICULTURAL SCIENCES
Bangalore

CERTIFICATE

This is to certify that the thesis entitled "BIOGAS PRODUCTION FROM POULTRY DROPPINGS AND INFLUENCE OF FERMENTED SLURRY ON SOIL MICROFLORA" submitted in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL MICROBIOLOGY to the University of Agricultural Sciences, Bangalore, is a record of bona-fide research work carried out by Mr. K. RAMANAND under my guidance and supervision and that no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or other similar titles.

BANGALORE,
October 10th, 1984

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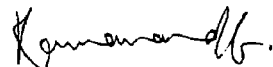
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(K. RAMANAND)

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INTRODUCTION

I. INTRODUCTION

With increasing prices of conventional fuels and possible shortage of these fuels, the production of energy from alternative source became not only more desirable but also economically more feasible. Bioconversion of organic wastes through anaerobic digestion offer high degree of waste stabilization and biogas production. Conversion of organic wastes through anaerobic digestion is accomplished by bacteria under anaerobic conditions. Anaerobic digestion chiefly consists of hydrolysis of complex waste components into its component subunits which are further subjected to fermentation, B-oxidation and other metabolic process leading to formation of fatty acids and alcohol. In turn, these are converted to methane and carbon dioxide by a strict, obligately anaerobic, highly sensitive methane fermenting bacteria.

To convince the farmer of the practical usefulness of the refuse materials, it is necessary that a simple equipment be devised which could be set up at a low cost in village homes by the villager himself. The biogas production from cow dung, cattle waste and poultry droppings was worked out by many scientists (Desai and Biswas, 1945; Acharya, 1958; Sheila Sousfield et al, 1979). A number of developing as well as developed countries and international organisation have been evincing interest in this area from different view point viz. renewable sources of energy.

bio-fertilizer, land reclamation, recycling of waste, rural development, public health and hygiene, population control among developing countries.

The anaerobic breakdown of organic waste in biogas plants results not only in the generation of rich biogas, but also in the production of non-offensively smelling manure ready for application to crop fields. It has been reported that the digested slurry when applied to crops gave better response (Laura and Idnani, 1972; Ravikumar and Krishnamurthy, 1980). It was therefore, considered essential to develop techniques and evaluate the different organic wastes for biogas production and manurial value.

The main objectives of the study are given below:

1a. To study the effect of solids concentration, pH and retention time on biogas production from poultry droppings on a laboratory scale.

1b. Production of biogas on a pilot-plant scale from poultry droppings and cow dung using the optimum conditions as found in laboratory scale.

2. To study the effect of substrates mixing viz. cow dung, water hyacinth and banana leaves with poultry droppings on biogas production.

3. To find out the effect of fermented slurry on soil microflora viz., microbial population, nitrogen mineralization and crop response.

REVIEW OF LITERATURE

IX. REVIEW OF LITERATURE

2.1.1. Studies on biogas production from plant and animal wastes

Alessandro Volta was the first to associate burning gas with decaying vegetation matter, who found that to detect gas it was necessary to disturb the bottom sediments of stagnant water and he recognised that there was close relation between the abundance of combustible gas and the amount of plant material in the sediment (Sathianathan, 1975). Bechamp in the year 1968 demonstrated that methane gas was derived from simple carbon compound by microbial action and subsequently more knowledge and proof of the microbial origin of methane gas was given by Tappenier in the years 1882-1884 (Sathianathan, 1975).

Norman (1924) reported that the major loss in organic material was due to cellulose degradation and thus he concluded that cellulose was the main energy source for methane fermenting bacteria. Buswell and Neave (1930) reported that the quality of gas formed from the fraction of fat amounted to about 15 per cent of the weight of the material decomposed, the weight difference being obtained from the water added. Fowler and Joshi (1932) produced biogas from different materials which were rich in organic fractions like hemicelluloses,

celluloses, lignocelluloses along with sludge at room temperature of 35°C and found that the rate and period of biogas production greatly varied from one material to another material.

Kiefer and Knitz (1934) observed that the pH maintenance was an essential factor during gas production from garbage and sludge. Acharya (1935) reported that after prolonged anaerobic digestion, only about 10 to 20 per cent of lignin fraction of different straw materials of rice, wheat, oats, barley etc. were decomposed. The first stage of fermentation involved formation of organic acids and in the second stage of anaerobic digestion the acids were converted into gaseous products. He also reported that slightly alkaline reaction was favourable for second stage of digestion. Nelson et al (1939) reported in detail the anaerobic digestion of different organic materials like chopped fescue stalks, wheat straw, filter paper etc. at a pH range of 7.0 to 7.5 and at temperatures of 30°C and 50°C. The quality of biogas obtained was similar at both temperatures, but different materials produced different quantities of biogas and the composition of biogas also varied.

Desai and Biswas (1945) determined the different factors affecting biogas production from cattle dung

and vegetable litter with reference to the temperature influences and seasonal variation by designing a simple biogas plant. Jones and Stafford (1955) conducted experiments on methane production using industrial wastes in sewage sludge digesters and reported that toxic heavy metals, chemical wastes, chlorinated hydrocarbon and detergents affected hydraulic retention period and biogas production.

Acharya (1956) designed a simple cow-dung gas plant specially meant for village homes with 3 to 4 head of cattle yielding about 45 kgs of cow dung daily. Acharya (1958) examined some of the factors which influenced the production of combustible gas and manure during digestion of bullock dung and other organic waste materials. The essential factors studied were digestion period, dilution of bullock dung with water, proportion of inoculum, chemical composition and temperature. Hindin et al (1960) studied the effect of detention time on anaerobic digestion of sludge wherein it was found that one half of the volume of raw sludge needed a detention time of 90 days with an initial loading rate of 0.075 lb of volatile solids per cubic feet per day.

Prasad et al (1968) fermented various carbohydrates using one per cent nitrogen. They observed low

acid production and about 38 per cent methane reduction in complex carbohydrate molecule compared to the simpler carbohydrates. Grammes et al (1971) conducted experiments on anaerobic digestion of farm animal wastes and reported that loading rates should not be more than 0.18 lb vs/cft/day with retention time between 10 to 15 days.

Laura and Idnani (1971) showed increased biogas production from cowdung by addition of urea or calcium carbonate materials. Addition of cellulose also increased the rate of gas production but the biogas mixture obtained had a lower methane content. Hobson and Shaw (1973) worked on the anaerobic digestion of waste from an intensive pig unit. Diaz et al (1974) conducted experiment on the methane gas production as part of refuse recycling system. They reported biogas production at 20 and 30 per cent refuse loadings was equal to that at 100 per cent sludge loadings. Idnani and Varma-
rajan (1974) reported that cow dung added to anaerobic fermenter took 4 weeks to produce biogas upto 90 per cent of its gas yielding capacity. Optimum biogas production was obtained when total solids in the fermenting slurry was about 8 per cent and 15 per cent of the total nitrogen was converted to ammonical form. Pfeffer (1974) worked on the anaerobic fermentation of domestic

refuse and reported that it produced a significant source of methane.

Guha et al (1976) reported that water hyacinth can be used for the production of fuel and manure replacing cow dung and also reported that biogas production from water hyacinth was higher than cattle waste. Hobson and Shaw (1976) noted that production of methane from hydrogen and carbon dioxide by Methanobacterium formicicum was partially inhibited by total ammonia concentration of 3000 mg/litre and completely inhibited by 4000 mg/litre. Pfeffer and Khan (1976) showed that microbial production of methane from municipal refuse by giving a heat and caustic pre-treatment to determine increase in the biogas yield. A treatment temperature of 130°C and a sodium hydroxide concentration of 3 g/100 g of dry solids resulted in the highest biogas yield.

Anon (1977) studied the biogas production from weeds. Pathe et al (1977) found the seasonal variation on performance of anaerobic digestion of city refuse. The pH of the digesting mass remained constant around 6.8 and the average biogas production was 0.2 m³/kg volatile solid added per day and the volatile solids destruction ranged between 40 and 50 per cent.

Alone et al (1978) conducted experiment on anaerobic digestion of city refuse and cow dung. It was reported that the maximum biogas production was from a mixture containing 62.5 per cent of cow dung and 37.5 per cent of organic fraction. Knol et al (1978) made a preliminary study on biogas production from fruit and vegetable wastes and reported that volatile solids reduction ranged from 40 to 75 per cent. Moo-Young et al (1978) described a pilot-plant process for mesophilic anaerobic digesters. They loaded the digester with 7.5 percent dry matter cow manure and showed a biogas production rate of $0.23 \text{ m}^3/\text{kg}$ solid with a 60 per cent methane gas content. Sievers and Brine (1978) conducted experiment and showed carbon to nitrogen ratio of 15.5 to 19.1 was optimum for maximum methane gas production for swine manure. Carbon to nitrogen ratio less than 15.5 was found toxic to anaerobic digestion due to ammonia accumulation.

Deeshpande et al (1979) studied the use of water hyacinth as an additive, in biogas production. He reported that the water hyacinth enhances the volatile fatty acid in the fermenting slurry which was a precursor of methane in the anaerobic fermentation. The gas production rate with the water hyacinth-cow dung mixture was 4.3 litres per day with methane content of 40 to 60 per cent.

Hills (1979) changed the levels of C/N ratio of dairy manure by adding glucose initially and later cellulose for establishing the favourable C/N ratio for mixture of manure and carbonaceous wastes. He reported that greatest methane content production per unit loading rate occurred when the C/N ratio of the feed was 25. Klass and Ghosh (1979) reported that the digestion of Bermuda grass at mesophilic and thermophilic temperatures and obtained methane yields of $0.12 \text{ m}^3/\text{kg}$ volatile solid added under mesophilic conditions. They also reported that when supplemental nitrogen was added the methane yields increased to $0.22 \text{ m}^3/\text{kg}$ volatile solid added indicating nitrogen deficiency in the feed. Robbins et al (1979) found that methane production from added substrate was 1.5 times greater from delignified straw than from untreated straw when fermented with cattle manure. Sheila Bousfield et al (1979) conducted experiment on pilot-plant digestion of cattle and poultry wastes and showed that the methane content was lower from cattle than from poultry wastes. They observed that poultry waste digestion was better at lower than higher solids content, while the reverse was true for cattle waste. For both wastes, detention time of approximately 20 days was found optimal

Fujita (1980) studied the effect of corn addition

on the anaerobic digestion of swine manure. The biogas production was enhanced with more than 50 per cent of the carbon in maize stalks converted to biogas, but however had little effect on solids conversion efficiency. Hawkes et al (1980) designed a novel plug flow anaerobic digester to minimise the problem of scum formation and successfully tested on a laboratory scale using low solids pig manure as a substrate. Hawkes and Young (1980) reported a stable gas production stirring once in a day and feeding daily. The rate dropped sharply over 2 days starvation, requiring 2 to 3 days feeding to attain stable gas production. Hills (1980) reported biogas production from a high solids combination of dairy manure and barley straw. He increased the non-lignin carbon to nitrogen ratio of the feed to 30:1 and studied the different loading water for biogas production. Lang (1980) studied the complex digestion process for the production of biogas from whey, using whey or the distillation wastes recovered from the alcoholic fermentation. Lettinga (1980) reported biogas production from poultry droppings, cattle manure, sheep manure, lucerne hay etc., and found that poultry droppings produced more biogas than sheep or cattle manure for a 25-day retention time. They also studied the per cent volatile solids reduction of different

wastes. Rajasekharan (1980) also observed that cow dung, old slurry and water hyacinth mixture gave higher biogas yield than cow dung and old slurry mixture. He reported that water hyacinth substitution increased biogas production.

Fisher et al (1981) worked on anaerobic digestion of manure from swine fed on various diets and reported that changing swine ratio from corn-milo combination to corn-wheat combination resulted in lower gas production. Hashimoto et al (1981) reported the effect of ratio constituents, antibiotics, manure age and temperature on ultimate methane yield from beef cattle. Hills and Roberts (1981) conducted experiment to study the anaerobic digestion of dairy manure and field crop residues. The non-lignin carbon to nitrogen ratio of the various feed mixtures ranged between 12.3 and 40.0 and further reported that maximum bio gas production occurred when the non-lignin carbon to nitrogen ratio was between 25:1 and 32:1.

Huang et al (1981) worked on the potential of biological methane generation from chicken manure. They further reported that chicken manure therefore was able to support the methane yield at 270 lit/kg volatile

solid, a value comparatively higher than other kinds of livestock wastes. Rajasekharan (1981) experimenting on anaerobic digestion of fish and chicken wastes on the microbial population and biogas production reported that the fish waste gave maximum average gas output of 1038 cc/day compared to 899 cc/day by chicken waste over 12-weeks period. Singh et al (1981) reported that cattle waste substituted with 10 per cent press mud produced greater biogas compared to biogas produced by cattle waste alone.

Aubart et al (1982) worked on biogas production from pig, poultry and rabbit wastes. They also reported that biogas production at lower solids concentration was greater than at higher solids concentration for a 15-day retention time. Jain et al (1982) supplemented cattle waste with pig faeces at 10 per cent which resulted in an increased acid and gas production. Also the use of a spent slurry as inoculum at 5 per cent level reduced retention time by 4 weeks and improved biogas production. Odeyemi (1982) compared cassava leaves with two animal wastes viz. sheep and poultry manures and sewage sludge for biogas production. The peak production of biogas/kg for a 21-day

incubation was found maximum for poultry waste compared to other wastes.

Rajasekharan et al (1982) incorporated groundnut shell and composite mixture of weeds with cow dung and old slurry and observed the biogas production by anaerobic digestion. Singh et al (1982) studied the rate of anaerobic digestion of cattle waste and revealed that a 20-day retention time was optimum for highest gas returns per unit volume of the digester. He also reports that rates of cellulose digestion, loss of total solids and volatile solids were greatest in the initial period of digestion and slowed down with increasing period of digestion. Singh et al (1982) studied the production of biogas from cattle waste supplemented with poultry waste and saw-dust. Supplementation of cow dung with poultry waste at 10 per cent resulted in increased volatile fatty acids and high biogas production over cattle waste alone and cattle waste plus poultry waste plus saw-dust mixture.

Fisher (1983) observed production of methane gas from combination of wheat straw and swine manure. He reported that addition of wheat straw reduced biogas production per unit weight of volatile solid. Hills (1983) studied the various parameters and operating characteris-

tics of beef cattle waste. Four different volatile solids loading concentrations, two digester temperatures of 55°C and 60°C and varying detention time were studied to find out optimum biogas production. Jain *et al* (1983) conducted a comparative study between a semi-continuously operated and batch-type operated digesters for biogas production from cattle waste. They reported that loss of total solids, volatile solids and cellulose was more in batch-type digester than from KVIC semi-continuous digester. Singh *et al* (1983) reported that pre-digestion of cattle waste slurry increased acetate production. The biogas production was increased by 17 to 19 per cent and methane content from 68-75 per cent to 75-86 per cent.

2.1.2. Effect of temperature on biogas production from different agricultural wastes

The working of the biogas plant is based on fermentation of different organic materials. Being a biological process, it is effected by several factors, one of which is the temperature of the medium or system.

Idnani and Chawla (1969) reported that temperature influences bacterial activity adversely and found that biogas production was reduced to 13.5 lit./half-kg dung in winter as compared to 40.5 lit. in mid summer. Acharya in 1958 studied the effect of temperatures of different months in a year on biogas production from bullock dung.

He reported that temperatures in months of June (86.6°F) and July (83.2°F) produced greater biogas compared to temperatures of other months in that year (Sathianathan, 1975).

Pfeffer (1974) worked on anaerobic fermentation of domestic refuse and reported that optimum mesophilic temperature of 42°C and optimum thermophilic temperature of 60°C was favourable for significant production of fuel gas. Cooney and Wise (1975) experimented on thermophilic anaerobic digestion of organic solid wastes. Two temperatures of 37°C and 65°C were tested. Their results confirmed increased rate and conversion of waste to methane at high temperature. Vander Berg (1977) studied the effect of temperature on growth and activity of methanogenic cultures.

Feilden (1981) showed a relationship between critical solid concentration and temperature. He reported that the temperature requirement of $25-30^{\circ}\text{C}$ for solids which are less than the critical value and temperature of $40-44^{\circ}\text{C}$ for solids which are more than the critical solid value. Kanfuran (1982) operated full scale gas plant without heating at psychrophilic temperature. He reported that when once the digester was started successfully, the system was stable even after temperature drop, but the specific gas production was strongly dependent on temperature.

Nashimoto (1983) studied the effects of thermophilic (55°C) and mesophilic (35°C) anaerobic fermentation of swine manure. The highest methane production rate was achieved at 55°C with loading rates of 30.4 kg VS/m³. Hills (1983) operated the digestion of dairy waste at 35°C and 60°C. He reported that the methane yield for dairy waste when compared with beef, swine and poultry waste at identical operating conditions were much lower of the order of 30 per cent of beef waste yields. The minimum detention time at 35°C, 40°C and 60°C were 8, 6 and 4 days respectively.

Hills (1983) gave the design parameters and operating characteristics of beef cattle waste anaerobic digestion system. Two operating temperatures of 35°C and 60°C and 4 influx volatile solids loading concentrations were studied. For mesophilic digesters, temperature of 40°C; volatile solid loading of 83 g/litre and detention time of 8 days was optimal. For thermophilic digesters, the temperature of 60°C; volatile solid loading of 106 g/litre and detention time of 6 days was found optimal.

2.2 Studies on microbial population in soil as effected by organic matter incorporation

Application of organic matter and NPK fertilizers to soil are known to increase the microbial population. Balasubramanian *et al* (1972) reported that bacterial population was enhanced more by the application of phosphatic,

potassic and farm yard manure, while the fungal population was encouraged by farm yard manure and actinomycetes by nitrogen fertilizer.

Indiraraja and Raj (1979) reported that press mud application resulted in increased bacterial population of red soil and fungal populations of black soil. Ramaswami *et al* (1979) applied manures and fertilizers and studied the microbial population of soil. They found increased bacterial population with nitrogen application followed by cattle manure treatment. They reported that in general the microbial population was higher in soils receiving cattle manure than in those receiving mineral fertilizer. Actinomycetes populations increased in potassium and cattle manure treatment.

Makawi (1982) incorporated dried sludge, poultry, cow, horse and sheep manure and studied their effects on microbial populations and enzyme activity in the soil. Perre-cabrieles and Martin Alexander (1983) worked on growth of Rhizobium spp in soil amended with organic matter. Addition of corn-leaf residue or alfalfa residues reduced the number of 4 Rhizobium species. Sharma *et al* (1983) studied microbial changes in soil amended with continuous application of fertilizers, farm yard manure (FYM) and lime. They reported that bacteria, Azotobacter, cellulose decomposers and phosphate solubilizers increased in FYM, FYM plus lime.

They also revealed that farm yard manure application alone or in combination with the inorganic fertilizers and lime supported greater microbial populations of bacteria and actinomycetes.

Gautham et al (1984) worked on the effect of fertilizer and farm yard manure (FYM) application on soil bacteria. FYM or FYM plus NPK treatments markedly increased the number of bacteria.

2.3. Nitrogen mineralization in soil amended with organic wastes

Organic manures and plant residues differ markedly in their ability to supply available nitrogen to soils. Rapid mineralization has been observed in the presence of readily available nitrogen by Perry and Herman (1948), Nommick (1961) and Allison and Klein (1962). A detailed review on the mineralization aspects has been provided by Allison (1955) and Barthelomew (1965).

Tam and Magistad (1936), Hiltbold et al (1951), Colom and McCalla (1952), Janson and Clark (1952) and Amberger (1971) have all reported the effect of organic residue application on nitrate production. From these studies, it can be generalized that low nitrogen residues initially immobilized nitrogen from soil, and later released nitrate when mineralization set in. High nitrogen residues initially

liberated substantial quantities of nitrogen in available form followed by decreasingly lower rates of mineralization with the process of decomposition.

Jenson (1931) studied the microbiological aspects of farm yard manure and reported that nitrogen from farm yard manure nitrified rather slowly and never completely. Quastel and Scholefield (1951) have given methods and studied the effect of various additives on nitrification.

Acharya (1958) indicated that about 7.4 per cent of the total nitrogen added as digested slurry nitrified in a period of 3 months, as compared to about 4.75 per cent in the case of farm yard manure and 87 per cent in case of ammonium sulphate.

Rothwell and Hortenstine (1969) determined the effects of high levels of garbage compost, chicken manure, cow manure and sewage sludge on microbial activity carbon evolution and nitrification. They noted that nitrification decreased with increased levels of both sewage sludge and chicken manure and increased with increased levels of manure.

Laura and Idnani (1972) also reported that 7.64 per cent of the total nitrogen in digested slurry nitrified as compared to 5.05 for farm compost. Ryan et al (1973) studied nitrogen transformation and availability in soils incubated under aerobic conditions with different levels of an

anaerobically digested sewage sludge. The inorganic nitrogen at lower levels was all converted to nitrate and nitrite nitrogen while at higher levels a significant amount of ammonical nitrogen was not nitrified even after 16 weeks of incubation. Polesko *et al* (1974) in his laboratory experiment found that mineralization of the organic nitrogen in straw labelled with ^{32}P was greater with N, NP or NPK fertilizer than with no fertilizer or PK fertilizer.

Sabey *et al* (1975) studies using anaerobically digested sewage sludge and wood and bark residues added to clay loam observed that nitrate accumulation was low whenever the wood residue - sludge mixtures had more than 50 per cent wood refuse and that the wood-bark sludge mixed showed a tendency to immobilize nitrogen.

Kelling *et al* (1977) noted that digested liquid sewage sludge applied at rates from 3.75 to 60 metric tons/ha increased significantly the concentration of inorganic nitrogen and organic nitrogen. The applied organic nitrogen was mineralized upto 50 per cent within 3 weeks after the last sludge application. Raj and Sinha (1977) studied the rate of mineralization of nitrogen in town-compost mixed with different soils of Bihar state. Until 4th week, the mineralization rate of nitrogen was slow, but increased gradually reaching zenith by the 8th to 10th week. Nitrate nitrogen to ammonical nitrogen ratio were consistently greater than

unity indicating nitrogen mobilization in all 3 soil types studied. Tester et al (1977) conducted laboratory incubation studies to determine the rate of decomposition of sewage sludge compost in soil at an incubation temperature of 22°C. Nitrogen mineralization was lowest in the siltloam-compost treatment. In the sand compost mixture, mineral nitrogen was immobilized during incubation.

Epstein et al (1978) conducted an incubation study to determine nitrogen mineralization from the sewage sludge and sludge compost applied to a silt loam soil. Digested sludge gave net mineralization patterns similar to native soil organic nitrogen although larger amounts can be released from digested sludge. King et al (1978) incorporated fermented residue (wafers of press cake) at rates supplying 223, 446 and 669 ppm nitrogen incubated for 32 weeks. Nitrate nitrogen accumulated rather rapidly during first 8 weeks, with little accumulation thereafter.

Volz (1979) amended soil with fermentation residue and studied the nitrogen transformation. During the growing seasons, nitrate nitrogen accumulation greater than 80 mg/g over dry soil were observed in the top 5 cm treated soil, compared with accumulation of 15 mg/g or less in the control. Magdoff and Amadon (1980) applied anaerobically treated secondary sewage sludge to corn soils. About 54 per cent of the organic nitrogen added to the sludge amended

soils was mineralized under laboratory conditions. Sims and Boswell (1980) conducted experiment to study the effect of synthetic N-fertilizers, organic matter and fortified organic wastes on soil minerals, total nitrogen crop yield and elemental composition, soil levels of ammonical, nitrate and total nitrogen indicated that the organic waste materials provided adequate amounts of available nitrogen for crops.

Hsieh *et al* (1981) conducted laboratory incubation studies on nitrogen transformation in two sewage sludge soil systems. The nitrogen mineralization potential was found to be 30 and 38 per cent of the organic nitrogen in the activated sludge and digested sludge respectively. The mineralization rate constant was 0.026 per day at 21°C. Esteban *et al* (1982) conducted experiment on nitrification of pig slurry in an agricultural soil at rates of 39,000 and 146,000 litres slurry per hectare incubated at pH 8. They found that nitrification was more rapid at the lower application rate. All ammonical nitrogen was lost after 2 months and the rate of nitrate nitrogen formation was constant after 3 months.

Flowers and Callaghan (1983) studied the nitrification of soils incubated with pig slurry or ammonium sulphate. They found that the accumulation of nitrate nitrogen was linear for the addition of 50-250 mg $\text{NH}_4\text{-N/g}$ soil, either as ammonium sulphate or pig slurry. Addition of 250 mg ammonical nitrogen as ammonium sulphate caused a marked

inhibition of nitrification at all moisture content and temperature whereas in case of pig slurry it showed a marked increase in nitrification rate. Parker and Sommers (1983) determined the mineralization of sludge organic nitrogen during a 16-week incubation by analysis of inorganic nitrogen. The approximate amounts as a percentage of organic nitrogen were raw and primary, 25 per cent; waste activated, 40 per cent; anaerobically digested, 15 per cent; and compost, 8 per cent.

2.4. Manurial value of organic substrates

The manurial value of organic wastes and its use as a soil conditioner has been subjected to detailed study by several workers because of its advantages over inorganic fertilizers and their long term beneficial effects.

Acharya (1940) indicated that composts acted in three ways, namely (1) improved soil physical condition; (2) supplied plant nutrients; and (3) enhanced or increased biological factors that help to supply plant nutrients. Acharya (1945) collected data on the use of town compost on different crops and found that yields of groundnut, maize and chilli receiving compost was better than yields got from farm yard manure application. Acharya (1945) observed in his manurial trials that increased yields of crops was of the same order for both town compost and FYM for cereals but in case of vegetables, town compost gave higher yields compared to FYM.

Sanyasi Raju *et al* (1957) reported that compost and FYM did not increase the yields of short duration crops, like cereals significantly during the first year but in the second and third year they showed their superiority over no manure application. Gallino and Rodriguez (1963) reported best yields of sugarbeet from a combination of mineral fertilizers and composted refuse.

Kuszelewski and Jagiela (1973) found that untreated pig slurry was of higher fertilizing value compared to compost produced after mechanical and biological treatment of pig slurry and gave higher yields of maize, oats, sunflower, potato etc. Gupta and Singh (1974) revealed that addition of super phosphate to compost either while composting or to the mature compost gave significant better yields responses of rice and wheat than untreated compost soils. King *et al* (1974) applied grinded municipal refuse and liquid sewage sludge or liquid manure to land and later planted rye followed by maize, and observed highest yield of corn on soil receiving 188 metric tons per hectare of municipal refuse compared to soil receiving sludge alone and a combination of sludge and refuse, but rye forage yields were not affected by the treatments.

Duggan and Wiles (1976) determined the physical and chemical effects of municipal compost fortified with sewage sludge and nitrogen fertilizers on soil and corn plants and

found that corn grain yields were increased and soil physical properties improved with annual compost rates of 200 tons/acre applied for five years. Glenn (1976) in a survey on use of organic manures in crop production in southern India reported that farmers in Karnataka state utilised animal manure, urban compost and even cover crops on a regular basis to supplement chemical fertilizers to maintain soil fertility and to increase crop yields. Under actual farm conditions in Karnataka state, organic manures were found to improve yields of maize, jowar, sugarcane and other crops.

Furrer (1977) found that high rates of sewage sludge or pig slurry reduced yield and quality of wheat, but not maize, sugarbeet or grassland. Pain et al (1977) observed that fodder maize given cow slurry at 0, 35, 75 or 105 tons/ha and 0, 40, 80 or 120 kg inorganic nitrogen/ha, revealed that slurry upto 70 tons/ha improved response to inorganic nitrogen but at 105 tons/ha, it tended to delay maturity and decreased yields when combined with more than 40 kg inorganic nitrogen/ha.

Mazur et al (1979) revealed that cattle and pig slurries increased yields of the test crops, maize being especially responsive. Cattle slurry increased yields more than farm yard manure with the first crop, but was less effective than FYM on the after crops. Patrick et al (1979) conducted

experiment to study the effect of cattle feed lot manure and inorganic fertilizers on the improvement of subsoil productivity. They reported that the maize (ISA MAYA L) seedling emergence was 2 to 3 days sooner on the top soil and manure treated subsoil compared with untreated and fertilized subsoils. Subbaiah and Sree Ramulu (1979) studied the influence of sewage waste addition on the characters of soil and its effect on germination percentage, dry matter yield and macro-nutrient uptake by sorghum seedlings. Weil (1979) amended soil heavily with poultry manure to study the organic matter decomposition. It was reported that the overall ability of the soil to accept and dispose the poultry manure did not appear to be seriously impaired even at high rates of manure application.

Chellamuthu and Kodandaraman (1980) observed that the yield of ragi grain and straw increased with increased levels of nitrogen either as farm yard manure or ammonium sulphate. Indiraraja and Raj (1980) reported that press mud, a by product of sugar industry increased the plant heights, grain yield and straw yield compared to control for ragi crop. Ravi Kumar and Krishnamoorthy (1980) studied to evaluate the efficacy of organic and inorganic amendments on black soil, revealed that organic amendments viz. poultry manure, maize straw and FYM were superior to inorganic industrial waste and mineral amendments in improving the yield of ragi crop.

Ravi Kumar and Krishnamoorthy (1980) further conducted experiments by amending the soil with poultry manure, FYM, lime sludge and furnace slag on yield of finger millet. They reported that organic wastes improved the grain and straw yield of finger millet. Shanmugam and Ravi Kumar (1980) incorporated organic residue like FYM and pig manure at 25 tons/ha and observed that these manures increased the yield of sorghum (CSH-5).

Vasil'ev et al (1981) showed that anaerobically digested litterless manure lost organic matter of 7-18 per cent after 5-10 days and 31-33 per cent after 25-26 days. In micro-plot experiment with maize and a green house experiment with oats the fermented manure was as effective in increasing crop yield as unfermented manure. Bahtiya (1982) conducted experiment with barley as test plant and revealed that application of refuse compost, except at an optimum rate delayed germination by upto one week. Yields were increased by compost application except at highest rates. Juste (1982) tested 5 organic wastes (2 samples of pig manure and one each of sewage sludge, cattle manure and maize stover) with rye grass before and after anaerobic and aerobic digestion. At equal rates of dry matter, wastes treated anaerobically increased rye grass yield by 6 per cent when applied in combination with NPK and 17 per cent in the absence of nitrogen fertilizer. Niklewski et al (1982) treated maize

and fodder cabbage soils with 0, 20, 40 or 60 tons solid pig manure/ha with or without 70 kgs NPK/ha and with 0, 3, 6 or 9 kg rye straw per 40 kg manure. The highest fresh matter yield of maize and fodder cabbage were obtained with 60 tons manure per hectare and with additional NPK fertilizers.

Balakhonov et al (1983) conducted trials on demopodzolic soils and showed that effectiveness of the application of straw plus slurry or FYM plus bedding straw in increasing yields of potatoes, barley, perennial herbage species and fodder beet. Mathers and Stewart (1983) applied feed lot manure and found that yields of sorghum, corn silage and wheat at 22 tons/ha of manure annually gave maximum crop yields. Higher manure rates effectively improved soil physical properties but did not increase the yields.

Shiva Shankar et al (1976) reported that under field conditions, straw addition at 3 and 6 tons/ha improved soybean yields. They also reported that straw addition at 3 and 6 tons per hectare increased nodule weight over control. Joseph (1977) observed that nitrogen fixation and nodulation were severely suppressed by the addition of nitrogen source either as ammonium or nitrate nitrogen. Shiva Shankar et al (1978) in their experiment with field grown soybeans reported that straw application at 2 and 4 tons/ha with or without carbondioxide enrichment markedly increased the nitrogen fixation, nodule weight and yield over control. Sundaram et al

(1979) conducted experiment to find out the effect of nitrogen fertilizer on nodulation and nitrogen fixation in bengal gram. They reported that with increase in the nitrogen level of the soil, nodulation was significantly reduced.

Shivashankar and Shantaram (1980) reported that application of paddy straw to soil improved the yield of soybean significantly. The nodulation was unaffected in rainfed conditions and improved under irrigated conditions. Addition of cow dung slurry as a source of inoculum for straw decomposition failed to affect nodulation and yield of soybean. Robinson (1983) compared the yields between field bean and Adzuki bean in response to compost and nitrogen. Highest yields of field bean were obtained from compost plus inorganic nitrogen. Datta and Gupta (1983) studied the response of legume crops to press mud and lime application to soil. Press mud at 20 tons/ha with NPK fertilizers recorded significantly higher yield of soybean and pea greens over lime applied at 25 tons per hectare, thus showing the relative effectiveness of press mud.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

3.1. Experimental set-up for the laboratory scale biogas production.

The experiments in the laboratory were carried out by using three litre capacity bottles of uniform size as digestion chambers and one litre capacity gas holders for collecting the biogas. All the digestors were mouthed with one holed rubber cork and further sealed with wax in the sides to prevent any little gaseous exchange and thus made airtight.

The gas was collected by the downward displacement of water and the gas was filled up in the gas collecting jars. The volume of the gas produced during each 24 hours were measured by the water displacement from the gas collecting jars and calculated to normal temperature and pressure (NTP). The temperature and pressure of the atmosphere was noted at the time of measurement and the volume of biogas produced was calculated at NTP after deducting the saturated vapour pressure of water from the atmospheric pressure. Five per cent slurry from a working biogas plant was added to each digester as inoculum.

3.1.1. Studies on the effect of total solids concentration on biogas production from poultry droppings.

The effect of different concentration of total solids on biogas production from poultry droppings were conducted on laboratory scale digesters. The total solids in each digester were adjusted based on the data on the percentage

on a laboratory scale digesters. The total solids in each digester were adjusted based on the data on the percentage of moisture content in the fresh poultry droppings. The total solids established were 4.0, 5.0, 7.5, 10.0, 12.5 and 15.0 percent. The biogas produced at 10th, 30th and 60th day retention time was recorded. The changes in the total solids and volatile solids concentrations at different retention times were determined. The total and volatile solids were estimated as follows.

3.1.1.1. Total solids: Total solids of the poultry droppings were determined by keeping weighed quantities of the samples in an hot air electric oven at $103 \pm 1^{\circ}\text{C}$ to a constant weight. The weight of the samples remaining after drying to constant weight was the total solids and the loss in weight gives the moisture content.

3.1.1.2. Volatile solids: Volatile solids of the poultry droppings samples were determined by taking weighed quantities of dried samples at $103 \pm 1^{\circ}\text{C}$ in a silica crucible and keeping in a muffle furnace at temperatures of $550 \pm 50^{\circ}\text{C}$ for 3 to 4 hours. The crucibles later were directly transferred into a desiccator, cooled and weighed immediately. The portion of the sample remaining was the ash content (A.O.A.C., 1980). The difference between the dry weight initially taken and the ash remaining after ignition was the volatile solid or total carbon (Jackson, 1973).

3.1.2. Studies on the effect on the different initially adjusted pH on biogas production from poultry droppings

The effect of different initially adjusted pH and un-adjusted control were studied on biogas production from poultry droppings. 175 g quantity of poultry droppings on dry weight basis was loaded into the digesters at 5 per cent total solids concentration. Treatments with different pH's of 6.0, 7.0, 8.0 and 9.0 were established. The control treatment showed a pH of 7.6. The biogas produced at different retention time was recorded and measured as outlined in 3.1. The changes in pH during different intervals was measured potentiometrically (Phillip's pH meter).

3.1.3. Studies on the effect of different retention time on biogas production from poultry droppings

The effect of different retention time on biogas production from poultry droppings were studied. The digestion was carried out for a 90 days period. 175 g quantities on dry weight basis were loaded at 5 per cent total solids concentration into a 3 litre digester bottles. The gas production for different retention times was recorded and calculated at NTP. The composition of the biogas was determined as given below.

3.1.3.1. Analysis of biogas composition: The biogas collected by the downward displacement of the water was analysed for the percentage composition of methane, carbon dioxide

Plate-1: Orsat's gas analyzing apparatus.

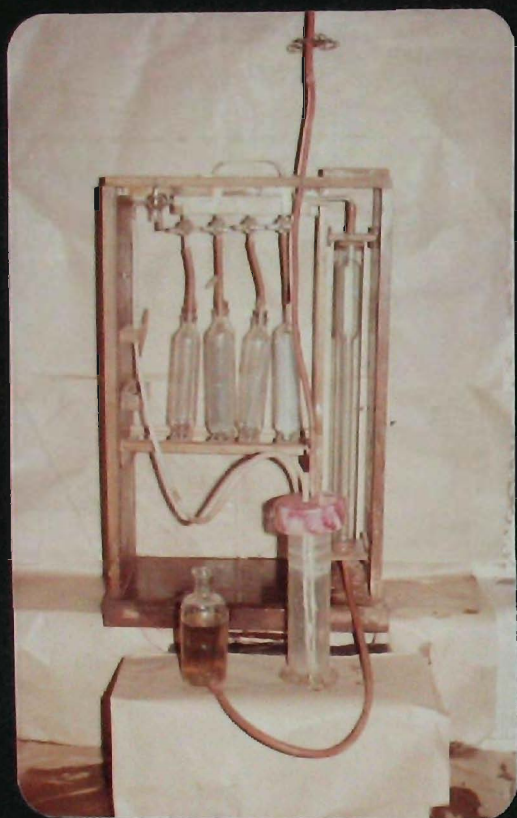


Plate-1

and residual gases using Orsat's gas analysing apparatus following the methods given by Vogel (1961). (Plate-1)

3.1.4. Studies on the biogas production by substituting different agricultural wastes with poultry droppings.

A laboratory experiment was carried out in a three litre digester bottles by substituting weighed quantities of cow dung, water hyacinth and banana leaves with poultry droppings in different proportions. The various treatments established by mixing cow dung, poultry droppings, water hyacinth and banana leaves are as follows.

1. Poultry droppings alone.....(control) (P.D.)
2. Cow dung alone..... (C.D.)
3. 1 part of poultry droppings +
3 parts cow dung..... (PD:CD; 1:3)
4. 3 parts poultry droppings +
1 part cow dung (PD:CD; 3:1)
5. 1 part poultry droppings +
1 part cow dung (PD:CD; 1:1)
6. Water hyacinth alone..... (WH)
7. Poultry droppings+ 10% water hyacinth..(PD+10% WH)
8. Poultry droppings +20% water hyacinth..(PD+20% WH)
9. Banana leaves alone..... (BL)
10. Poultry droppings + 10% banana leaves..(PD+10% BL)
11. Poultry droppings + 20% banana leaves..(PD+20% BL)

In all the treatments 200 g quantities on dry weight basis were established. Treatments 1,4,6,7,8,9,10 and 11 are diluted with tap water to get 5 per cent total

solids. Treatments 2 and 3 are diluted to 8 per cent total solids while treatment 4 was diluted to give 6 per cent total solids. 20 g of water hyacinth and 20 g of banana leaves were added to 180 g of poultry droppings for the treatments 7 and 10. Similarly in case of treatments 8 and 11, 40 g of water hyacinth and 40 g of banana leaves were added to 160 g poultry droppings.

The biogas produced at different intervals of fermentation were recorded and calculated at NTP. Samples were taken out from the digesters at different retention times and analysed for nitrogen, phosphorus, cellulose, total solids and volatile solids.

3.1.4.1. Moisture content: Samples were collected, weighed and dried in an hot air electric oven at 100°C to constant weight and the percentage of moisture content was calculated.

The dried materials were powdered in an electric grinder and stored in a butter paper bags for further analysis.

3.1.4.2. Nitrogen: The total nitrogen in the samples was estimated by following the micro-kjedhal method as outlined by Jackson (1973).

The analysis was done on five hundred milligrams portions of oven dried, finely powdered (to pass through a 100 mesh sieve) samples which involved digestion with concentrated sulphuric acid in the presence of 200 mg catalyst mixture.

containing potassium sulphate, copper sulphate and selenium in the ratio of 100:10:1. Five ml of concentrated sulphuric acid was used and the samples were digested for 12 hours on a micro-kjeldhal digestion unit. The digested samples were diluted with distill water and distilled over after addition of sufficient quantities (about 20 ml) of 40 per cent sodium hydroxide to make the digest alkaline, in a parnas-wayers type semi-micro kjeldhal distillation unit. The evolved ammonia was absorbed in a 4 per cent boric acid solution and titrated against a 0.05 N sulphuric acid. A standard was run by using 1 mg of nitrogen per 3 ml solution of ammonium sulphate and the titre values were converted to milligrams of nitrogen. And then, the percentage of nitrogen was calculated in the samples by estimating the volumes of the acid consumed.

3.1.4.3. Total phosphorus: The elemental composition of different substrates were determined by following vanado-molybdo phosphoric yellow colour method, in nitric acid system as outlined by Jackson (1973).

Five hundred milligrams dried and powdered samples were digested with 10 ml of a triacid mixture consisting of concentrated nitric acid, concentrated sulphuric acid and concentrated perchloric acid in the ratio of 10:1:4 on a hot plate until dense brown fumes are evolved. The digestion was allowed to continue till dense white fumes

of sulphuric acid appeared under low heat. Completion of digestion was indicated by a colourless nature of the liquid remaining in the flask. Small amounts of distilled water was added and transferred to 50 ml volumetric flask and volume was made up with distilled water. 5 ml of this aliquot was taken into another 50 ml volumetric flask and the colour was developed using 10 ml vanado molybdate reagent and the volume made up with distilled water. After the colour was stabilised for 15 minutes, it was read at 420 nm in a spectronic-20 (Bausch and Lomb).

Vanado molybdate reagent: Reagent 'A' was prepared by dissolving 25 gm of ammonium molybdate in 400 ml water. Reagent 'B' was prepared by dissolving 1.25 gm of ammonium metavanadate in 300 ml boiling water. After cooling, 250 ml of concentrated nitric acid was added and the solution was cooled. Finally 'A' and 'B' were mixed and volume made up to one litre to give Vanado molybdate reagent.

3.1.4.5. Cellulose: The cellulose content of different substrated was determined by semi micro determination using anthrone reagent as described by Updegraff (1969).

Two hundred and fifty milligrams dried powdered samples were taken into a test tube and 30 ml of acetic nitric reagent was added. It was mixed thoroughly by adding 1 ml, mixed well on a vortex mixture, then adding

the remaining 2 ml and remixing, with a plastic sheet wrapped on the top to reduce evaporation and create a reflexing action, tubes were placed in a boiling water bath for 30 minutes. Then tubes were centrifuged at high speed (6000 rpm) for five minutes. Supernatant was decanted and discarded. 10 ml of distilled water was added as explained above. They were further centrifuged for five minutes at high speed (6000 rpm). Again the supernatant was decanted and discarded. Then 10 ml of 67 per cent sulphuric acid was added, mixed thoroughly and allowed to stand for one hour. 1 ml of this was diluted with distilled water to 100 ml. From this 1 ml of aliquot was taken out into a test tube and 4 ml of distilled water was added. The tubes were placed in an ice bath to cool. Then 10 ml of anthrone reagent was added by layering with a pipette and mixed well on vortex mixture and returned to ice bath untill all tubes were mixed. These tubes were put in the boiling water bath for 16 minutes by covering with polythene sheet on top. Tubes were cooled in ice bath for 2 to 3 minutes and allowed to stand at a room temperature for 5 to 10 minutes. Colour was read in spectronic-20 (Bausch and Lomb) at 620 nm against a reagent blank.

Standard curve was prepared by dissolving 150 mg pure cellulose dried for 6 hours at 105°C and cooled over anhydrous alumina in 10 ml 67 per cent sulphuric acid with

gentle heat. Now this was diluted to 500 ml with distilled water to contain 100 ug cellulose per ml. It was then analysed to 0.5, 1.0 and 1.5 ml stock standard corresponding to 50, 100 and 150 ug of cellulose. The volume was made upto 5 ml and further colour development and readings were taken according to procedure mentioned above.

Total solids and volatile solids were determined as outlined in 3.1.1.1. and 3.1.1.2.

3.1.5. Studies on biogas production on a pilot plant project from poultry droppings and cow dung.

Description of pilot plant digester: An experiment was conducted on a pilot plant project for biogas production from poultry droppings and cow dung.

The digester was made from a cylindrical drum of length 4 feet and diameter 1 foot and 6 inches. The volume of the digester was 5.3 cubic feet or 0.51 cubic metre. The digesters are fabricated to give 5.3 cubic feet capacity at Sri Venkateswara industries, Guttahalli, Bangalore. The gas collecting drum had a capacity of 1.47 cubic feet. On the top of the gas collecting drum, there was a single outlet of 1 inch diameter connected to a tap valve for the control of flow rate of biogas. The rods supporting the gas collecting drum glides over a bush welded over the top of the digester. At the bottom of these rods, screws were provided to block the upward movement of gas collecting

Plate-2: Pilot-plant digester.



Plate-2

drum once it reaches the peak. On the sides of the digester three openings of 1.5 inches diameter at different heights were gas welded so as to facilitate easy collection of the samples during anaerobic fermentation of the substrates. Inlet and outlet pipes (6 inches diameter) were also fixed to the digester as shown in plate-2.

By knowing the optimum parameters as obtained from the laboratory scale experiments, pilot plant studies were conducted by loading the poultry droppings at 5 per cent total solids concentration. The pH of the poultry droppings slurry was 7.4. The digester was loaded with 48 kgs of fresh poultry droppings (14.4 kg on dry weight basis). The biogas produced for a 50-day period was recorded. The manurial value of nitrogen, phosphorous and cellulose was determined by methods mentioned earlier. Total solids and volatile solids before and after anaerobic fermentation was determined.

Similar experiment was carried out with cow dung at 8 per cent total solids concentration. The pH of the slurry was 7.12. The biogas produced for a 50-day period was recorded. The manurial values of nitrogen, phosphorous and cellulose were determined. Total solids and volatile solids were determined before and after anaerobic fermentation.

3.2.1. Studies of the organic matter amended soils on
microbial populations.

The experiment was conducted to study the effect of organic matter viz., fresh poultry droppings, digested slurry and farm yard manure addition on soil microbial populations. The NPK fertilizers were supplemented to soils equally in all the treatments. Eight treatments with three replications in each were maintained which were as follows.

1. Soil alone Control
2. Soil + farm yard manure at 10T/ha.... FYM - 10 - T
3. Soil + fresh poultry droppings at 5T/ha.. F-5-T
4. Soil " " at 10 T/ha ...F-10-T
5. Soil + " " at 20 T/ha.. .F-20-T
6. Soil + digested slurry at 5 T/ha....D-5-T
7. Soil + " " at 10 T/ha....D-10-T
8. Soil + " " at 20 T/ha....D-20-T

In this laboratory incubation study 1000 g portions of soil ground to pass through 2 mm sieve were placed in plastic pots. NPK fertilizers at the rate of 87 mg of urea 126 mg of super phosphate and 33 mg of mureate of potash were applied to all the treatments equivalent to 1000 kg N, 50 kg P_2O_5 and 50 kg K_2O per ha. respectively.

Fresh poultry manure was applied at the rates of 6.67 g, 13.33 g and 26.67 g for the treatments receiving organic amendments at 5, 10 and 20 tons per hectare respectively (2g,4g and 8g respectively on dry weight basis). Similarly, anaerobically digested poultry slurry was applied at the rates of 53.19, 106.38 and 212.77 g for the treatments receiving organic amendments at 5, 10 and 20 tons per hectare respectively. (2 g, 4 g and 8 g respectively on dry weight basis). Farm yard manure was applied at the rate of 5.6 g for the treatment receiving 10 tons per hectare.

After establishing the various treatments the moisture content in all the pots were brought upto 60 per cent of the water holding capacity by adding suitable amounts of distilled water. The pots were covered with plastic lids. Four pin holes were made on the top cover to facilitate gas exchange. Microbial populations were obtained from 10 g portions of amended soils.

3.2.2. Soil Moisture:

Moisture content of the soil samples was determined by drying 10.0 g portions of the samples to constant weight at 105°C.

3.2.3. Microbial Populations:

Standard dilution plate count technique was used for enumeration of bacteria, fungi and actinomycetes.

Bacteria: Soil extract agar medium as modified by Bunt and Rovira (1965) was used. The composition of the medium is given in appendix-I.

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Fungi: Martin's Rose Bengal agar medium (Martin, 1952) was used for plating the fungal dilutions. Just before use, to the medium 3 ml of Streptomycin sulphate was added per litre of the medium. The composition of the medium is given in appendix-II.

Actinomycetes: Kuster's agar (Kuster and Williams, 1964) medium was used to plate actinomycetes populations. The composition of the medium is given in the appendix-III.

Plating for the bacteria, fungi and actinomycetes were done on 0, 30th and 60th day of incubation. The population in all the treatments was expressed on per gram dry soil.

3.3.1. Nitrogen mineralization studies:

The same treatments as outlined in section 3.2.1. were used to study the effect of fresh poultry droppings, anaerobically digested slurry and farm yard manure addition on nitrogen mineralization in soil.

This experiment was conducted simultaneously along with the experiment as outlined in section 3.2.1. Samples were collected using a thick walled glass cylinder open at both ends. The soil collected were mixed thoroughly and 10 g soil was taken for further analysis. The moisture contents of the soils samples and ammonical as well as nitrate nitrogen content were determined. The samples were collected at weekly intervals.

10 g of soil sample drawn after thorough mixing

was vigorously shaken for 30 minutes with 50 ml Morgan's extractant (Morgan's extractants: 100 g sodium acetate + 30 ml glacial acetic acid, volume made up to 1 litre, pH adjusted to 4.8). The soil suspension was filtered through Whatman No. 1 filter paper by quantitatively transferring all the soil. Filtrate was refiltered after adding a spatula full of activated charcoal to take care of turbidity and pigments, if any. The clear filtrate was obtained and suitable aliquots of this filtrate were used for the determination of ammonical and nitrate nitrogen.

3.3.1.1. Ammonical nitrogen:

Ammonical nitrogen in the soil was established calorimetrically at 410 nm in a Bausch and Lomb spectronic-20 by nesslerisation (Jackson, 1973).

For nesslerisation 2 ml of aliquot was taken in a 10 ml volumetric flask, to this was added 0.2 ml of a 10 per cent acidified (pH 2.5) solution of sodium chloride. Then 0.5 ml of nessler's reagent was added and the solution was made up to volume with distilled water, mixed thoroughly and the transmittance read at the end of 25 minute standing in a Bausch and Lomb spectronic-20 calorimeter using 410 nm light maxima.

3.3.1.2. Nitrate nitrogen:

The nitrate nitrogen in the soil samples was estimated

by phenol 2, 4- disulphonic acid method (Jackson,1973). 10 ml of the filtrate were transferred to porcelain evaporating dishes with a pipette and evaporated on a water bath. After complete evaporation to dryness, 3 ml of phenol didulphonic acid reagent was added. After allowing the dish to stand for 10 minutes, 20 ml water was added. Then dilute ammonium hydroxide (1:1) was added to make the solution alkaline. The content of this dish was transferred to a 100 ml volume flask and diluted to volume with distilled water. The intensity of the yellow colour was measured calorimetrically in a Bausch and Lomb spectronic-20 calorimeter at 420 nm against a reagent blank.

Ammonical and nitrate nitrogen were calculated by referring to their respective standard calibration graphs. The values are expressed on per 100 g over dry soil.

3.4.1. Manurial value of Organic manures:

3.4.1.1. Studies on ragi crop: A pot culture experiment was conducted under green house conditions at GKVK campus, Bangalore, to study the comparative effects of fresh poultry droppings, anaerobically digested slurry and farm yard manure on the dry matter yields and nitrogen uptake by ragi plants. The treatments were the same as outlined in section 3.2.1. Each of the treatments were replicated three times.

All the treatment pots contained 9 kg soil each plus the other manures depending upon the treatments. Fresh poultry manure was applied at the rates of 60 g, 120 g and 240 g for the treatments receiving organic amendments at 5, 10 and 20 tons per hectare respectively (18 g, 36 g and 72 g respectively on dry weight basis). Similarly anaerobically digested slurry were applied at the rates of 478.72, 957.45 and 1914.89 g for the treatments receiving organic amendments at 5, 10 and 20 tons per hectare respectively (18 g, 36 g and 72 g respectively on dry weight basis). Farm yard manure was applied at the rate of 51.43 g for the treatment receiving 10 tons per hectare. NPK fertilizers at the rate of 0.78 g of urea, 1.125 g of super phosphate and 0.30 g of muriate of potash were applied to all the treatments equivalent to 100 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare respectively.

After establishing all the treatments, ragi seedlings of 25 days age were transplanted at the rate of 4 seedlings per pot (Indaf-5 variety ragi seeds were sown in one pot for raising nursery). After 12 days of transplantation, seedlings were thinned out leaving two plants per pot. The plants were grown for 60 days. After 60 days the plants were removed, the roots washed with water to remove adhering soil particles and air dried for 3 days. Then the roots and the shoots portion were separated and placed in a brown paper bag and oven dried at $60^{\circ}C$ to a

constant weight. The weight of the oven dried portion of shoot and root were recorded on a top pan balance. The samples were then ground in electric grinder and stored in butter paper bags for nitrogen estimation.

3.4.1.2. Studies on Cowpea crop:

A pot culture experiment was conducted under green house conditions of the GKVK campus, Bangalore, to study the effect of fresh poultry manure, digested slurry and farm yard manure on the dry matter yields, nitrogen uptake and nodulation by cowpea plants. There were 8 treatments as outlined section 3.2.1. The application rate of organic manure were same as outlined in section 3.4.1.1. NPK fertilizers were applied at the rate of 0.19 g of urea, 1.13 g of super phosphate and 0.30 g of murexate of potash to all the treatments equivalent to 25 kg N, 50 kg P_2O_5 and 50 kg of K_2O per hectare respectively.

Cowpea seeds were treated with Rhizobium strain TAL 169. Four seeds were grown in each pot which were later thinned out to two seedlings per pot after 12 days. At 60 days age of crop, plants were harvested, washed and air dried. Afterwards it was oven dried at $60^{\circ}C$ to constant weight. The nodules were separated from the plant root system and dried separately. The oven dried weights of shoot, root and nodules were recorded by the top-pan balance. The shoot portions were then ground by electric grinder and stored in butter paper bags for nitrogen estimation.

EXPERIMENTAL RESULTS

Plate-3: Laboratory scale set-up for biogas production.



Plate-3

IV. RESULTS

Biogas production by anaerobic digestion of different organic wastes is effected by several factors like total and volatile solids concentration, pH, retention time, temperature etc. Some of the factors which effected and influenced biogas production were explained below. The experimental set-up of biogas production from different substrates is given in Plate-1. The characteristics of the various substrates used for biogas production is given in table -1.

4.1.1. Effect of total solids concentration on biogas production from poultry droppings

The effect of different total solids of poultry droppings on biogas production were studied. The biogas produced was determined by water displacement method. The results are given in table-2 (Fig.1).

The data indicated that significantly greater biogas was obtained at lower total solids compared to higher total solids. Maximum total biogas production of 23811 ml was obtained at 5 per cent total solids and minimum total biogas production was obtained at 15 per cent total solids concentration. The total biogas produced at 4 per cent and 7.5 per cent total solids was 22361 ml and 21643 ml respectively which closely followed the biogas produced by 5 per cent total solids treatment. The biogas produced during first 30-days

Table 1: Chemical composition of the various substrates used for biogas production

Constitu- ent	Nitro- gen (%)	Total phosp- horus (%)	Cellu- lose (%)	Total carbon (%)	* C/H	Mole- ture (%)	Ash (%)
Cow dung(CD)	1.52	0.422	23.92	83.7	55.07	82.0	16.3
Poultry droppings(PD)	2.24	1.312	26.50	63.9	30.76	70.0	31.1
Water hyacinth(WH)	1.67	0.410	32.47	86.9	52.04	94.2	13.1
Banana leaves (BL)	1.12	0.608	31.94	83.9	79.37	93.4	11.1

* Total carbon

Table 2: Effect of total solids concentration on biogas production from poultry droppings

Total solids (%)	Biogas production(ml)			Total biogas (ml)	Biogas (ml/g)
	Hydraulic retention time (days)				
	10	30	60		
4.0	3652	9743	9926	22361	149.1
5.0	3903	10933	8950	23811	152.1
7.5	3932	9204	8427	21643	144.3
10.0	2823	8960	8374	20157	134.4
12.5	2859	7699	7839	18347	122.3
15.0	2001	6649	8245	16695	112.7
F - Value	**	**	**	**	-
C.D. at 5%	574	1755	204	3742	-

Note: The average mean room temperature on 10th, 30th and 60th day of digestion periods were 23.7°C, 24.3°C and 30.0°C respectively.

** Significant at 5 per cent and 1 per cent.

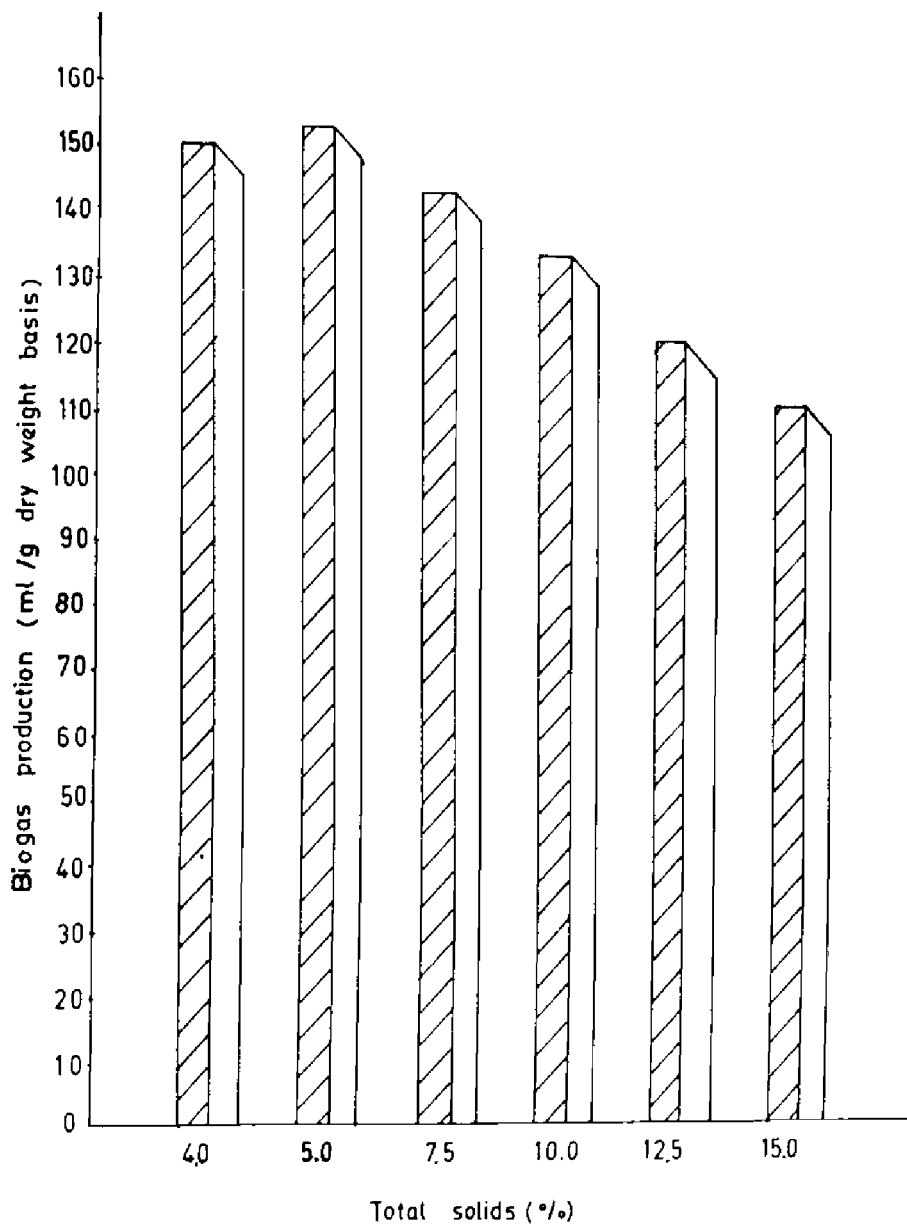


FIG:1 EFFECT OF TOTAL SOLIDS CONCENTRATION ON BIOGAS PRODUCTION FROM POULTRY DROPPINGS

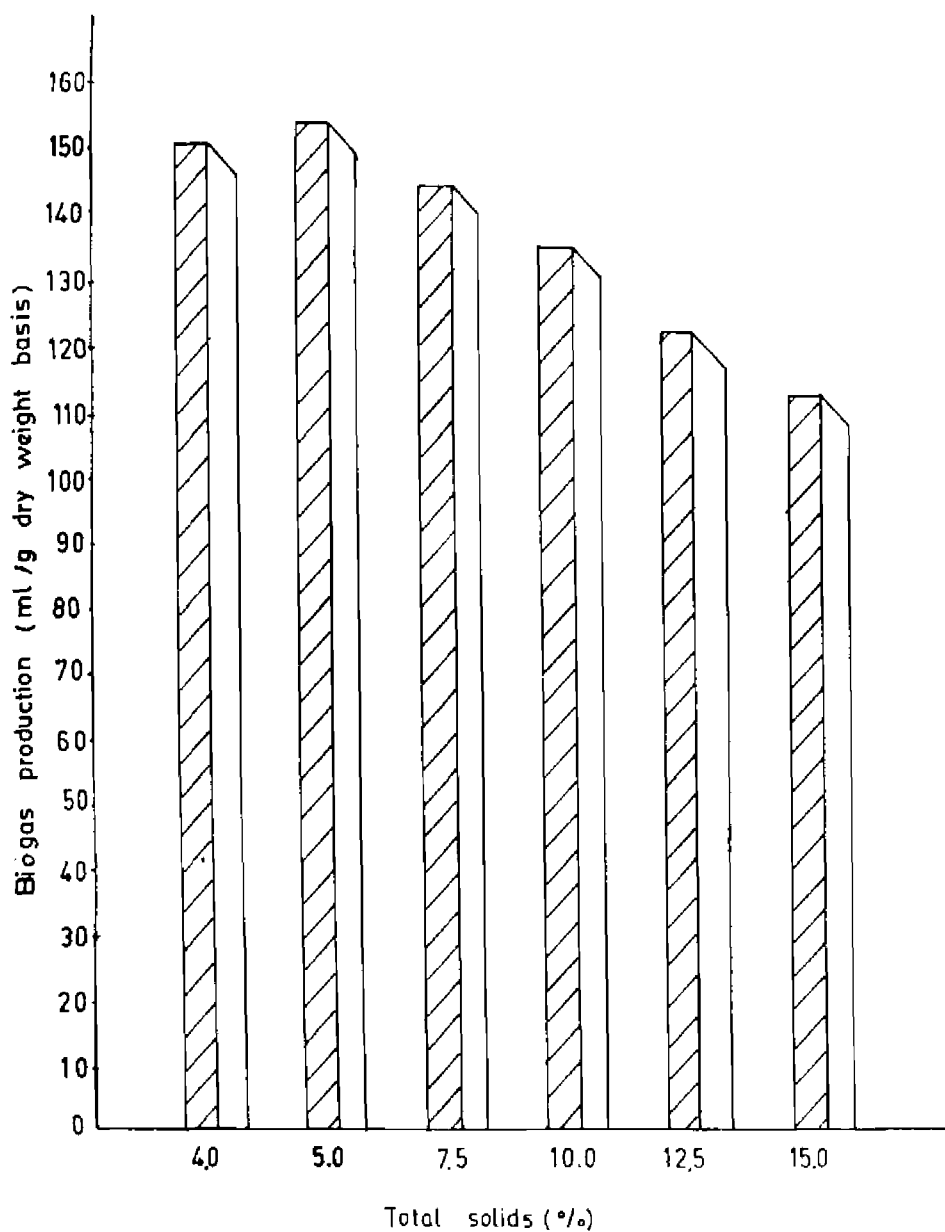


FIG:1 EFFECT OF TOTAL SOLIDS CONCENTRATION ON BIOGAS PRODUCTION FROM POULTRY DROPPINGS

was more compared to that produced during last 30-days. The biogas produced during first 30 days by 5 per cent total solids treatment was significantly greater than the biogas produced by 10.0, 12.5 and 15.0 per cent total solids treatments.

Changes in total solids and volatile solids: The changes occurring in total and volatile solids during 0, 30th and 60th day periods were determined. The results are presented in table-3 (Fig. 2)

The data indicated that per cent loss of total and volatile solids by 4.0 and 5.0 per cent solids treatments were significantly greater compared to higher total solids of 10.0, 12.5 and 15.0 per cent. The treatment with 5 per cent total solids degraded maximum in total and volatile solids in the order of 28.20 and 40.04 per cent respectively while the treatment with 15 per cent total solids degraded minimum in total and volatile solids in the order of 14.72 and 23.34 per cent respectively. The treatment with 4 per cent total solids closely followed 5 per cent total solids treatment and showed second highest per cent degradation of total and volatile solids in the order of 27.23 and 36.74 respectively. The per cent degradation in total and volatile solids was more than 50 per cent during the first 30 days compared to the last 30 days in all the treatments.

Table 3: Changes in total solids and volatile solids during biogas production

Total initial solids (%)	Total solids (%)			Volatile solids(%)		
	Hydraulic retention time (days)			Hydraulic retention time (days)		
	0	30	60	0	30	60
4	4.000 **(0.0)	3.420 (14.50)	2.911 (27.23)	70.760 (0.0)	55.040 (22.22)	44.720 (36.74)
5	5.000 (0.0)	4.246 (15.08)	3.590 (28.20)	70.760 (0.0)	52.575 (25.70)	42.426 (40.04)
7.5	7.500 (0.0)	6.432 (14.24)	5.694 (24.08)	70.760 (0.0)	56.975 (19.34)	46.091 (38.73)
10.0	10.000 (0.0)	8.784 (12.16)	7.945 (20.55)	70.760 (0.0)	57.145 (19.24)	47.974 (33.62)
12.5	12.500 (0.0)	11.326 (9.39)	10.428 (16.58)	70.760 (0.0)	59.400 (16.05)	51.047 (27.86)
15.0	15.000 (0.0)	13.565 (10.45)	12.792 (14.72)	70.760 (0.0)	61.789 (12.69)	54.245 (23.34)
F - Value	-	**	**	-	**	**
C.D. at 5%	-	1.192	1.494	-	1.551	1.440

* Total solids

** Figures in parenthesis indicate % degradation.

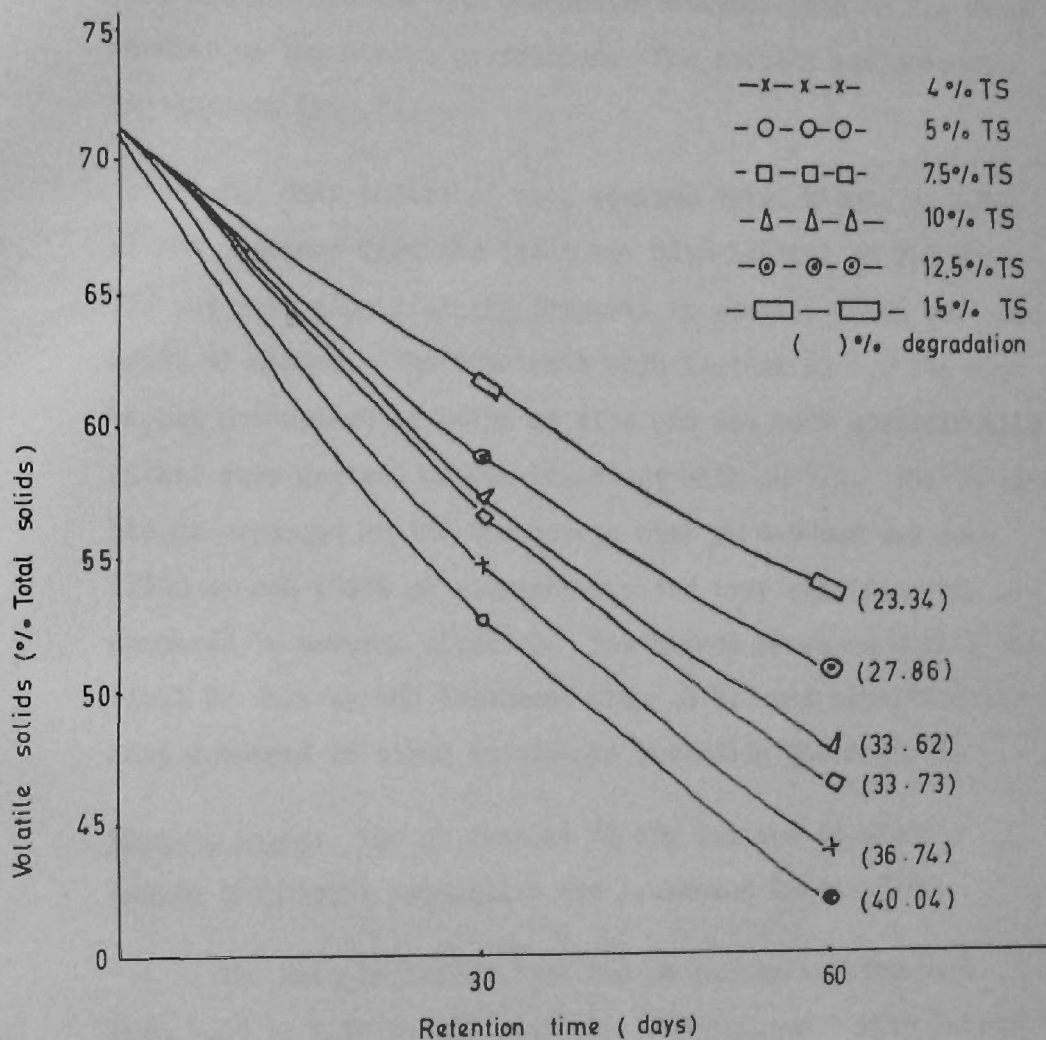


FIG 2 CHANGES IN VOLATILE SOLIDS DURING BIOGAS PRODUCTION FROM POULTRY DROPPINGS

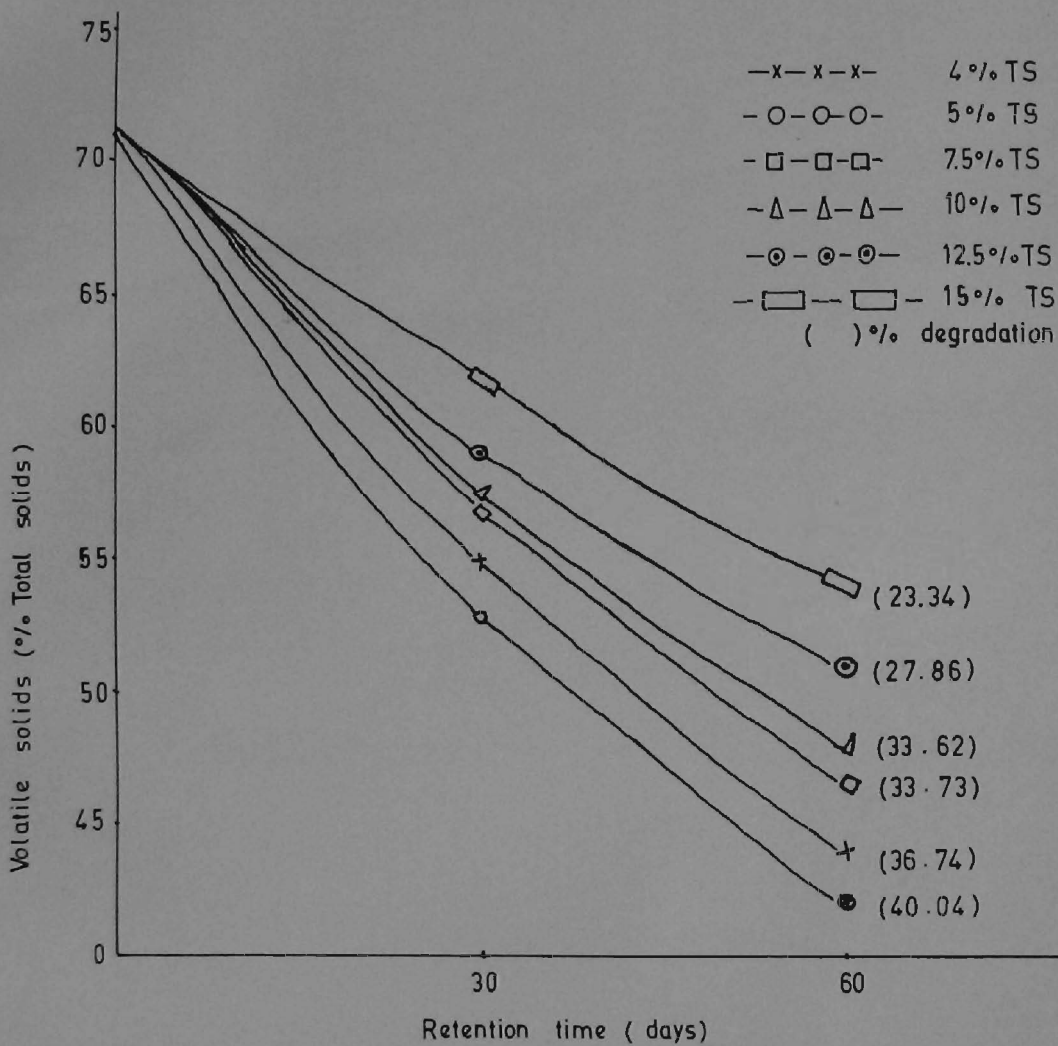


FIG 2 CHANGES IN VOLATILE SOLIDS DURING BIOGAS PRODUCTION FROM POULTRY DROPPINGS

4.1.2. Effect of different initial pH on biogas production from poultry droppings

The effect of different initially adjusted pH of 6.0, 7.0, 8.0 and 9.0 and the unadjusted control with pH 7.6 were studied on the biogas production. The results are presented in table-4a (Fig.3).

The data indicated that maximum total biogas of 24388 ml was obtained from the treatment with initial pH 7.0 and did not vary significantly compared to control which produced 24181 ml biogas. The treatment with initial pH 8.0 and with biogas production of 24106 ml also did not vary significantly either from control or the treatment with pH 7.0. The total biogas produced by the treatments with pH 6.0 and 9.0 were 17920 ml and 13625 ml respectively and were significantly less compared to control digester. The biogas produced during the first 30 days by the treatment with pH 7.0 was significantly more compared to other treatments including the control.

Changes in pH: The pH changes of the various treatments during the biogas production are presented in table-4b.

The data indicated that the pH gradually decreased from 7.60 to 7.04 in the control. The treatment with initial pH 8.0 also decreased gradually to 7.24 at the end of the 60th day. For the treatment with initial pH 9.0, there was a drastic decrease during first 10 days and then the decrease

Table 4a: Optimum pH requirement for biogas production from poultry droppings

Treatments	Total biogas (ml)				
	Retention time (days)				ml/g
	10	30	60	Total(ml)	
pH = 7.6(control)	2079	9283	12819	24181	138.2
pH = 6.0	1032	7345	9543	17920	102.4
pH = 7.0	2164	9951	12473	24588	140.5
pH = 8.0	2539	8052	13516	24106	137.8
pH = 9.0	2047	6168	5410	13625	77.9
F - Value	**	**	**	**	
C.D. at 5%	287	663	1243	2980	

Note: The average mean room temperature on 10th, 30th and 60th day of digestion period was 23.34°C, 21.30°C and 21.10°C respectively.

Table 4b: Changes in pH during biogas production

Treatments	pH		
	Retention time (days)		
	10	30	60
pH = 7.6(Control)	7.42	7.28	7.04
pH = 6.0	7.12	7.02	6.91
pH = 7.0	7.44	7.31	7.19
pH = 8.0	7.69	7.54	7.24
pH = 9.0	7.78	7.60	7.54

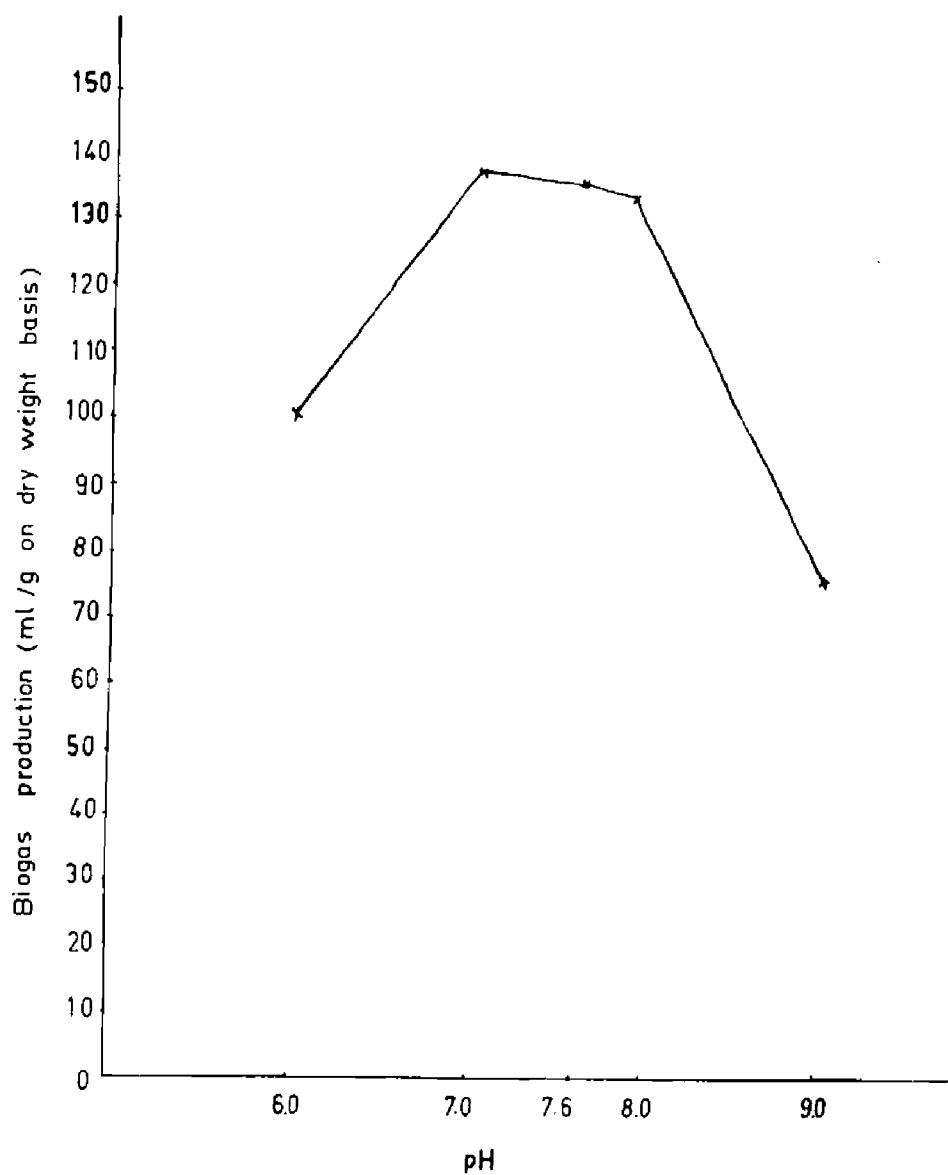


FIG:3 INFLUENCE OF INITIAL pH ON BIOGAS PRODUCTION
FROM POULTRY DROPPINGS

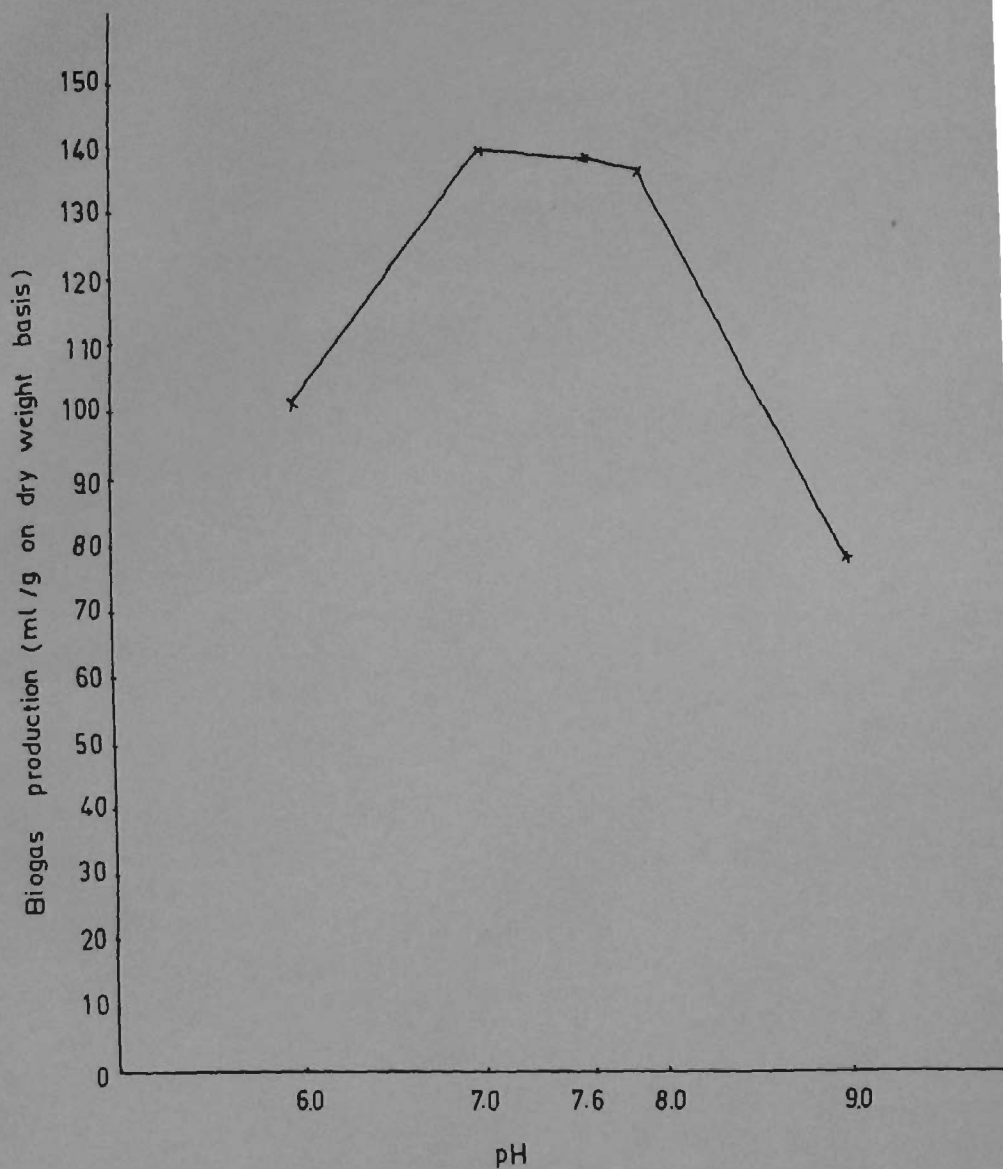


FIG:3 INFLUENCE OF INITIAL pH ON BIOGAS PRODUCTION
FROM POULTRY DROPPINGS

was gradual. The treatment with pH 6.0, increased to 7.12 during the first 10 days and decreased to 6.91 at the end of 60th day. The treatment with pH 7.0, increased to 7.44 during the first 10 days and then decreased to 7.19 at the end of 60th day.

4.1.3. Effect of retention time on biogas production from poultry droppings

The effect of different retention time on the biogas production was studied to find out the optimum retention time for maximum biogas production. The quantities and percentages of methane and carbon dioxide were also calculated. The results are presented in table-5 (Fig.4).

The biogas production started from the third day and the total biogas produced for every 5-day frequency initially and 10-days frequency later was calculated upto 90 days after which the biogas production was negligible. The data indicated that the biogas production during the first 40 days was greater compared to the biogas produced in the last 50 days. The biogas production increased upto 25 days period and then decreased for the rest of the retention period. During the first 50 days, the gas production was 26129 ml which accounted for 78.12 per cent of the total biogas produced for a 90-day period. The biogas produced during the last 40 days represented only 21.89 per cent of the total biogas production.

The methane yield for the first 50 days retention time

Table 5: Effect of different retention time on the quality of biogas production from poultry droppings.

Retention time (days)	Total biogas (ml)	Methane		Carbon dioxide		Residual gas		% Biogas to total
		Total	%	Total	%	Total	%	
5	1127	326	28.90	642	56.93	159	14.17	3.38
10	2089	1025	49.04	873	41.80	191	9.16	6.26
15	2746	1461	53.20	1033	37.63	252	9.17	8.24
20	2991	1738	58.76	1050	35.10	183	6.14	9.01
25	4082	2731	66.89	916	22.45	435	10.66	12.25
30	3472	2365	68.11	757	21.80	350	10.09	10.42
35	3006	1978	65.80	679	22.60	349	11.64	9.01
40	2501	1863	74.50	480	19.20	158	6.30	7.51
45	2308	1662	72.00	426	18.45	220	9.55	6.93
50	1805	1392	76.59	289	15.76	138	7.65	5.42
60	3001	2326	77.49	521	17.37	154	5.14	9.01
70	2447	1924	78.65	366	14.94	157	6.42	7.34
80	1171	879	75.10	176	15.00	116	9.90	3.51
90	570	430	75.45	83	14.32	58	10.23	1.71
F - Value	**	**	-	**	-	**	-	-
C.D. at 5%	4.96	2.91	-	117	-	51	-	-

Note: The average mean room temperature for a 90-day digestion period was 22.32°C.

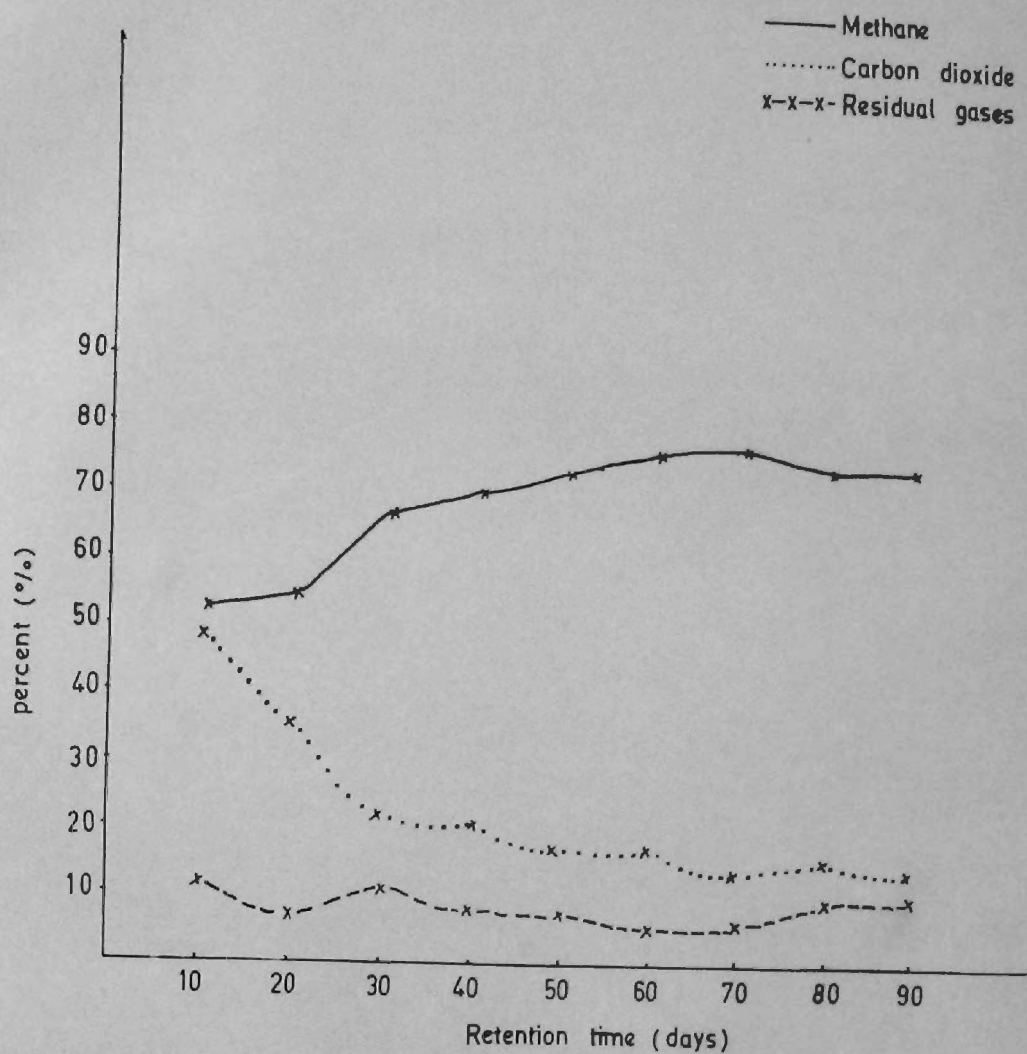


FIG:4. EFFECT OF RETENTION TIME ON THE QUALITY OF BIOGAS PRODUCED FROM POULTRY DROPPINGS

was 74.85 per cent of the total methane gas yield while the carbon dioxide gas produced was 86.19 per cent of the total carbon dioxide yield. The percent methane in the biogas mixture increased from 28.90 to 78.65.

4.1.4. Studies on biogas production by substituting different agricultural wastes with poultry droppings

The effect of substituting various agricultural wastes viz. cow dung, water hyacinth and banana leaves with poultry droppings on biogas production was determined. The characteristics of the different wastes are listed in table-1. The results of the experiment are presented in table-6 (Fig.5).

By screening different wastes, it was found that maximum total biogas production of 50484 ml was obtained for the treatment with banana leaves followed by water hyacinth with 45490 ml which resulted in 57.71 and 42.10 percent increase respectively over poultry droppings. The poultry droppings alone produced 32012 ml biogas while cow dung which produced 27012 ml biogas was significantly less than the biogas produced by poultry droppings alone.

The data also indicated that poultry droppings substituted with banana leaves and water hyacinth increased total biogas production significantly except at 10 per cent water hyacinth substitution. Poultry droppings substituted by cow dung at 3 different proportions did not increase the gas production compared to poultry droppings, but were significant

Table 6: Effect of substrate mixing in different proportion on biogas production

*Treat- ment	Biogas production (ml).				Total biogas (ml)	Biogas (ml/g)
	Retention time in days					
	10	30	60	90		
P.D. (control)	2865	12874	12145	4128	32012 (0.0)	160.1
C.D.	2175	10156	11089	3593	27012 (-15.6)	135.1
PD+CD (1:3)	2969	10268	12213	3918	29368 (-8.25)	146.8
PD+CD (3:1)	2809	12378	12491	4066	31744 (-0.83)	158.7
PD+CD (1:1)	2954	11460	12516	4050	31080 (-2.9)	155.4
W.H.	6700	18617	16543	3630	45490 (42.10)	227.5
P.D.+ 10% W.H.	2908	9450	14139	7422	33919 (5.95)	169.6
P.D. + 20% W.H.	3301	11980	14754	7098	37213 (16.30)	186.1
B.L.	6888	20439	18758	4399	53434 (57.71)	252.4
P.D. + 10% B.L.	4484	14842	12267	4545	36538 (14.14)	182.7
P.D. + 20% B.L.	4834	16701	15023	5223	39781 (24.27)	198.9
F - Value	**	**	**	**	**	-
C.D. at 5%	583	1114	1362	427	2032	-

Note 1. Figures in parenthesis indicates % increase over control.

2. The average mean room temperature for the 90 day digestion period was 21.90°C.

* P.D: Poultry droppings.
 CD : Cow dung
 WH : Water hyacinth
 BL : Banana leaves

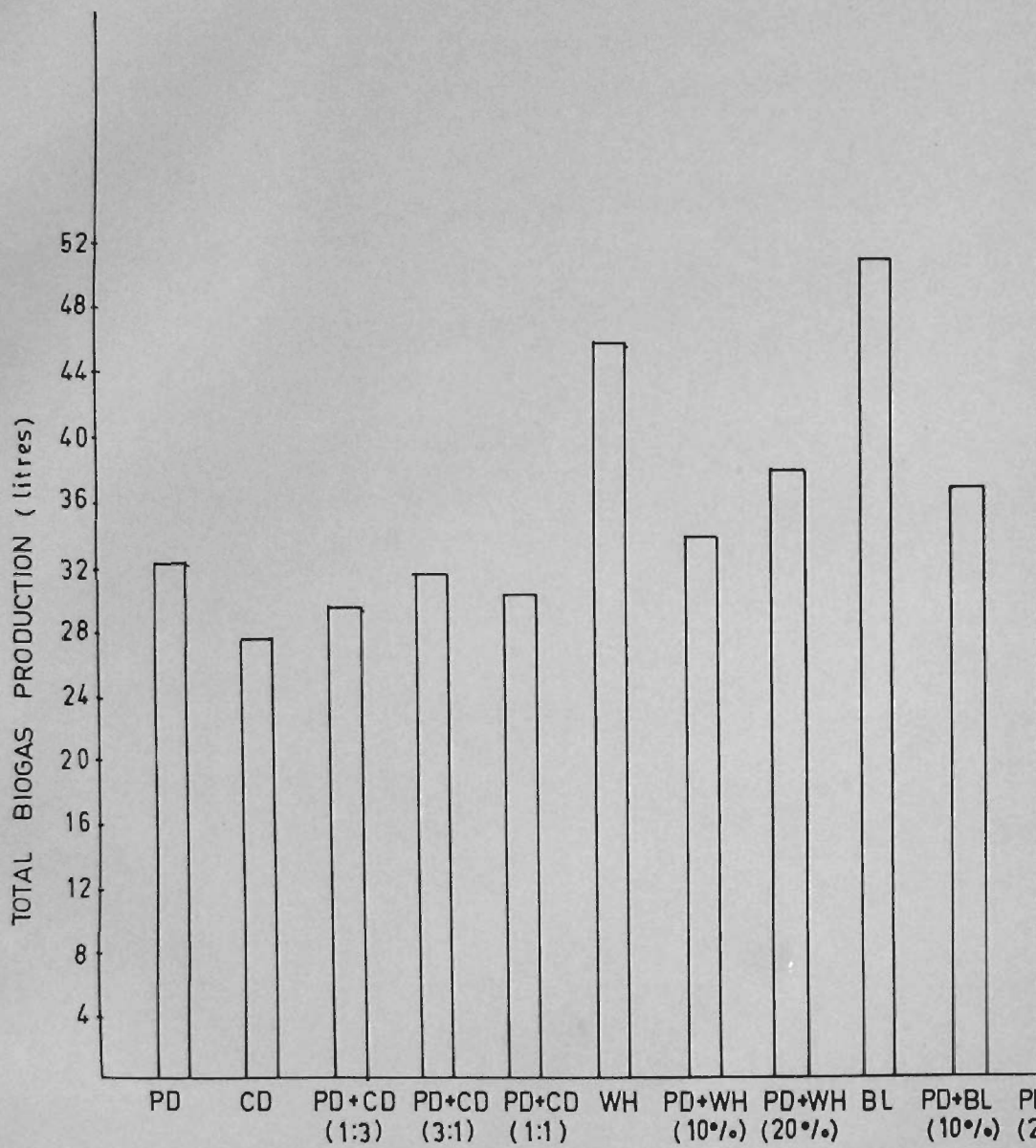


FIG: 5 INFLUENCE OF SUBSTRATE MIXING ON BIOGAS PRODUCTION

greater than cow dung alone. Poultry droppings supplemented with 10 and 20 per cent water hyacinth resulted in 33919 ml and 37213 ml of biogas respectively which accounted for 5.95 and 16.30 per cent increase over control. Similarly poultry droppings substituted with 10 and 20 per cent of banana leaves increased biogas production by 14.14 and 24.27 per cent respectively over control.

The amount and percentage of methane and carbon dioxide are presented in table-7 (Fig.6). The maximum methane yield of 35743 ml was obtained from banana leaves followed by water hyacinth with 23382 ml. The minimum methane production was obtained from cow dung while poultry droppings alone produced 19786 ml. Poultry droppings and cow dung mixed in the ratio of 3:1 and 1:1 gave higher methane yield, while those in 1:3 ratio respectively gave lower methane yields compared to the methane produced by poultry droppings alone. The maximum average per cent methane of 70.80 in biogas mixture was obtained from banana leaves treatment. The average methane per cent in biogas was 68.20 for poultry droppings.

Biochemical changes during biogas production: The biochemical changes of the different treatments at 0, 45th and 90th day was determined. The changes in total and volatile solids are presented in table-8 and manurial changes of nitrogen, phosphorus and cellulose are presented in tables-9 and 10.

Table 7: Effect of substrates mixing on composition of biogas

Treatments	Total biogas (ml)	Methane		Carbondioxide		Residual gas		*C/H ratio
		Total (ml)	%	Total (ml)	%	Total (ml)	%	
PC (Control)	32012	19786	63.20	6466	22.29	2760	9.50	2.15
C.D.	27012	15891	58.83	8306	32.60	2315	8.54	1.43
PD+CD (1:2)	29368	17591	59.90	9178	31.25	2599	8.85	1.49
PD+CD (3:1)	31794	21078	66.40	8106	25.54	2560	8.06	1.98
PD+CD (1:1)	31980	19329	63.80	9789	31.50	1462	4.07	1.76
WH	45400	23382	51.40	16239	35.70	5069	12.90	1.06
PD+10% WH	33919	21541	63.50	8897	26.23	3481	10.26	1.66
PD+20% WH	37213	22663	60.90	12596	33.85	1954	5.25	1.56
BL	50484	35743	70.80	11661	23.10	3079	6.10	2.42
PD+10% BL	36538	22471	61.50	11379	31.14	2668	7.36	1.59
PD+20% BL	39781	26971	67.90	10373	26.03	2436	6.12	2.11
F - Value	**	**	-	**	-	**	-	
C.D. at 5%	2032	2142	-	1314	-	849	-	

* Combustible to non-combustible ratio.

** PD: Poultry droppings

CD: Cow dung

WH: Water hyacinth

BL: Banana leaves

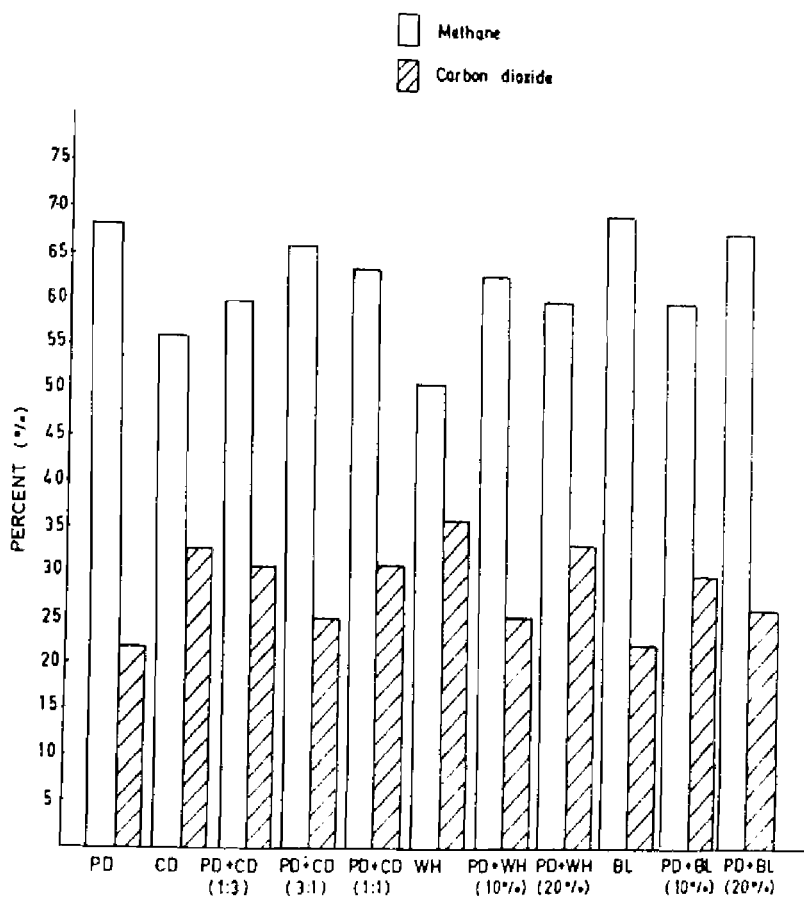


FIG: 6 INFLUENCE OF SUBSTRATE MIXING ON THE QUALITY OF BIOGAS

50

Change in total solids: The data indicated that the per cent degradation of total solids for banana leaves was significantly greater compared to poultry droppings. Maximum per cent total solids degradation of 36.10 was obtained from banana leaves followed by water hyacinth with 34.48. The per cent degradation of total solids for poultry droppings was 31.86 while for cow dung it was 27.45.

The results also indicated that per cent total solids in poultry droppings substituted with 10 and 20 per cent of banana leaves and water hyacinth showed higher per cent total solids degradation compared to poultry droppings alone. Poultry droppings substituted with cow dung at different rates showed less degradation in total solids than poultry droppings alone. In all the treatments, the per cent total solids degradation was more during first 45 days as compared to last 45 days.

Changes in volatile solids: The data indicated that per cent volatile solids degradation in banana leaves and water hyacinth were significantly greater compared to poultry droppings. Maximum per cent volatile solids destruction of 60.4 was obtained from banana leaves followed by water hyacinth with 56.0. The per cent volatile solids destroyed for poultry droppings was 48.3 while for cow dung it was 41.2.

The results also revealed that per cent volatile solid

Table 8: Effect of substrate mixing on per cent solids during biogas production

*Proportion of substrates	% Total solids			% Volatile solids (VTS)		
	Retention time (days)			Retention time (days)		
	0	45	90	0	45	90
P.D.	5.0 (0.0)	3.907 (21.86)	3.407 (31.86)	68.9 (0.0)	47.3 (31.4)	35.6 (40.3)
C.D.	8.0 (0.0)	6.321 (20.99)	5.804 (27.45)	83.7 (0.0)	58.4 (30.2)	49.2 (41.2)
PD+CD (1:3)	8.0 (0.0)	6.345 (20.56)	5.762 (27.98)	80.0 (0.0)	54.7 (31.0)	45.7 (43.3)
PD+CD (3:1)	5.0 (0.0)	3.899 (22.02)	3.505 (29.70)	74.5 (0.0)	40.1 (35.4)	37.8 (49.4)
PD+CD (1:1)	6.0 (0.0)	4.603 (21.94)	4.332 (27.80)	72.7 (0.0)	49.2 (32.3)	39.4 (45.8)
WH	5.0 (0.0)	3.870 (22.60)	3.276 (34.48)	86.9 (0.0)	54.2 (37.6)	38.2 (56.0)
PD+ 10% WH	5.0 (0.0)	3.745 (23.10)	3.397 (32.06)	72.6 (0.0)	45.3 (36.9)	36.9 (49.2)
PD+ 20% WH	5.0 (0.0)	3.844 (23.12)	3.304 (33.92)	74.4 (0.0)	46.5 (37.5)	36.9 (50.4)
BL	5.0 (0.0)	3.654 (26.92)	3.193 (36.10)	83.9 (0.0)	50.1 (43.6)	35.2 (60.4)
PD+ 10% BL	5.0 (0.0)	3.872 (22.56)	3.372 (32.56)	73.2 (0.0)	45.5 (37.0)	35.8 (51.1)
PD+ 20% BL	5.0 (0.0)	3.912 (21.76)	3.269 (34.62)	74.7 (0.0)	46.7 (37.5)	35.4 (52.6)
F - Value	-	**	**	**	**	**
C.D. at 5%	-	0.538	0.503 (4.04)	4.84	4.79	4.62 (4.49)

Note: Figures in parenthesis indicate % degradation.

* PD: Poultry droppings WH: Water hyacinth
CD: Cow dung BL: Banana leaves

in poultry droppings substituted with banana leaves and water hyacinth degraded greater than control. Poultry droppings substituted with 10 and 20 per cent of banana leaves reduced per cent volatile solids from 73.2 to 35.0 and 74.7 to 35.4 respectively. Similarly poultry dropping substituted with 10 and 20 per cent of water hyacinth reduced per cent volatile solids from 72.6 to 36.9 and 74.4 to 36.9 respectively. Poultry droppings and cow dung at 1:3 and 1:1 ratio respectively showed less per cent volatile solids degradation while the treatment with 3:1 ratio showed more per cent volatile solids degradation compared to control.

Changes in manurial value: The manurial value of nitrogen, phosphorus and cellulose in different treatments at 0, 45th and 90th day are presented in tables 9 and 10. The changes in C/N ratio was also determined. In all the treatments per cent nitrogen and phosphorus increased with increasing retention time.

The results showed that per cent nitrogen increase over 0-day in cow dung and banana leaves was significantly greater than control poultry droppings. Poultry droppings substituted with banana leaves and water hyacinth also significantly increased per cent nitrogen than poultry droppings. The per cent nitrogen for poultry droppings was highest with 2.24 at 0-day but the increase over 0-day was less.⁶ The maximum per cent nitrogen increase of 41.0 over 0-day was obtained

from banana leaves alone followed by poultry droppings substituted with 20 per cent banana leaves with 39.9. The minimum increase in per cent nitrogen was obtained from poultry droppings. The per cent nitrogen for control increased from 2.24 to 2.58 accounting for 13.2 per cent increase while for cow dung it increased from 1.52 to 1.75 accounting for 21.7 per cent increase. Poultry droppings and cow dung at 1:3 ratio showed less per cent nitrogen increase while the ratios with 1:1 and 3:1 showed greater per cent nitrogen increase over poultry droppings alone.

The results on per cent total phosphorus indicated that poultry droppings substituted with 20 per cent banana leaves gave maximum per cent phosphorus with 1.78 and minimum of 0.410 for water hyacinth treatment on 0-day. The per cent phosphorus increase over 0-day in cow dung, banana leaves and poultry droppings substituted with banana leaves was found significant compared to control. Maximum per cent phosphorus increase over 0-day was obtained from poultry droppings substituted with 10 per cent banana leaves. Water hyacinth alone reduced in per cent phosphorus from 0.410 to 0.396 accounting for 3.4 per cent decrease over 0-day.

The per cent phosphorus in poultry droppings increased from 1.312 to 1.913 accounting for 26.5 per cent increase while for cow dung it increased from 0.422 to 0.591 accounting for 40.1 per cent increase over 0-day. Poultry droppings and

Table 9: Changes in manurial value (nitrogen and phosphorus) of different substrates used for biogas production

*Substrates	% Nitrogen			% Total phosphorus		
	Retention time (days)			Retention time (days)		
	0	45	90	0	45	90
PD	2.24	2.44	2.58 (13.2)	1.512	1.707	1.913 (26.5)
CD	1.52	1.64	1.75 (21.7)	0.422	0.544	0.591 (40.1)
PD+CD (1:3)	1.72	1.86	1.90 (10.5)	0.958	0.996	1.183 (23.5)
PD+CD (3:1)	1.96	2.21	2.32 (18.4)	1.417	1.596	1.627 (14.8)
PD+CD (1:1)	1.96	2.18	2.24 (15.3)	1.340	1.526	1.694 (26.4)
WH	1.67	1.88	1.94 (16.2)	0.410	0.449	0.396 (-3.4)
PD+ 10% WH	1.82	2.06	2.30 (26.4)	1.443	1.577	1.643 (18.9)
PD+ 20% WH	1.91	2.12	2.46 (28.8)	1.410	1.578	1.677 (18.9)
BL	1.12	1.42	1.66 (41.2)	0.608	0.720	0.832 (36.8)
PD+ 10% BL	1.96	2.12	2.40 (22.5)	1.577	2.190	2.220 (40.8)
PD+ 20% BL	2.13	2.46	2.98 (39.9)	1.780	2.318	2.415 (35.7)
F - Value	**	**	**	**	**	**
C.D. at 5%	0.287	0.314	0.362 (4.24)	0.862	0.813	0.938 (4.66)

Note: Figures in parenthesis indicate % increase over 0-day.

- * PD: Poultry droppings WH: Water hyacinth
 CD: Cow dung BL: Banana leaves

cow dung mixed at different ratios did not increase the per cent phosphorus over 0-day compared to poultry droppings alone.

The results on changes in cellulose content at different intervals are given in table-10. The data indicated that on 0-day, the per cent cellulose was maximum for water hyacinth treatment followed by the treatment with banana leaves alone. The lowest per cent cellulose was obtained in the treatment receiving only cow dung. With increasing retention time, the per cent cellulose was decreased in all the treatments. Maximum per cent loss over 0-day was obtained from the treatment receiving poultry dropping substituted with 20 per cent water hyacinth. The least per cent loss over 0-day was obtained from the treatment of with poultry droppings and cow dung mixture (1:1). The per cent cellulose for poultry droppings reduced from 26.50 to 19.16 during 90 days period while for cow dung it reduced from 23.92 to 18.08. The per cent loss of cellulose was more during first 45 days and decreased with increasing retention time.

The data on changes in C/N ratio at different intervals are presented in table-10. The results indicated that the maximum C/N ratio on a 0-day with 79.38 was found for the treatment with banana leaves alone followed by cow dung alone. Poultry droppings with 30.76 showed lowest C/N ratio for 0-day.

Table 10: Changes in C/N ratio and cellulose content of different substrates used for biogas production

** Substrates	*Carbon to nitrogen ratio			% Cellulose		
	Retention time (days)			Retention time(days)		
	0	45	90	0	45	90
PD	30.76	19.39	13.80	26.50	21.76	19.16 (27.70)
CD	55.07	35.61	28.11	23.92	20.84	18.08 (24.41)
PD+CD (1:3)	46.31	29.41	24.05	26.89	22.00	19.40 (27.35)
PD+CD (3:1)	38.01	21.77	16.29	26.94	22.47	20.26 (24.30)
PD+CD (1:1)	37.09	22.57	17.59	25.25	21.87	20.85 (17.43)
WH	52.04	28.83	19.69	32.47	26.66	23.48 (27.69)
PD+ 10% WH	39.89	22.23	16.04	28.56	23.89	21.67 (24.13)
PD+ 20% WH	38.95	21.93	15.90	27.72	20.19	18.40 (33.62)
BL	79.38	35.28	21.11	31.94	26.15	23.72 (25.73)
PD+ 10% BL	37.35	23.00	16.27	24.43	22.17	19.40 (20.59)
PD+ 20% BL	55.07	18.98	11.08	27.14	23.09	21.38 (21.22)
P - Value	**	**	**	**	*	**
C.D. at 5%	4.54	4.87	5.36	3.50	3.79	2.35 (4.37)

Note: Figures in parenthesis represent % loss over 90-day.

* Total carbon

** PD: Poultry droppings

WH: Water hyacinth

CD: Cow dung

BL: Banana leaves

Poultry droppings substituted with 10 and 20 per cent of banana leaves and water hyacinth increased the C/N ratio compared to the C/N ratio for poultry droppings alone. Poultry droppings and cow dung mixed at different ratios showed less C/N ratio compared to the C/N ratio of cow dung alone. The C/N ratio decreased in all the treatments with increasing retention time. The decrease in C/N ratio during first 45 day was more rapid compared to last 45 day period.

4.1.5. Studies on biogas production from poultry droppings and cow dung on a pilot plant project

The effect of poultry droppings and cow dung for biogas production was studied on pilot plant project. The results are presented in tables 11 and 12.

The poultry droppings was loaded at five per cent total solids and with pH 7.46 into a 5.3 cubic feet digester. The fermentation was run for a period of 50 days. The characteristics of the waste before and after digestion are presented in table-11. The per cent nitrogen, total phosphorus, crude protein and cellulose before fermentation was 2.16, 1.330, 13.50 and 26.48 respectively and after fermentation it was found to be 2.31, 1.876, 13.69 and 19.24 respectively. The per cent increase of nitrogen and phosphorus over 0-day was 16.22 and 40.60 respectively. The cellulose content decreased by 26.32 per cent compared to cellulose content on 0-day. The per cent total solids and volatile solids degradation was

24.80 and 40.03 per cent respectively.

Similarly, cow dung was loaded at eight per cent total solids concentration and with pH 7.12 into a 5.13 cubic feet digester. The fermentation was run for a period of 50 days. The characteristics of the waste are presented in table-12. The percent nitrogen, phosphorus, crude protein and cellulose were 1.49, 0.372, 9.31 and 23.74 respectively before fermentation and 1.71, 0.482, 10.69 and 18.20 respectively after fermentation. The per cent increase in nitrogen and phosphorus was 14.77 and 29.57 respectively. Cellulose degraded by 23.34 per cent when compared to cellulose content on 0-day. The per cent total and volatile solids degradation was 27.25 and 36.20 respectively.

The biogas produced by poultry droppings and cow dung are presented in table-13. The total biogas produced was 2389.95 litres and 1844.11 litres respectively for poultry droppings and cow dung. In both the organic wastes, there was an increase in biogas production upto 20 days and then decreased with increasing retention time. The biogas produced per kg of total solids at different retention time was also determined for poultry droppings and cow dung. (Fig.8)

4.2. Studies of the farm yard manure, fresh and digested poultry slurry amended soils on microbial population

The effect of fresh poultry droppings, digested slurry and farm yard manure addition to soil on microbial population

Table 11: Changes in chemical parameters of poultry droppings used for biogas production on a pilot plant scale

Constituent	Before Fermentation		After Fermentation		% increase or decrease over zero day
	In slurry	In total solids	In slurry	In total solids	
Total solids(%)	5.00	100.00	3.76	100.00	-24.80
Volatile solids (%)	3.54	70.80	1.66	42.46	-40.03
Cellulose(%)	1.32	26.40	0.73	19.40	-26.52
Crude protein(%)	0.60	13.50	0.59	15.69	+16.22
Total nitrogen (%)	0.11	2.16	0.094	2.51	+16.20
Total phosphorus (%)	0.066	1.33	0.071	1.87	+40.60
Ash (%)	1.46	29.20	2.16	57.34	-
C/N	32.18	32.78	17.66	17.61	-
pH	7.46	-	6.96	-	-

Table 12: Changes in chemical parameters of cow dung used for biogas production on a pilot plant scale

Constituent	Before Fermentation		After Fermentation		%increase over zero day
	In slurry	In total solids	In slurry	In total solids	
Total solids(%)	8.00	100.00	5.82	100.00	-27.25
Volatile solids(%)	6.70	83.70	3.11	53.40	-36.20
Cellulose(%)	1.89	23.74	1.06	18.20	-23.34
Crude protein(%)	0.74	9.31	0.62	10.69	+14.82
Total nitrogen(%)	0.12	1.49	0.10	1.71	+14.77
Total phosphorus (%)	0.03	0.372	0.03	0.482	+29.57
Ash (%)	1.30	16.30	2.71	46.6	-
C/N	54.25	54.63	31.10	31.20	-
pH	7.12	-	6.90	-	-

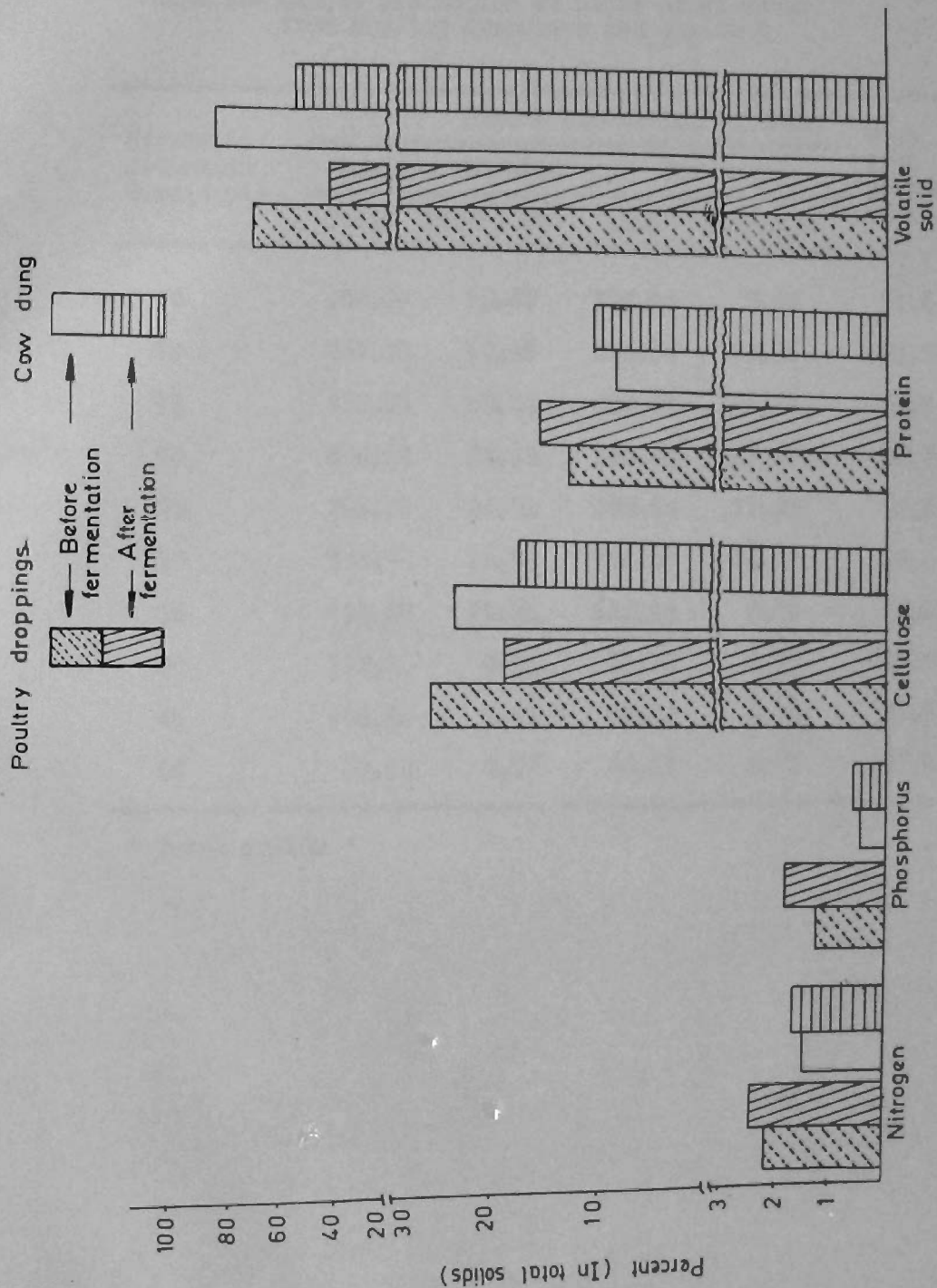


FIG:7 CHANGES IN CHEMICAL CONSTITUENTS OF POULTRY DROPPINGS AND COW DUNG DURING BIOGAS PRODUCTION ON A PILOT PLANT SCALE

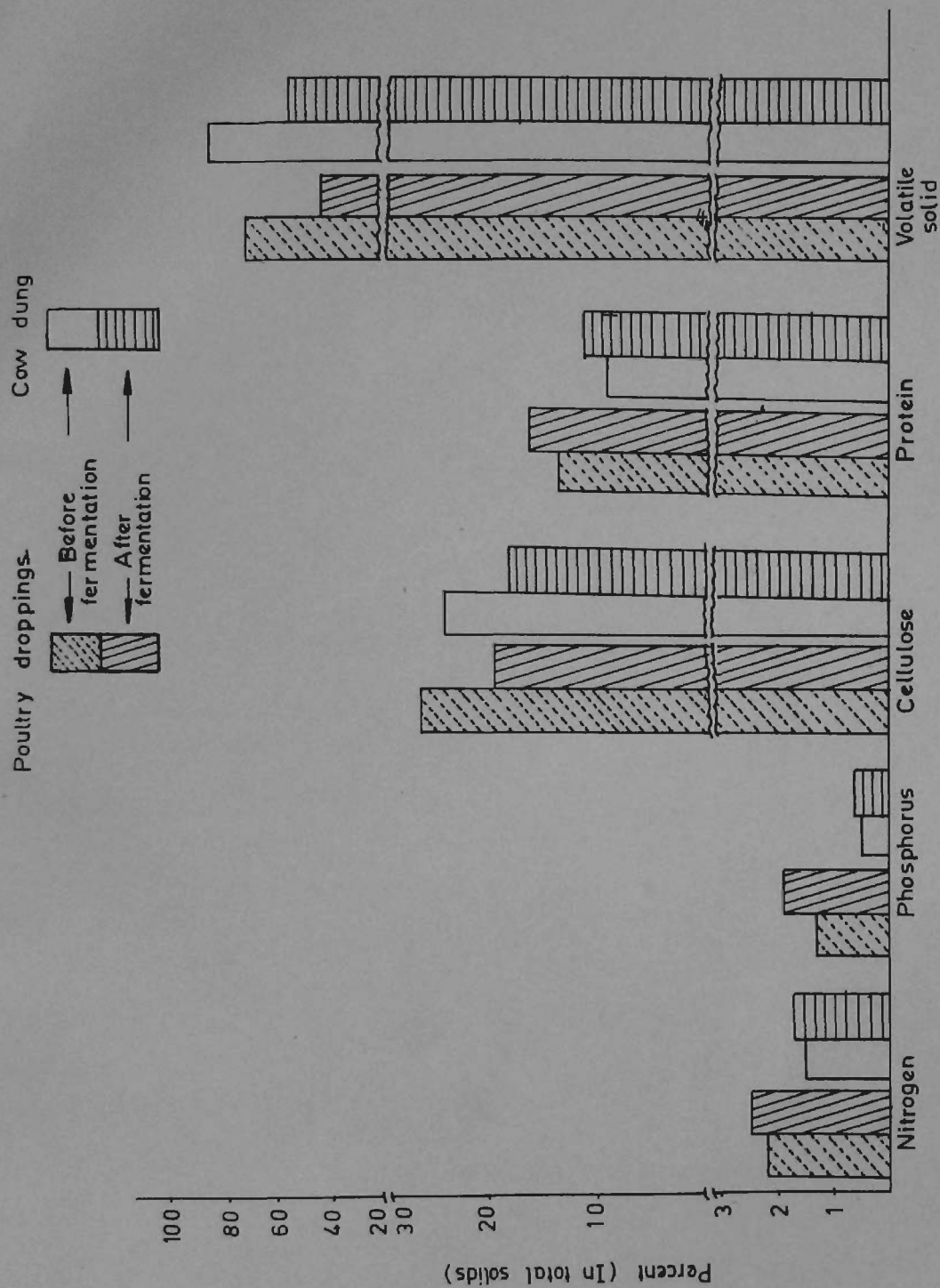


FIG. 7. CHANGES IN CHEMICAL CONSTITUENTS OF POULTRY DROPPINGS AND COW DUNG

**Table 13: Biogas production on pilot plant scale
from poultry droppings and cow dung**

Hydraulic retention time(days)	Biogas production (litres)				Mean room temper- ature °C
	Poultry dropping		Cow dung		
	Total	Lit/kg TS	Total	Lit/kg TS	
5	150.69	10.47	107.64	7.48	21.0
10	254.75	17.69	212.50	14.76	21.0
15	410.85	28.33	290.67	20.19	20.5
20	494.62	34.35	393.45	27.67	22.7
25	356.00	24.72	302.64	21.02	22.5
30	244.50	16.90	191.50	13.30	20.5
35	190.80	13.25	142.45	9.89	21.21
40	117.40	8.15	95.75	6.72	21.8
45	100.65	6.99	56.34	3.95	21.9
50	63.64	4.77	44.67	3.10	21.8

* Total solids

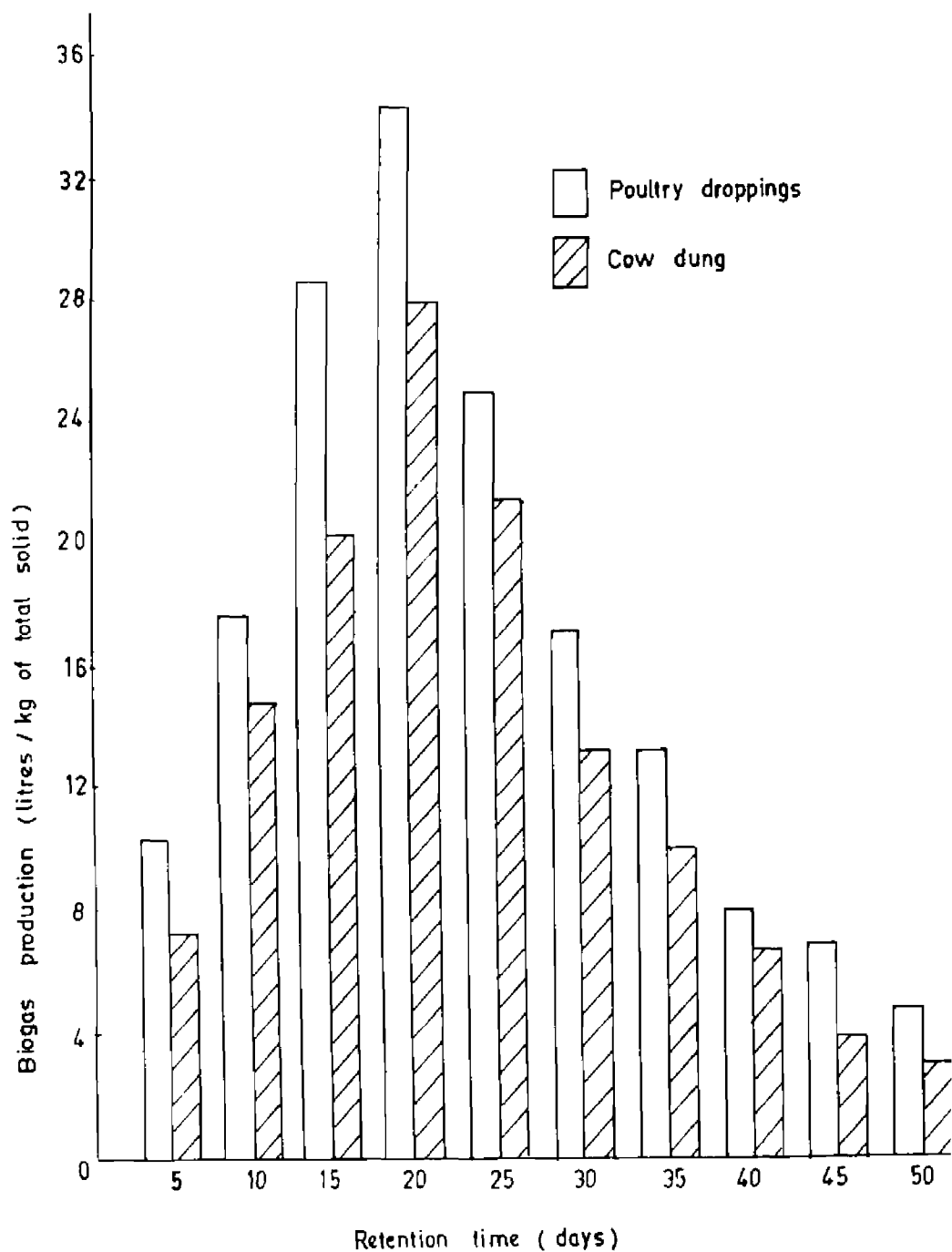


FIG:8 EFFECT OF RETENTION TIME ON BIOGAS PRODUCTION FROM POULTRY DROPPINGS AND COW DUNG ON A PILOT-PLANT SC.

were studied. All the treatments were supplemented with equal amounts of NPK fertilizers. The treatments are detailed in material and methods.

The soil microflora obtained at 0, 30th and 60th day of incubation periods are presented in table-14. All the populations were expressed on per gram dry soil. The data indicated that per cent increase over control for fungi and bacteria was more in all the treatments while actinomycetes populations increased in all treatments except for the treatment which received 5 tons/ha dosage when compared to control.

In control, there was a gradual increase of fungal population from 7.1×10^3 to 19.8×10^3 during a 60-day incubation period accounting for 178.9 per cent increase over 0-day. Similarly in all the other treatments, there was an increase in fungal populations over 0-day. The maximum per cent increase for fungi of 119.3 over control was obtained for the treatment receiving digested slurry at the rate of 10 tons/ha followed by the treatment receiving farm yard manure at the rate of 10 tons/ha with 105.6. In general, the treatments receiving digested slurry showed more per cent increase over control compared to treatments receiving fresh poultry droppings except for the treatment which received digested slurry at the rate of 20 tons/ha. At higher doses of 20 tons/ha, fresh and digested poultry slurry showed less per cent increase of fungi compared to the treatments

receiving 10 tons/ha dosage of fresh and digested poultry slurry.

In case of bacteria, there was a gradual increase from 31.3 to 56.9 $\times 10^5$ for a 60-day incubation period for control, accounting for 81.7 per cent increase over 0-day. Similarly in all the other treatments there was increase in bacterial populations over 0-day. The maximum per cent increase over control at the end of 60 days incubation period was obtained for treatment receiving digested slurry at the rate of 10 tons/ha with 103.8. Farm yard manure treatment at 10 tons/ha rate, showed an increase from 36.5 to 83.5 $\times 10^5$ accounting for 57.6 per cent increase over control. In general, the treatments receiving digested slurry showed more percent increase over control compared to treatments receiving fresh poultry droppings except for treatment receiving digested slurry at 5 tons/ha rate. The treatment with 5 tons/ha dosage of digested slurry showed less per cent increase compared to treatment receiving 5 tons/ha rate of fresh poultry dropping. Treatment with digested slurry at 20 tons/ha rate showed less per cent increase than at 10 tons/ha rate.

In case of control, the actinomycetes increased from 1.31 to 3.51 $\times 10^3$. Similarly in all the other treatments actinomycetes population increased with increasing incubation period. The per cent increase over control was found in all the treatments except the treatment which received 5 tons/ha

Table 14: Influence of farm yard manure, fresh and digested poultry slurry on soil microbial populations

*** treatments	Incubation period (days)										% increase over 0-day				
	0					30							60		
	F	**B	*A	F	B	A	F	D	A	F	B	A	F	B	A
oil control)	7.1	31.3	1.31	11.2	41.2	1.77	19.8	56.9	1.91	178.9 (0.0)	81.7 (0.0)	51.9 (0.0)			
Y14-10-I	7.6	36.5	1.30	22.5	69.3	2.48	34.8	83.5	2.18	357.6 (105.6)	128.8 (57.6)	67.7 (11.2)			
5-I	7.6	31.2	1.52	15.5	53.5	1.72	24.3	72.0	1.90	219.7 (22.81)	133.9 (63.9)	25.0 (-51.8)			
10-I	7.9	41.6	2.09	20.2	77.5	2.25	36.2	99.3	3.26	345.6 (93.2)	138.7 (69.8)	56.0 (7.9)			
20-I	11.0	46.0	2.44	21.5	87.6	2.78	43.1	110.0	3.86	291.8 (63.1)	139.1 (70.3)	58.2 (12.1)			
35-I	8.1	44.3	1.23	16.0	53.3	3.22	29.0	89.8	2.29	258.0 (44.2)	118.5 (45.0)	83.2 (60.3)			
10-I	9.1	51.1	1.57	18.4	103.5	3.65	44.8	136.2	3.17	392.3 (119.3)	166.5 (103.8)	101.9 (96.3)			
23-I	12.7	52.8	2.46	22.1	116.3	4.65	49.1	137.0	5.24	236.3 (60.0)	159.5 (95.2)	113.0 (117.7)			

Note: Figures in parenthesis indicate % increase over control.

* Fungal population $\times 10^3$ ** Actinomycetes population $\times 10^3$

** Bacterial population $\times 10^5$

*** FY14-10-I: Farm yard manure at the rate of 10 tons per hectare
 F-5-I; F-10-I; F-20-I: Fresh poultry slurry at the rates of 5, 10 and 20 tons per hectare
 D-5-I; D-10-I; D-20-I: Digested poultry slurry at the rates of 5, 10 and 20 tons per hectare.

rate of fresh poultry droppings. Maximum per cent increase of 117.7 over control was obtained for treatment receiving digested slurry at 20 tons/ha rate. The farm yard manure treatment receiving 10 tons/ha dosage showed an increase of 11.2 per cent over control. In general, the treatments receiving digested slurry showed more increase in actinomycetes population than the fresh poultry droppings treatments.

4.3. Studies of the farm yard manure, fresh and digested poultry slurry amended soils on nitrogen mineralization

The effect of addition of fresh poultry droppings, digested slurry and farm yard manure to soil on rate of nitrogen mineralization was determined by estimating the amount of ammonical nitrogen and nitrate nitrogen at weekly interval by following the procedure as outlined in material and method. All the treatments were supplemented with equal amounts of NPK fertilizers.

Ammonical-nitrogen: The results on the changes in ammonical-nitrogen content in soils amended with the organic manure are presented in table-15. All the values are expressed as $\mu\text{C}/\text{mg}/100\text{g}$ oven dry soil. The data indicated that the addition of fresh poultry droppings, digested slurry and farm yard manure to soil caused an increase in the concentration of ammonical-nitrogen as compared to the unamended control. This showed that organic nitrogen from the added organic matter were mineralized and released in the ammonical form. This

was evident from the data obtained on the content of ammonical-nitrogen amended with organic matter up to 8 weeks of incubation. The unamended control showed maximum ammonical nitrogen content of 36.0 mg/100 g on 2nd week and then decreased gradually. The treatments receiving fresh poultry dropping showed maximum ammonical-nitrogen content at 3rd week and decreased thereafter. The ammonical nitrogen content in soils amended with fresh poultry dropping on 3rd week of incubation decreased with increased dosage of application. The ammonical-nitrogen content at 3rd week 49.3, 48.5 and 46.5 mg/100 g oven dry soil for the treatments receiving fresh poultry dropping at the rates of 5, 10 and 20 tons/ha respectively.

The treatment which received digested poultry slurry showed maximum ammonical-nitrogen content on 2nd week, one week ahead than the treatments which received fresh poultry dropping. The ammonical-nitrogen content for the soils amended with digested slurry at the end of 3rd week was 49.3 and 50.8 mg/100 g soil for the treatments receiving slurry at rates 5 and 10 tons/ha. However the treatment receiving 20 tons/ha of digested slurry showed lower ammonical-nitrogen content compared to the treatment receiving 10 tons/ha of digested slurry. The ammonification was almost negligible at the end of 8th week of incubation in all the treatments.

Table 15: Influence of farm yard manure, fresh and digested poultry slurry on ammonical nitrogen content in soil ($\text{NH}_4\text{-N}$ expressed in $\text{mg}/100\text{ g}$ oven dry soil)

*Treatments	Incubation period (weeks)							
	0)	1	2	3	4	5	6	8
Soil (control)	20.3	26.4	36.0	28.4	21.6	12.7	9.9	0.0
FYM-10-T	32.8	36.8	41.2	42.5	35.4	27.5	14.8	4.7
F-5-T	24.3	31.2	46.8	49.3	34.3	21.3	14.0	4.2
F-10-T	31.3	37.3	41.5	48.5	38.3	24.4	15.6	5.9
F-20-T	35.8	39.4	41.5	46.5	37.4	23.3	14.4	6.0
D-5-T	40.3	45.6	49.3	45.3	22.8	17.3	9.5	1.1
D-10-T	42.0	49.2	50.8	42.4	29.7	21.6	12.9	3.5
D-20-T	53.5	60.2	50.5	43.6	25.9	19.6	11.1	1.0

*FYM-10-T: Farm yard manure at the rate of 10 tons per hectare

F-5-T; F-10-T; F-20-T: Fresh poultry slurry at the rates of 5, 10 and 20 tons per hectare

D-5-T; D-10-T; D-20-T: Digested poultry slurry at the rates of 5, 10 and 20 tons per hectare

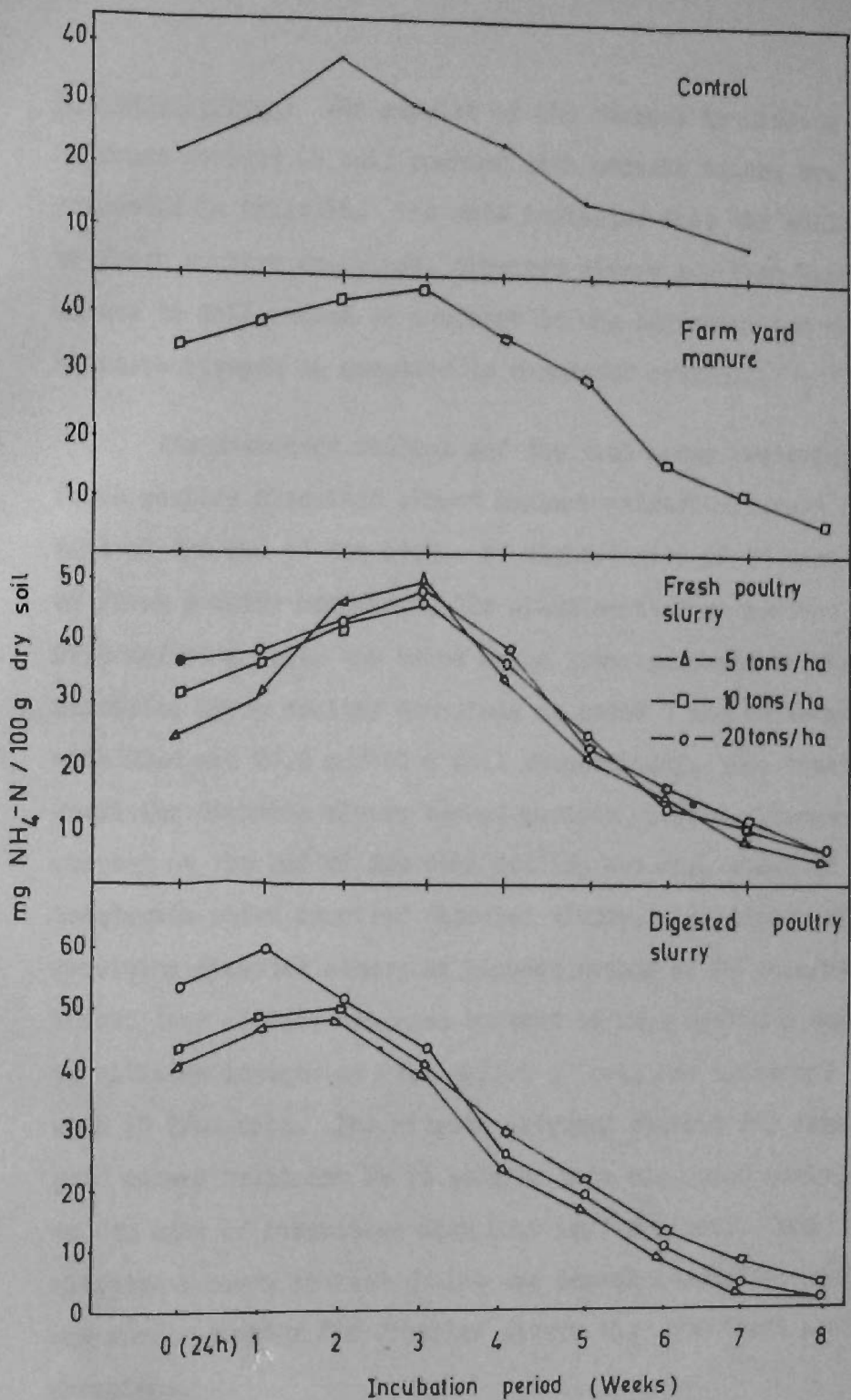


FIG:9 INFLUENCE OF FARM YARD MANURE, FRESH AND DIGESTED POULTRY SLURRY ON AMMONIFICATION OF SOIL

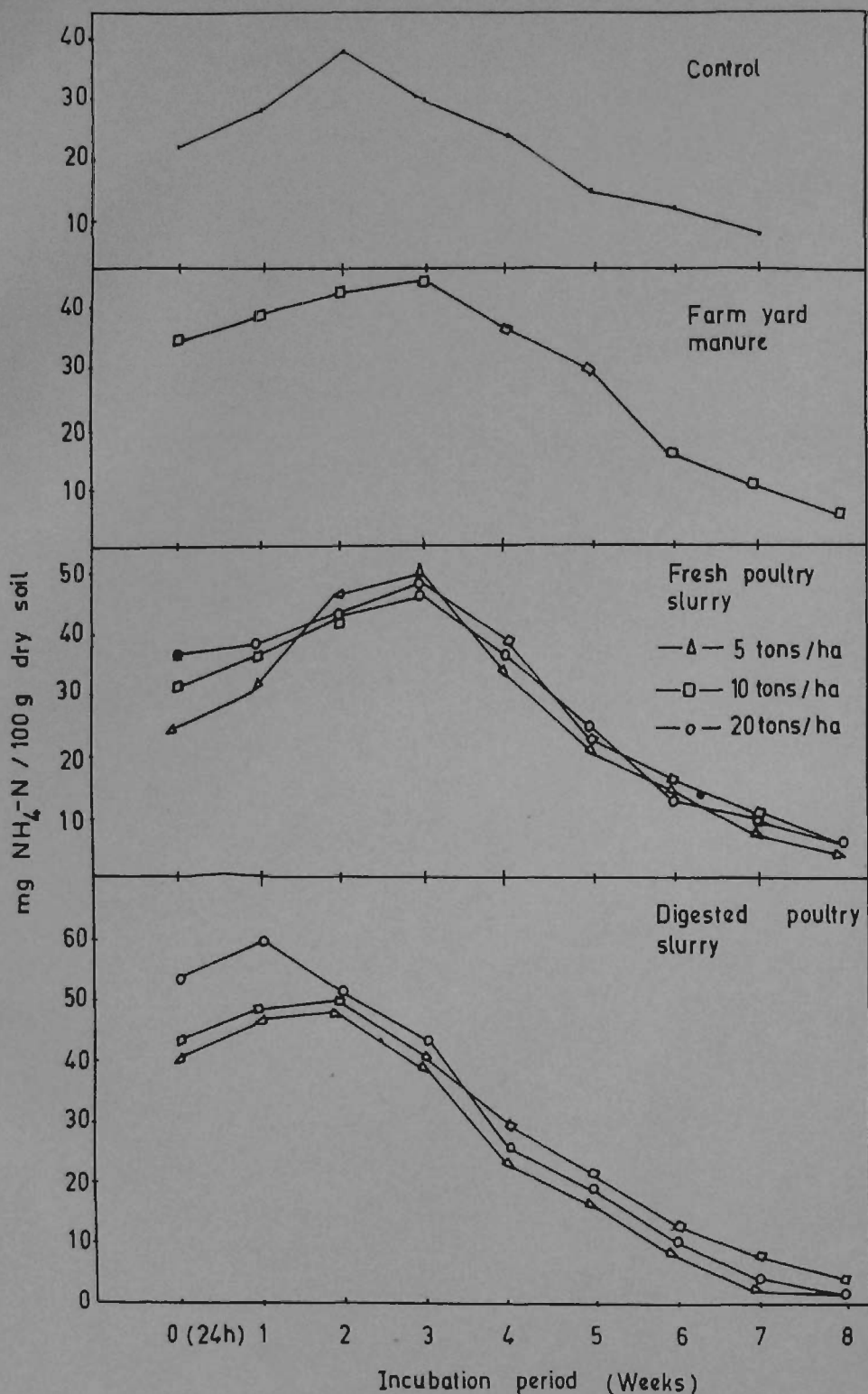


FIG:9 INFLUENCE OF FARM YARD MANURE, FRESH AND DIGESTED POULTRY SLURRY ON AMMONIFICATION OF SOIL

Nitrate-nitrogen: The results of the changes in nitrate nitrogen content in soil amended with organic manure are presented in table-16. The data indicated that the addition of fresh poultry droppings, digested slurry and farm yard manure to soil caused an increase in the concentration of nitrate-nitrogen as compared to unamended control. (Fig. 10)

The unamended control and the treatments receiving fresh poultry droppings showed maximum nitrate-nitrogen content at the end of 4th week. At highest rate of 20 tons/ha of fresh poultry droppings, the nitrate-nitrogen content was 21.2 mg/100 g soil, the value being lower compared to those receiving fresh poultry droppings at rates 5 and 10 tons/ha with 22.4 and 24.9 mg/100 g soil respectively. The treatment receiving digested slurry showed maximum nitrate nitrogen content at the end of 3rd week itself, one week ahead of the treatments which received digested slurry. The treatment receiving digested slurry at highest dosage of 20 tons/ha showed less nitrate-nitrogen content of 26.5 mg/100 g compared to nitrate-nitrogen of 27.0 mg/100 g soil for treatment with 10 T/ha rate. The nitrate nitrogen content for farm yard manure treatment at 10 tons/ha rate was found maximum on 4th week of incubation with 23.0 mg/100 g soil. The nitrate-nitrogen content during the 8week incubation period was mostly greater for digested slurry than the fresh poultry droppings.

Table 16: Influence of farm yard manure, fresh and digested poultry slurry on nitrate-nitrogen content in soil ($\text{NO}_3\text{-N}$ expressed in $\text{mg}/100 \text{ g}$ oven dry soil)

Treatments	Incubation period (weeks)							
	0	1	2	3	4	5	6	7
Soil (control)	6.4	6.9	8.1	9.6	17.5	10.0	14.0	12.1
FYM-10-I	7.4	14.7	16.5	19.6	23.0	18.4	14.5	15.3
F-5-I	6.7	7.5	11.0	13.0	22.4	19.0	18.7	15.6
F-10-I	7.1	15.0	19.5	16.0	24.9	17.0	14.5	14.1
F-20-I	7.7	11.5	16.5	21.0	21.2	18.5	14.5	15.2
D-5-I	12.0	13.4	16.4	22.7	22.2	21.4	19.6	17.4
D-10-I	13.1	16.2	19.7	27.0	23.8	21.5	24.0	19.6
D-20-I	12.7	18.1	21.0	26.5	21.0	22.9	18.9	17.6

* FYM-10-I: Farm yard manure at the rate of 10 tons per hectare

F-5-I; F-10-I; F-20-I: Fresh poultry slurry at the rates of 5, 10 and 20 tons per hectare.

D-5-I; D-10-I; D-20-I: Digested poultry slurry at the rates of 5, 10 and 20 tons per hectare.

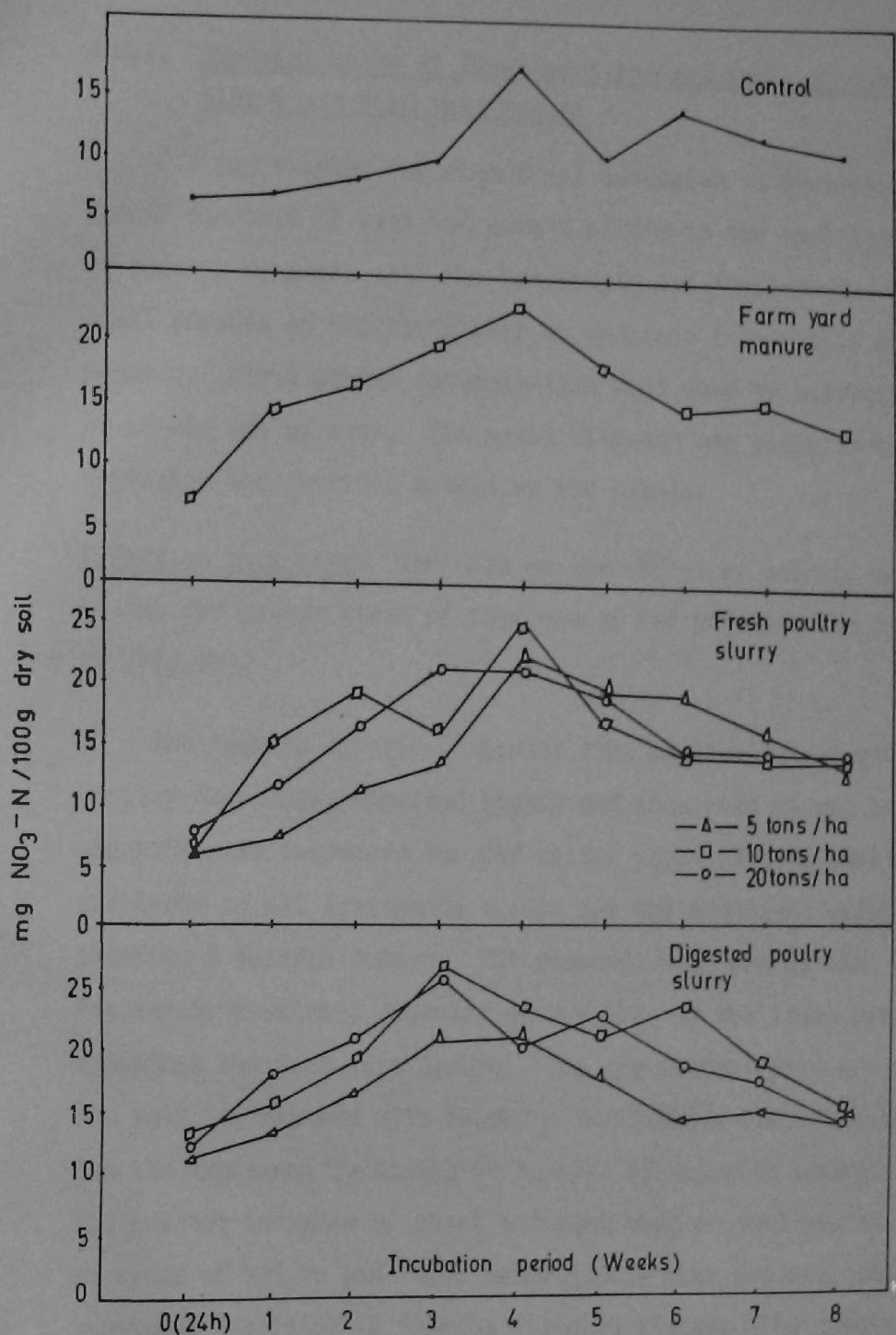


FIG: 10 INFLUENCE OF FARM YARD MANURE, FRESH AND DIGESTED POULTRY SLURRY ON NITRIFICATION OF SOIL

4.4.1. Manurial value of fresh poultry droppings, digested slurry and farm yard manure

A pot culture experiment was conducted to evaluate the growth response of ragi and cowpea plants to the application of organic manures. All the treatments are supplemented with equal amounts of NPK fertilizer as outlined in material and methods. Plant growth determination were made by harvesting at 60-day age of crop. The total nitrogen was analysed to determine the nutrient uptake by the plants.

Effect on ragi crop: The data on the effect of organic manure on the dry matter yield of ragi plants are presented in table-17 (Fig.1f).

The results clearly indicated that application of fresh poultry droppings, digested slurry and farm yard manure had significantly increased the dry matter yield of both shoots and roots in all treatments except for the treatment which received 5 tons/ha dosage. The response was more by the treatments receiving digested slurry than by the fresh poultry droppings and farm yard manure. The dry matter yield of shoot and root was maximum with 14.987 g and 5.814 g respectively for the treatment receiving 10 tons/ha of digested slurry. The percent increase of shoot and root over control was more in order of 106.89 and 76.08 respectively over control for treatment receiving 10 tons/ha digested slurry. The treatment receiving 20 tons/ha rate of digested slurry gave less yields

Table 17: Effect of farm yard manure, fresh and digested poultry slurry on the dry matter yield of ragi plants

*Treatments	Dry matter yield (gm/pot)		% increase over control	
	Shoot	Root	Shoot(%)	Root(%)
Soil(control)	7.244	3.302	0.0	0.0
FYM-10-T	12.451	4.918	71.88	48.94
F-5-T	8.185	4.138	12.99	25.32
F-10-T	9.367	5.104	29.30	51.54
F-20-T	11.120	5.426	53.51	64.32
D-5-T	11.924	4.865	64.61	47.33
D-10-T	14.987	5.814	106.89	76.08
D-20-T	14.761	5.800	103.77	75.65
F - Value	**	**	-	-
C.D. at 5%	1.731	1.34	-	-

* FYM-10-T: Farm yard manure at the rate of 10 tons per hectare.

F-5-T; F-10-T; F-20-T: Fresh poultry slurry at the rates of 5, 10 and 20 tons per hectare.

D-5-T; D-10-T; D-20-T: Digested poultry slurry at the rates of 5, 10 and 20 tons per hectare.

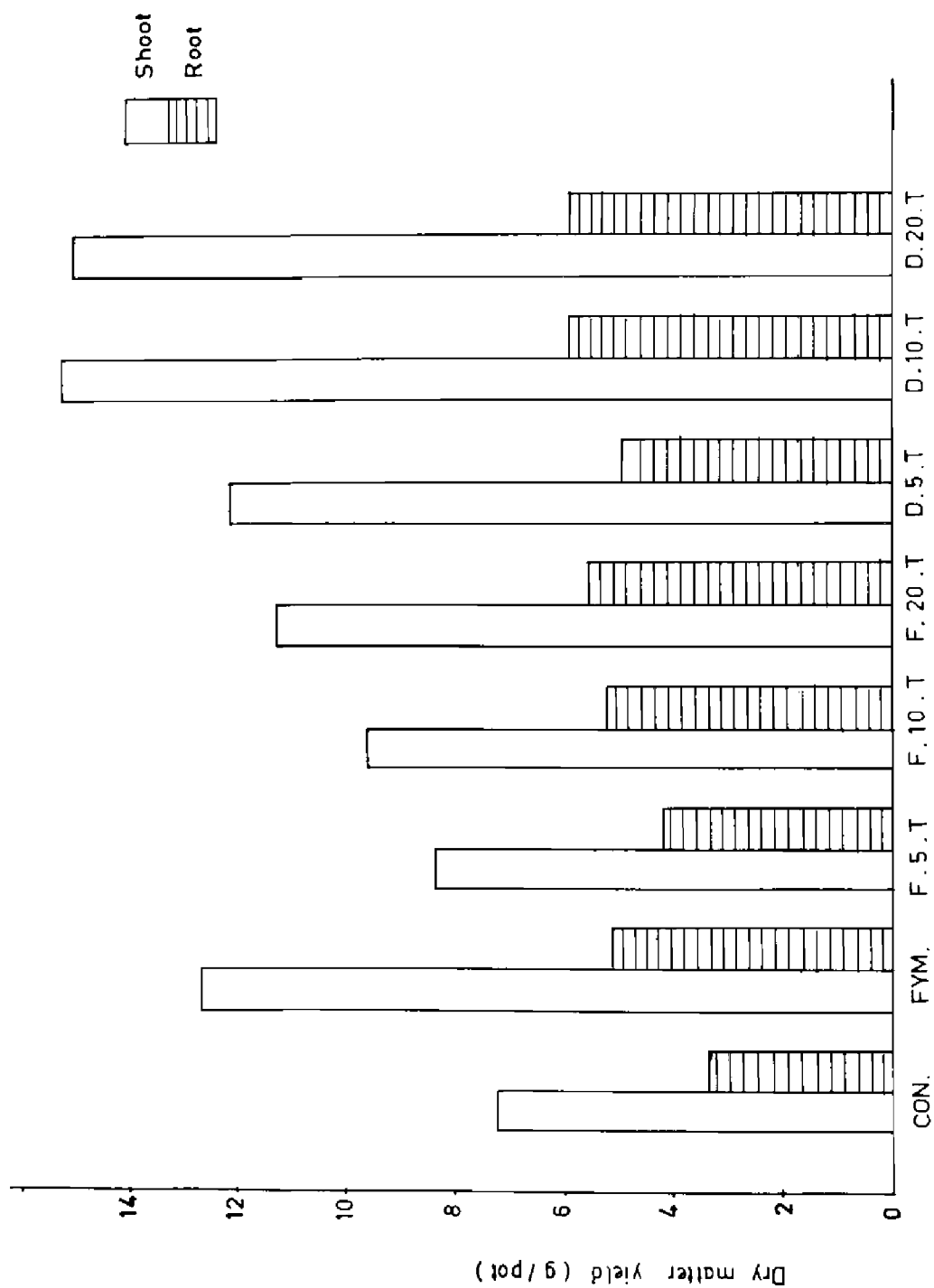


FIG 11 INFLUENCE OF FARM YARD MANURE, FRESH AND DIGESTED POULTRY SLURRY ON DRY MATTER YIELD OF RAGI PLANTS

of 14.761 g compared to the treatment which received 10 tons/ha dosage digested slurry. Farm yard manure at 10 tons/ha rate produced shoot and root yield of 12.451 g and 4.918 g which was 71.88 and 48.94 per cent increase over control.

Nitrogen uptake: The nitrogen uptake by ragi plants grown in soils receiving organic manure was computed by estimating the total nitrogen content of the plant shoot weight. The results are presented in table-18.

The data indicated that the application of fresh poultry dropping, digested slurry and farm yard manure increased the nitrogen uptake by ragi plants in shoot system significantly compared to unamended control. The percent nitrogen in all the treatments are significantly greater compared to control. The maximum per cent nitrogen of 2.49 was obtained from the treatment which received digested slurry at 5 tons/ha dosage while the minimum per cent nitrogen of 1.74 was obtained for the control treatment. The nitrogen per cent for the treatment receiving digested slurry was more compared to the treatments receiving fresh poultry slurry except at rates of 10 tons/ha of digested slurry.

The maximum nitrogen uptake of 316.2 mg/pot was obtained for the treatment receiving 10 tons/ha of digested slurry. In general, the plants receiving digested slurry showed more nitrogen uptake compared to the plants receiving fresh poultry droppings. The nitrogen uptake in case of farm yard manure

Table 18: Effect of farm yard manure, fresh and digested poultry slurry amendment on the nitrogen uptake by ragi plants

**Treatments	Nitrogen (%)	Nitrogen uptake (mg/pot)	Crude protein (mg/pot)	Nitrogen use efficiency*
Soil (control)	1.74	126.0	787.8	0.91
FYM-10-T	1.97	245.3	1533.0	1.46
F-5-T	1.92	157.2	982.2	0.98
F-10-T	2.34	219.2	1376.0	1.07
F-20-T	2.19	243.5	1522.1	1.17
D-5-T	2.49	296.9	1855.7	1.41
D-10-T	2.11	316.2	1976.4	1.69
D-20-T	1.99	293.7	1835.9	1.51
F - Value	**	**	**	-
C.D. at 5%	0.35	30.6	191.25	-

* Nitrogen use efficiency indicates the dry matter yield obtained per unit of nitrogen in the particular treatment.

** FYM-10-T: Farm yard manure at the rate of 10 tons per hectare

F-5-T; F-10-T; F-20-T: Fresh poultry slurry at the rates of 5, 10 and 20 tons per hectare.

D-5-T; D-10-T; D-20-T: Digested poultry slurry at the rates of 5, 10 and 20 tons per hectare.

treatment which received 10 tons/ha rate showed 245.3 mg/pot of nitrogen uptake which was almost equal to the treatment which received fresh poultry dropping at 20 tons/ha rate. The crude protein in all the treatments was obtained by multiplying the per cent nitrogen with a factor 6.25.

Effect on cowpea crop: The data on the effect of organic matter on the dry matter yield of cowpea plants are presented in table 17 (Fig.12).

The results indicated that application of fresh poultry dropping, digested slurry and farm yard manure has significantly increased dry matter yield of shoot and root system in all treatments except for the treatment which received 5 tons/ha of fresh poultry droppings. Maximum shoot yield of 13.481 g was obtained by the treatment receiving 10 tons/ha rate of digested poultry slurry which showed an increase of 51.93 per cent over control. The treatment receiving 10 tons/ha of digested slurry showed more shoot yield compared to the treatments receiving 20 tons/ha of fresh and digested poultry slurry. In general, the treatments receiving digested slurry showed more shoot yield compared to fresh poultry droppings except at 20 tons/ha of digested slurry. Farm yard manure at 10 tons/ha dosage gave 12.924 g and 2.707 g of shoot and root weight which showed an increase of 45.46 and 22.82 per cent over control. The maximum root yield of 3.320 g was obtained for the treatment which received 20 tons/ha of

Table 19: Effect of farm yard manure, fresh and digested poultry slurry on dry matter yield of cowpea plants

*Treatments	Dry matter yield (gm/plant)		% increase over control	
	Shoot	Root	Shoot(%)	Root(%)
Soil(control)	8.885	2.204	0.0	0.0
FYM-10-T	12.924	2.707	45.46	22.82
F-5-T	10.143	2.653	14.16	20.37
F-10-T	12.264	2.761	38.03	25.27
F-20-T	13.207	2.873	48.64	30.35
D-5-T	12.869	2.765	44.84	25.45
D-10-T	13.481	3.164	51.73	41.11
D-20-T	13.091	3.320	47.34	50.64
F - Value	**	**	-	-
C.D. at 5%	1.73	0.490	-	-

* FYM-10-T: Farm yard manure at the rate of 10 tons per hectare

F-5-T; F-10-T; F-20-T: Fresh poultry slurry at the rates
5, 10 and 20 tons per hectare.

D-5-T; D-10-T; D-20-T: Digested poultry slurry at the rates
of 5, 10 and 20 tons per hectare.

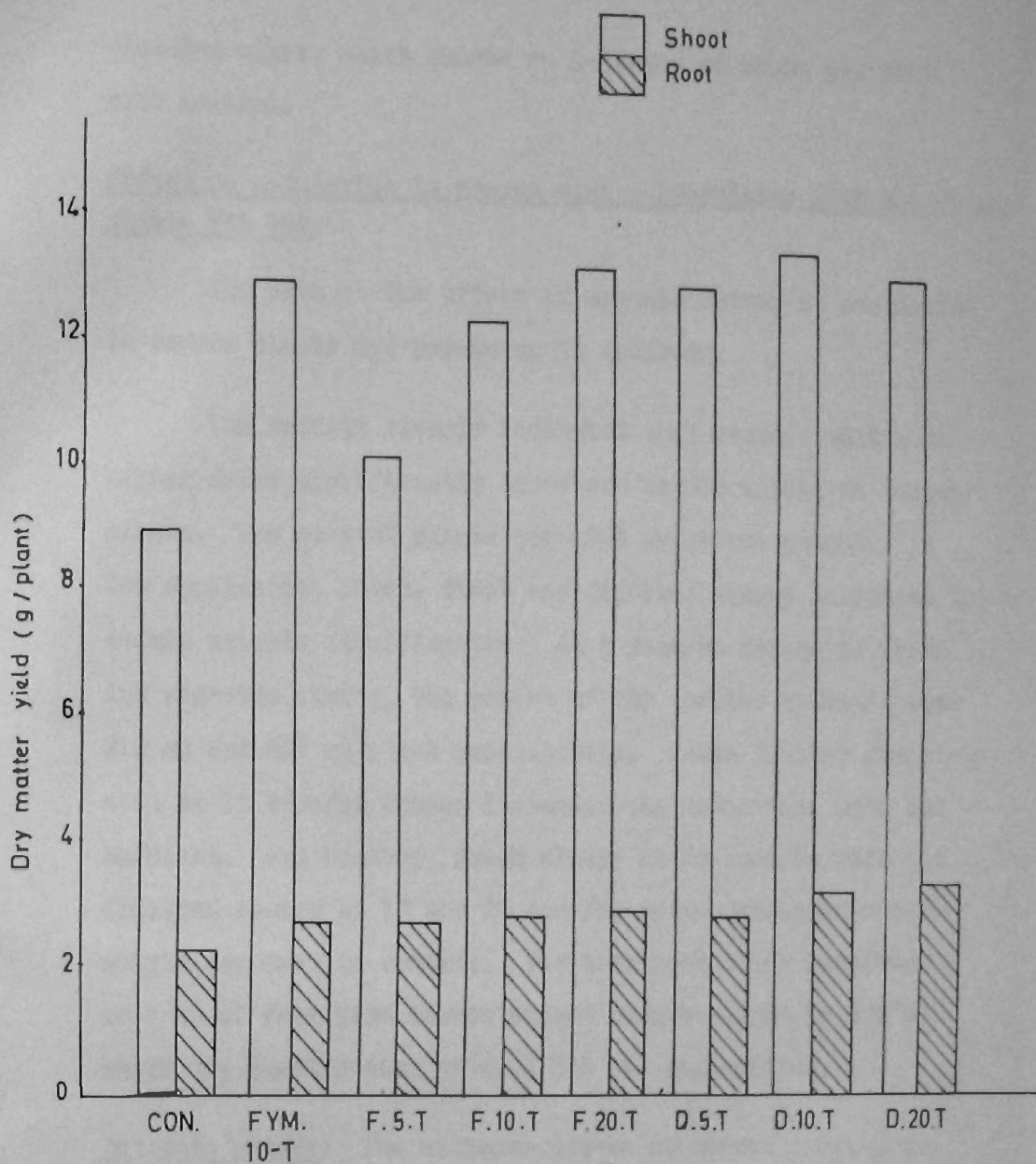


FIG: 12 INFLUENCE OF FARM YARD MANURE, FRESH AND DIGESTED POULTRY SLURRY ON DRY MATTER YIELD OF COWPEA PLANTS

digested slurry which showed an increase of 30.64 per cent over control.

Effect on nodulation in cowpea plants inoculated with Rhizobi strain TAL 169.

The data on the effect of organic matter on nodulation in cowpea plants are presented in table-20.

The results clearly indicated that organic matter at higher doses significantly decreased nodule weight in cowpea plants. The control plants gave 306 mg nodule weight. At low application rates, fresh and digested slurry increased the nodule weights significantly. At 5 tons/ha dosage of fresh and digested slurry, the weight of the nodules obtained were 312 mg and 402 mg/plant respectively. Fresh poultry dropping even at 10 tons/ha dosage increased the nodulation upto 392 mg/plant. But however, fresh slurry at 20 tons/ha rate and digested slurry at 10 and 20 tons/ha rates decreased nodule weight compared to control. The treatment which received 10 tons/ha of farm yard manure showed nodule weight of 326 mg which was greater than control but not significant.

Nitrogen uptake: The nitrogen uptake by cowpea plant grown in soils receiving organic matter was computed by estimating the total nitrogen content of the plant shoot weight yield. The results are presented in table-20.

Table 20: Effect of farm yard manure, fresh and digested poultry slurry on the nitrogen uptake and nodulation by cowpea plants

** Treatments	Nitrogen (%)	Nitrogen uptake (mg/plant)	Crude protein (gm/plant)	Nodule weight (mg/plant)	* Nitrogen use efficiency
Soil (control)	2.91	258.5	1.616	306	1.14
FYM-10-T	3.29	425.2	2.658	326	1.63
F-5-T	3.16	320.8	2.003	312	1.26
F-10-T	3.24	397.6	2.485	392	1.50
F-20-T	3.22	425.3	2.658	286	1.48
D-5-T	3.22	414.4	2.590	402	1.64
D-10-T	3.31	445.2	2.789	298	1.63
D-20-T	3.43	449.9	2.812	220	1.42
F - Value	NS	**	**	**	-
C.D. at 5%	-	47.4	0.296	39.2	-

* Nitrogen use efficiency indicates the dry matter yield obtained per unit of nitrogen in the particular treatment.

** FYM-10-T: Farm yard manure at the rate of 10 tons per hectare

F-5-T; F-10-T; F-20-T: Fresh poultry slurry at the rates 5, 10 and 20 tons per hectare

D-5-T; D-10-T; D-20-T: Digested poultry slurry at the rates of 5, 10 and 20 tons per hectare.

The data indicated that the application of fresh slurry, digested slurry and farm yard manure increased significantly the nitrogen uptake by cowpea plants in shoot system for all treatments compared to unamended control soil. In general, the treatments receiving digested slurry showed greater nitrogen uptake compared to the treatments receiving fresh poultry droppings. Maximum nitrogen uptake of 449.9mg/plant was obtained for the treatment receiving 20 tons/ha of digested poultry slurry. The nitrogen uptake by farm yard manure at 10 tons/ha rate was 425.2mg/plant which was almost equal to the treatment receiving 20 tons/ha of fresh poultry slurry. The crude protein in all the treatments was obtained by multiplying per cent nitrogen with the factor 6.25.

DISCUSSION

DISCUSSION

Biogas production is a three step process wherein various carbohydrates, proteins, fats and lipids are converted to methane gas by obligate anaerobic methanogenic bacteria. Various plants and animals wastes are used for biogas production by anaerobic bacteria. In the present studies poultry droppings are screened for biogas production. Once it was confirmed that poultry droppings produced biogas, the various factors effecting biogas production was studied. The factors studied were the optimum total solids concentration, pH and retention time. A pilot plant studies was conducted by operating the digester with optimum total solids concentration, pH and retention time as found in laboratory scale digesters to find out the feasibility of biogas production on a large scale. An experiment with poultry droppings substituted with cow dung, water hyacinth and banana leaves was studied to find out which substitution gave maximum biogas compound to poultry droppings alone. The second part of the study consisted of utilization of digested slurry on soil microflora, properties. Fresh poultry droppings, digested slurry and farm yard manure were taken in different levels to find out their influence on soil microbial population, nitrification and crop response.

The effect of different poultry droppings total solid concentration was studied for biogas production. The

biogas produced at lower solids was significantly greater compared to higher solids concentration. Maximum total biogas production of 23811 ml was obtained at 5 per cent total solids, followed closely by 4 per cent with 22361 ml. The minimum total biogas production of 16895 ml was obtained at higher solids of 15 per cent. At higher total solids of 15 per cent and 12.5 per cent, the biogas production was significantly less compared to biogas produced at 4 per cent and 5 per cent total solids concentration. This present observation got a bearing on the earlier reports of Sheila Bousfield et al (1979) who observed that optimum biogas production was obtained at lower solids concentration of 5 and 4 per cent than at 12 per cent solids concentration. Aubart et al (1982) in his experiment diluted poultry dropping to 3.8, 6.0 and 8.1 per cent total solids concentration and studied for biogas production. They found that for 15-day retention time biogas produced for 3.8 per cent total solids was maximum compared to the biogas produced from 6.0 and 8.1 per cent total solids concentration. A possible reason for less biogas production at higher total solids concentration from poultry droppings was that the poultry waste digestion was being inhibited by the high ammonia concentration (4900 mg per litre at 12 percent total solids) as reported by Hobson and Shaw (1976).

The changes occurring in total and volatile solids

during anaerobic digestion from poultry waste was studied. The treatments with lower total solids of 5 per cent showed significantly greater degradation compared to the treatments with higher total solids concentration. The per cent degradation was 28.20 and 27.30 respectively for the total solids concentration of 5.0 and 4.0 per cent for a 60-day period. Similar results have been obtained by Sheila Bousfield et al (1979) who reported that per cent total solids degradation was 22.6 from poultry droppings over 20-day period. Jain et al (1983) made a comparative study of per cent total solids degradation in cattle waste semi-continuously operated digester. In batch-type fermenter the per cent total solids degradation was in the range of 16.70-24.50 while in semi-continuously operated KVIC digester it was in the range of 42.00-46.20.

The volatile solids degradation was also greater at lower solids of 5 per cent and 5 per cent solids compared to higher solids concentration of 10, 12.5 and 15 per cent total solids. The highest volatile solids reduction of 40.04 per cent was obtained from the treatment with 5 per cent total solids and the lowest of 23.34 per cent for the treatment with 15 per cent total solids concentration. Grammes et al (1971) reported that per cent volatile solids reduction for poultry droppings ranged from 67.2±5.34 where as Jain et al (1983) reported that per cent volatile solids reduction for cattle waste was 20.20 to 29.00 in batch-type digesters and

and 44.00 - 52.10 for KVIC semicontinuous digester.

The percent degradation of total and volatile solids were more during the first 30 days compared to the last 30 days. During the first 30 days, the degradation was more than 50 percent and then the percent degradation decreased with increasing retention time. This is in agreement with the results of Rajendra Singh *et al* (1982) who reported that percent degradation of total and volatile solids for cattle waste were greatest in the initial period of digestion and slowed down with increasing period digestion.

The effect of different initially adjusted pH of 6.0, 7.0, 8.0 and 9.0 and the unadjusted control with pH 7.6 were studied on the biogas production from poultry droppings at 5 percent total solids concentration. The gas production at acid pH of 6.0 and high alkaline pH of 9.0 showed significantly less biogas yield compared to control. The maximum total biogas production of 24597 ml was obtained from the treatment with initial pH 7.0 and did not vary significantly compared to control (pH 7.6) which produced 24181 ml biogas. This is in conformity with the results of Huang *et al* (1971) reported that an optimum pH of 7.5 gave maximum methane yields from chicken wastes.

The treatments with initial pH 8.0 and 9.0 reduced to 7.69 and 7.78 respectively by end of 10 days. This may be due to production of fatty acids by acid bacteria during fermentation which lowers the pH. At the end of

30th day the pH in all the treatments were between 7.02 to 7.6. Nelson et al (1939) reported the anaerobic digestion of different organic materials at a pH range of 7.0 to 7.5.

The effect of different retention times on biogas production from poultry droppings was studied to find out optimum retention time for maximum biogas production. The quantities and percent of methane and carbon dioxide were also analysed. The biogas production started from the third day and was carried for a 90-day period. Retention time of 25 days was found optimum for maximum gas production when it produced 4083 ml during 20th and 25th day interval, a value higher than the other intervals. The present observation on retention time has got a bearing on the earlier results of Sheila and Bousfield et al (1982) who reported the optimal retention time of 20 days for maximum biogas production from poultry and cattle wastes. Rajendra Singh et al (1982) also reported that for cattle waste a 20-day retention time was optimum for highest gas returns per unit volume of the digester. The biogas production during the first 50 days was 26129 ml which accounted for 78.12 percent of the total biogas produced for a 90-day period. Idnani and Varadarajan (1974) reported that cow dung added to anaerobic fermenter took 4 weeks to produce gas upto 90 percent of its gas yielding capacity.

Here, the low temperature may have delayed the gas production and that may be the reason for 78.12 per cent gas returns during first 30 days. The methane content in the biogas produced from poultry dropping increased with increasing period of retention time. The per cent methane in the biogas ranged from 28.90 to 78.65 while the carbon dioxide contents ranged from 56.93 to 14.32. The average methane content for a 90-day period by a poultry dropping was 65.75.

Different agricultural wastes viz., cow dung, water hyacinth and banana leaves were used alone and in combination of poultry droppings to find out maximum biogas production by substitution at different levels. By screening different wastes, it was found that treatments with banana leaves alone gave maximum total gas production of 50484 ml which was significantly greater compared to any other treatments. The treatments with water hyacinth alone gave 45490 ml biogas, a value higher compared to biogas produced by poultry and cow dung wastes. This got a bearing on the earlier report of Guha *et al* (1976) who reported that water hyacinth alone provided 6 litres while cattle waste produced 3.4 litres for a 3-week period.

The poultry droppings alone produced 32012 ml biogas while cow dung which produced 27012 ml biogas was significantly less compared to biogas produced by poultry

dropping alone. This is in conformity with the results of Huang et al (1981) who reported that chicken manure was able to support the methane yield of 270 litres per kg volatile solid, a value higher compared to other kinds of livestock wastes. Odeyemi (1982) compared cassava leaves, sheep and poultry manure as well as sewage sludge for biogas production and reported that poultry manure produces more biogas compared to others.

Poultry droppings substituted with banana leaves and water hyacinth increased total biogas production significantly except at 10 per cent water hyacinth substitution. Poultry dropping substituted with 10 and 20 per cent banana leaves increased biogas production by 14.14 per cent and 24.27 per cent respectively over poultry droppings alone. Similarly poultry droppings substituted with 10 and 20 per cent water hyacinth resulted in 33919 ml and 37213 ml of biogas accounting for 5.95 and 16.3 per cent increase over poultry droppings alone. This observation has got a bearing with the findings of Deshpande et al (1979) who reported that water hyacinth used as an additive in biogas production enhanced the volatile fatty acid in the fermenting slurry which was a precursor of methane gas in the anaerobic fermentation. The gas production was 4.3 litres per day with true water hyacinth-cow dung mixture and 3.84 litres per day for cow dung alone. Rajasekharan (1980) also reported that water hyacinth as an additive increased

biogas production. He reported that cow dung, old slurry and water hyacinth in 1:1:1 ratio gave 1264.28 cc per day compared to cow dung and old slurry in 1:1 ratio which gave 668.30 cc per day.

Poultry droppings substituted by cow dung at 3 different levels did not increase the gas production compared to poultry dropping alone. But the biogas production by these three different mixtures were significantly greater compared to biogas produced by cow dung alone. This observation got a bearing with the results obtained by Singh et al (1982). They supplemented cattle waste with poultry waste and saw dust and reported that supplementation of cow dung with poultry droppings at 10 per cent resulted in increased volatile fatty acid and high gas production of 35.97 litres over cow dung alone and a mixture of cattle waste + poultry waste+ saw dust which produced 26.48 and 25.63 litres per kg for 8 weeks respectively. Jain et al (1982) also reported that cattle waste substituted with pig faeces at 10 per cent resulted in an increased acid and gas production.

The changes in the total and volatile solids for various treatments during a 90-day period were studied. The data indicated that greater per cent degradation of total solids with 36.10 and 34.48 was obtained from banana leaves and water hyacinth treatments respectively. The

per cent total solids degradation for poultry dropping was 30.66. Similar results were obtained by Sheila and Bousfield et al (1979) who reported that the per cent total solids degradation for poultry droppings was 22.6 for a 20-day period. Cow dung showed 27.45 per cent degradation which was in correlation with the results of Rajendra Singh et al (1981) who reported that 19.88 per cent total solids was degraded in a 20-day period. Jain et al (1983) also reported a per cent total solids degradation in the range of 16.70 - 24.30 for cattle waste digestion on batch scale.

The data also indicated that poultry droppings substituted with 10 and 20 per cent of banana leaves and water hyacinth showed significantly greater per cent total solids degradation compared to poultry droppings alone. Poultry droppings substituted with cow dung at different levels of 1:1 and 1:3 respectively gave per cent total solids degradation of 27.80 and 27.93 which was more than per cent total solids degradation of 27.45 for cow dung alone. This observation has got a bearing with the results of Singh et al (1982) who reported that cattle and poultry wastes at 1:1 ratio gave per cent total solids degradation of 20.80 while cow dung alone gave 19.88.

The studies on volatile solids changes showed that per cent destruction of volatile solids were signi-

ficantly higher for banana leaves and water hyacinth of 60.4 and 56.0 respectively as compared to poultry droppings. Similar results was obtained by Lettinga (1980) who reported that volatile solids reduction for water hyacinth was 66 per cent. This value was slightly higher compared to the values obtained during the experiment. This may be due to the low temperatures at which the digesters were operated. The volatile solids degradation for poultry droppings was 48.3 percent and for cow dung it was 41.2 per cent. A slightly higher values of volatile solids destruction of 67.2 ± 5.34 was obtained by Grammes *et al* (1971). This low value may be again due to low temperature at which the digesters were operated. However for cow manure, similar results were reported by Lettinga (1980) with 40.6 per bent volatile solids destruction. Poultry droppings substituted with banana leaves and water hyacinth showed greater percent volatile solids reduction over control. Poultry droppings and cow dung at 1:3 and 1:1 ratio respectively showed less per cent volatile solids degradation while the treatment with 3:1 ratio showed more per cent volatile solids destruction over control. The per cent total and volatile solids was more during first 45 days than last 45 days. This was comparable with the results obtained by Singh *et al* (1982) who observed that per cent total and volatile solids of cattle waste degraded greater in the initial period and slowed down with increasing period of digestion.

The manurial value of nitrogen, phosphorus and cellulose in different treatments at 0, 45th and 90th day were determined. In all the treatments per cent nitrogen increased with increased retention time. This may be due to the utilization of carbon by micro-organisms which lowers the C/N ratio and thus increases per cent nitrogen. The data indicated that per cent nitrogen increase over 0-day in cow dung and banana leaves was significantly greater than poultry droppings. Poultry droppings substituted with 10 and 20 per cent of water hyacinth showed per cent nitrogen increase of 26.4 and 28.0 respectively over 0-day. This observation got a bearing with the results of Rajasekharan (1980) who reported that cow dung, old slurry and water hyacinth (1.5: 1: 0.5) mixture gave 19.27 per cent nitrogen increase over control after digestion. The maximum per cent nitrogen increase over control after digestion was obtained from banana leaves treatment. The nitrogen per cent in poultry droppings increased from 2.24 to 2.58 while in cow dung it increased from 1.52 to 1.75. Similar reports was obtained by Singh et al (1981) who observed that per cent nitrogen increased from 1.89 to 1.93.

The per cent phosphorus increase over 0-day in cow dung, banana leaves and poultry droppings substituted with banana leaves was significantly greater than control. Maximum per cent phosphorus increase over 0-day was obtained from poultry droppings substituted with 10 per cent banana

leaves. Poultry droppings substituted with 10 per cent water hyacinth showed per cent phosphorus increase of 13.7. Similar results was obtained by Rajasekharan (1980) who reported that cow dung, old slurry and water hyacinth mixture (1:1:1) gave an increase of 22.00 per cent of phosphorus over control. The per cent phosphorus in poultry droppings increased from 1.512 to 1.913 while for cow dung it increased from 0.422 to 0.591.

In all the treatments, the percent cellulose decreased with increasing retention time. This may be due to the conversion of cellulose into biogas by action of micro-organisms. Norman (1924) reported that the major loss in organic material was due to cellulose degradation and he concluded that cellulose was the main energy source for methane fermenting bacteria. The highest cellulose content was found in water hyacinth treatment with 32.47 followed by 31.94 in banana leaves treatment. The cellulose in poultry dropping degraded by 27.70 per cent over 0-day while for cow dung cellulose degraded by 24.41 per cent. Similar results were obtained by Jain *et al* (1983) who reported that cellulose degradation in the range of 33.20 to 35.50 for cattle waste in a batch type fermenter. Poultry dropping and cow dung mixed at 1:3 and 3:1 and 1:1 ratio respectively showed more per cent cellulose loss over cow dung alone. This is in agreement with the results of Singh *et al* (1981) who reported that per cent cellulose

decreased from 22.81 to 18.04 for cattle waste and from 23.66 to 20.25 for poultry dropping and cattle waste mixture. Though the per cent loss in cellulose was more for the poultry droppings and cow dung mixture of 1:3 ratio than the other combinations of 1:1 and 3:1 ratios respectively, the biogas produced was less. This may be because the products of hydrolysis were not fermented to acetate and carbondioxide in the digestion. So higher cellulose degradation may not necessarily result in higher biogas production (Singh et al 1991).

The total carbon to nitrogen ratio in all the treatments decreased with increasing retention time. This may be due to utilization of carbon by micro-organisms, thus lowering C/N ratio and increasing per cent nitrogen. The treatment with banana leaves reduced in C/N ratio from 79.38 to 21.11 during a 90-day period. This drastic reduction may be due to the high per cent degradation of volatile solids and utilisation of carbon by micro-organisms. The C/N ratio in poultry droppings reduced from 30.76 to 13.80 while for cow dung it reduced from 55.07 to 28.11 during a 90-day period. Hills (1979) reported that the organic carbon to nitrogen ratio of 25:1 was optimum for maximum biogas production from dairy manure. The total carbon to nitrogen ratio for poultry dropping on 45th day was 19.39. Seiver and Brine (1978) reported that organic carbon to nitrogen

ratio of 15.5 to 19.1 was optimum for maximum methane production from swine manure.

Pilot plant studies were conducted for biogas production to study the feasibility of gas production on a large scale from poultry droppings and cow dung. The poultry droppings was loaded at 5 per cent total solids concentration into a 5.3 cubic feet digester as that concentration was found optimum for maximum biogas production in laboratory scale digester. Similar results had been reported by Sheila Bousfield *et al* (1979). The pH of the slurry was 7.6 and was not amended. (In the laboratory scale experiments, it was found that pH with 7.0 and 7.6 did not vary significantly in their biogas production).

Poultry droppings showed total and volatile solids degradation of 24.80 and 40.03 per cent respectively during 50 days period while cow dung degraded by 27.25 and 36.20 per cent respectively. Similar results was obtained by Sheila Bousfield *et al* (1979) who reported that per cent total solids loss for poultry and cattle wastes was 22.6 and 23.3 respectively. The per cent cellulose loss during 50 days period for poultry droppings and cow dung was 26.82 and 23.34 respectively. The per cent nitrogen and phosphorus increased by 16.20 and 40.60 respectively for poultry droppings and 14.77 and 29.57 respectively for cow dung.

The maximum gas production was obtained during 15th - 20th days interval. The biogas production after 20 days decreased gradually in both the organic wastes. Similar results were obtained by Sheila Bousfield *et al* (1979) and Singh *et al* (1982) who found that a 20-day retention time was found optimum for poultry droppings and cow dung. The total gas produced at the end of 50th day was 2389.95 litres for poultry droppings and 1344.11 litres for cow dung. The biogas produced from poultry droppings was greater than from cow dung. This is in agreement with the results obtained by Huang *et al* (1981) who reported that chicken manure produced biogas greater than any other kinds of livestock wastes. Lettinga (1980) also reported that poultry wastes produced more methane yield than cow dung. However the gas produced from poultry and cow dung wastes was less compared to the above scientists claim. This may be due to low winter temperatures at which the digesters were operated. Similar explanation was given by Acharya in 1958 who reported that biogas production from bullock dung during summer months was greater than in winter months (Sathianathan, 1975). Hashimoto (1983) and Hills (1993) also reported that at temperatures 55°C, the biogas produced from swine and dairy waste was more compared to the biogas produced at 35°C.

The second phase of the studies involved the utilization of digested slurry to find out their effect on soil

microbial populations, nitrogen mineralization and crop response.

The effect of fresh poultry droppings, digested slurry and farm yard manure addition to soil on microbial population were studied. All the treatments were supplemented with equal amounts of NPK fertilizers. In general, the treatments receiving digested slurry showed more per cent increase in population over control for fungi, bacteria and actinomycetes compared to the treatments receiving fresh poultry droppings. This may be due to more nutrients available in digested slurry after anaerobic digestion. Farm Yard manure (FYM) treatment also showed increase in microbial population over control.

For fungi, the control treatment increased from 7.1 to 19.8×10^3 during 60-day incubation period. The maximum per cent increase of 119.3 over control was obtained for the treatment receiving digested slurry at 10 tons/ha rate. Farm yard manure treatment at 10 tons/ha increased fungal populations by 105.6 per cent over control, a value lower compared to the treatment receiving 10 tons/ha of digested slurry. Similar results was obtained by Indiraraja and Raj (1979) who reported that application of organic matter increased fungal populations. At higher dosage of 20 tons/ha, fresh and digested poultry slurry showed less percent increase over control compared to the treatments receiving 10 tons/ha rate of fresh and digested poultry slurry.

In case of bacteria, there was a gradual increase from 31.3 to 55.9×10^5 during a 60-day incubation period. The soils amended with fresh and digested poultry slurry increased the bacterial populations significantly over soil. This observation got a bearing with the results of Ramaswami *et al* (1979) who reported that application of cattle manure increased bacterial population in soil. The maximum per cent increase of 103.8 over control was obtained for the treatment receiving digested poultry slurry at 10 tons/ha rate. The treatment receiving Farm yard manure at 10 tons/ha rate increased the bacterial population from 36.5 to 83.5×10^6 accounting for 57.6 percent increase over control. This was in correlation with the results of Sharma *et al* (1983) who reported that soil amended with Farm yard manure alone or in combination with inorganic fertilizer and lime supported greater microbial population of bacteria and actinomycetes. Gautham *et al* (1984) also reported that soil amended with FYM or FYM + NPK fertilizers markedly increased the number of bacteria over control.

In case of actinomycetes population, there was an increase from 1.31 to 1.91×10^3 for control during 60-day incubation period. Amending the soils with organic matter increased actinomycetes population. Similar results had been reported by Ramaswami *et al* (1979). They also reported that cattle manure alone and cattle manure plus potassic

fertilizer increased actinomycetes populations over NPK fertilizer application. The maximum per cent increase over control of 117.7 per cent was obtained for the treatment receiving digested slurry at 20 tons/ha. Farm yard manure treatment at 10 tons/ha also increased actinomycetes population. Similar results were obtained by Balasubramanian *et al* (1972) and Sharma *et al* (1983) who reported that actinomycetes population increased over control with farm yard manure amendment.

The soil nutrient that plants require in greater quantity is nitrogen. Yet, despite its critical role in plant nutrition, nitrogen is assimilated almost entirely in the inorganic state as nitrate or ammonical forms. The conversion of nitrogen to inorganic form is referred to as mineralization and is a result of microbiological activity.

In the present study, the changes in different form of nitrogen namely nitrate and ammonical nitrogen content attending the decomposition of organic matter were studied. The quantity of ammonical nitrogen in treatment receiving fresh poultry droppings, digested slurry and farm yard manure were higher than the unamended control, indicating that organic nitrogen were mineralized and released in ammonical form. The unamended control showed maximum ammonical nitrogen of 36.0 mg/100 g soil on the second

week and then gradually decreased. The treatments receiving fresh poultry droppings showed maximum ammonical nitrogen content on third week while the digested showed maximum ammonification on second week itself, one week ahead than the treatments which received fresh poultry droppings. This may be due to rapid ammonification in digested slurry which had already degraded to certain extent by anaerobic digestion. The treatment receiving high dosage of 20 tons/ha of fresh and digested slurry showed less ammonical nitrogen compared to lower rates of 10 tons/ha. Similar results has been obtained by Tester et al (1977) who reported that different ammonical nitrogen was produced when different levels of compost and sewage sludge mixture were incubated in different soils. The ammonical nitrogen content in fresh poultry dropping was less compared to digested slurry. This may be due to more nutrients present in digested slurry which had already been through anaerobic fermentation.

In the present studies, it was observed that addition of fresh poultry droppings, digested slurry and farm yard manure had increased nitrate-nitrogen content in soil. The control and the treatment receiving fresh poultry droppings showed maximum nitrate-nitrogen at the end of fourth week while the treatments receiving digested slurry showed maximum nitrate-nitrogen content at the end of third week. In general, the treatments receiving fresh poultry droppings

and farm yard manure showed less nitrate-nitrogen content compared to the treatments receiving digested slurry. This may be due to more nutrients present in digested slurry which was anaerobically digested. This is comparable with the results obtained by Acharya (1958) who reported that about 7.4 per cent of the nitrogen added as digested slurry nitrified in a period of three months, as compared to 4.75 per cent in the case of farm yard manure. Similar results was also reported by Laura and Idnani (1972). The digested slurry therefore appear to be superior to farm yard manure with regard to its nitrifiability in the soil.

The addition of fresh and digested poultry slurry at 20 tons/ha rate showed a lower nitrate nitrogen content than soils receiving fresh and digested slurry at 10 tons/ha rate. This trend in mineralization of ammonical nitrogen may be due to the resistant nature of the carbon source which may become available very slowly. Similar results were obtained by Rothwell and Hortenstine (1969) who reported that chicken manure (at 8 g and 10 g per 100 g soil), sewage sludge (at 8 g and 10 g per 100 g of soil) and garbage compost (at 10 g per 100 g soil) decreased nitrification with increased levels of both sewage and chicken manure. Ryan et al (1973) also reported that at lower levels of anaerobically digested sludge, the inorganic nitrogen was all converted to nitrate and nitrate-nitrogen while at higher

levels, a significant amount of ammonical-nitrogen was not nitrified even after 16 weeks of incubation.

The effect of fresh, digested slurry and farm yard manure on dry matter yield of ragi plants were studied. In the present studies, it was found that application of fresh poultry droppings, digested slurry and farm yard manure to soils significantly increased the dry matter yield of ragi plant in all treatments except for the treatment receiving 5 tons/ha of fresh poultry slurry. Similar results has been obtained by Ravikumar and Krishnamurthy (1980) who reported that organic amendment like poultry manure, maize straw and farm yard manure were superior in improving the yield of ragi crop. The dry matter yield of shoot and root was maximum with 14.987 g and 5.814 g respectively for the treatment receiving 10 tons/ha digested poultry slurry. The treatment receiving digested slurry gave more dry matter yield than the fresh poultry droppings. The dry matter yield of shoot and root of ragi crop for the treatment receiving high dosage 20 tons/ha was less compared to the treatment receiving 10 tons/ha of digested slurry. Furrer (1977) also found that high rates of sewage sludge or pig slurry reduced yield and quality of wheat. Mathews and Stewart (1983) reported that application of feed lot manure up to 22 tons/ha gave maximum yields and dosage more than this did not increase the yields.

Application of farm yard manure at 10 tons/ha gave increased dry matter yield of shoot and root of ragi plants over control. This is in conformity with results of Chellamuthu and Kedandaraman (1980) who reported that yield of ragi grain and straw increased with increased levels of nitrogen either as farm yard manure or ammonium sulphate. They reported that the straw yield was highest for combined application of farm yard manure at 60 kg N/ha and ammonium sulphate at 90 kg N/ha.

The present studies indicated that application of farm yard manure, fresh and digested poultry slurry significantly increased nitrogen uptake by ragi plant over control. The nitrogen uptake of fresh poultry droppings are significantly less compared to the digested slurry. The farm yard manure treatment receiving 10 tons/ha also increased significantly in the nitrogen uptake. Maximum nitrogen uptake of 316.2 mg/plant was obtained from the treatment receiving 10 tons/ha of digested slurry.

The effect of fresh poultry droppings, digested slurry and farm yard manure on dry matter yield of cowpea plants were studied. It was found that the yield of shoot and root system significantly increased in all the treatments except for the treatment which received 5 tons/ha rate of fresh poultry droppings. Similar results were reported by Robert Robinson (1983) who observed that highest yields of field

bean were got in response to compost plus inorganic nitrogen application to soil. Shivashankar et al (1976) also reported that addition of organic matter viz. paddy straw increased the yields of soybean. Maximum shoot yield of 13.481 g was obtained by the treatment receiving 10 tons/ha rate of digested slurry. In general, the treatments receiving digested slurry showed more yield than fresh poultry droppings. This may be due to the more nutrients present in digested slurry which had degraded anaerobically.

Addition of organic matter to certain level did not effect nodulation in cowpea plants. This got a bearing with the results obtained by Shivashankar et al (1980) who reported that straw application upto 6 tons/ha increased nodule weight over control. However, fresh poultry droppings at 20 tons/ha and digested slurry at 10 and 20 tons/ha decreased the nodule weight significantly. This may be due to the inhibition of nitrogenase enzyme in Rhizobium sps. by the presence of large amounts of nitrogen and so failed to nodulate. Maximum nodule weight of 402 mg per plant was obtained for the treatment receiving 10 tons/ha rate of digested slurry while for control the nodule weight was 306 mg/plant.

The practical implication of these studies are that the poultry droppings when loaded into a digester should have lower total solids concentration of 4 and 5 per cent

than higher total solids concentration of 10 per cent and above. The studies on the pH effect on biogas production has indicated that biogas production from a pH range of 7.0 to 8.0 gave optimum biogas. So, if the pH of the fresh poultry slurry is having a value between 7.0 and 8.0 it is not necessary to amend the poultry slurry's pH. The studies on the optimum retention time for biogas production revealed that a 25-day period was found suitable to get maximum gas yield.

The experiment on producing biogas by substituting various agricultural wastes like cow dung, water hyacinth and banana leaves with poultry droppings have indicated that banana leaves and water hyacinth alone gave maximum biogas yields. The substitution of the various above mentioned wastes with poultry droppings increased biogas production over poultry droppings alone except for cow dung waste substitution. The biogas produced on a pilot plant scale from poultry dropping was feasible on a 5.3 cubic feet digester and did not differ much in properties as earlier observed in laboratory scale digesters. However the retention time of 20 days was found optimal, unlike in laboratory scale digesters where optimal retention time was 25 days.

The studies on the utilization of spent slurry on microbial populations, nitrogen mineralization and crop response revealed that the digested slurry showed better

promise over fresh poultry droppings or farm yard manure. There is a need in India to utilise various organic manures for fuel and manurial purposes. It is hopeful that the knowledge gained through this studies will find use in the attempts at producing biogas by selecting proper material and combination and using the fermented residue for improving the soil properties and crop yields.

SUMMARY

VI. SUMMARY

The various factors effecting biogas production from poultry droppings and the influence of fermented slurry on soil microflora was worked out and summarised as below.

Studies on the effect of poultry dropping concentration on biogas production indicated that at 4 and 5 per cent the production of biogas was greatest of 22.8 litres compared to solids concentration of 10 per cent and above.

The effect of different initial pH, 6.0, 7.0, 8.0, 9.0 and the unamended control with pH 7.6 on biogas production indicated that maximum gas production of 24.6 litres was obtained for pH 7.0. At pH 6.0 and 9.0 biogas production was significantly less in the order of 17.9 litres and 13.6 litres respectively. The effect of hydraulic retention time on gas production at 5 per cent indicated that 25 days was optimum.

Studies on substitution of cow dung, water hyacinth and banana leaves with poultry droppings indicated that banana leaves and water hyacinth at 10 and 20 per cent substitution gave higher biogas yield compared to poultry droppings alone. Banana leaves substitution was superior to water hyacinth substitution. But However, poultry droppings and cow dung mixed at different proportions did not increase biogas yield compared to poultry droppings alone.

Banana leaves alone and water hyacinth alone gave greater biogas compared to poultry droppings or poultry droppings substituted with 10 and 20 per cent of water hyacinth and banana leaves. After digestion, the per cent nitrogen and phosphorus increased in all the treatments.

Pilot-plant studies indicated that biogas production from poultry droppings and cow dung was feasible on a large scale. The optimum retention time varied slightly from laboratory scale digestion. 20-day period was optimum for maximum biogas production. The per cent nitrogen and phosphorus in the slurry increased after fermentation.

Studies on the effect of digested slurry on soil microbial populations indicated that fungal, bacterial and actinomycetes populations increased more than fresh poultry droppings or farm yard manure. Actinomycetes population increased with the increased dosage of the slurry. Bacterial and fungal populations showed less response at 20 tons/ha rate compared to 10 tons/ha rate of fresh and digested poultry slurry.

Addition of farm yard manure, fresh and digested poultry slurry to soil increased the nitrogen mineralization. The increase was more for the treatments which received digested slurry than the fresh poultry slurry. At highest obligation rate of 20 tons/ha of fresh and digested slurry, the nitrogen

mineralization was less compared to the treatments which received 10 tons/ha rate of fresh and digested slurry.

Addition of farm yard manure, fresh and digested poultry slurry increased the dry matter yield of both ragi and cowpea plants. The response of crops was more for digested slurry than for fresh slurry. Nitrogen use efficiency also indicated that the digested slurry was superior to fresh slurry in increasing the dry matter yield. Cowpea plants at lower rate of 5 and 10 tons/ha of fresh slurry and 5 tons/ha of digested slurry showed increased nodulation. At higher rates of 20 tons/ha of fresh slurry and 10 and 20 tons/ha of digested slurry decreased nodulation. Farm yard manure at 10 tons/ha increased nodule weight but was not significant.

REFERENCES

VII. REFERENCES

- Acharya, C.N., 1935, Studies on anaerobic decomposition of plant materials. Biochem.J., 29: 528-541.
- Acharya, C.N., 1940, Composts and fertility. Indian Eng., 1: 66-68.
- Acharya, C.N., 1945, Manurial value of town compost. Indian J 6: 410-411.
- Acharya, C.N., 1956, Your home needs a gas plant. Indian Eng. 8: 27-30.
- Acharya, C.N., 1958, Preparation of fuel gas and manure by anaerobic fermentation of organic materials. ICAR Res. Ser., 15: 1-30.
- Allison, F.E., 1955, The enigma of soil nitrogen balance sheets. In: Advances in Agronomy. (Ed.) A.G. Narme 17: 213-250.
- Allison, F.E. and Klein, C.J., 1962, Rates of immobilization and release of nitrogen following additions of carbonaceous materials and nitrogen to soils. Soil sci., 83: 194-201.
- Alone, B.A., Pathe, P.R., Titus, S.K. and Bhide, A.D., 1978, Anaerobic digestion of city refuse and dung. Indian. J. Environ. Health., 20: 134-140.
- Amberger, A., 1971, Decomposition of maize straw in soil. Proceedings international symposium on soil fertility evaluation, New Delhi. Indian Soc. of Soil Sci., 1: 773-780.
- Anon., 1977, Fuel from weeds. Jagrithi, 21: 7-15.
- Anonymous, 1980, Official methods of Analysis of the Association of Official Analytical chemists. (Ed) William Horwitz, Washington, D.C., p 1018.

- Aubart, Ch., Bully, F. and Farinet, J.L., 1982, Anaerobic digestion of pig manure. Energy from Biomass. 2nd E.C. conference (Eds.) A. Strub, P. Chartier and G. Schieeer, p599-603.
- Bahtiya, M., 1981, Plant germination with various kinds and amounts of refuse compost in green house investigations. Zeitschrift für Kulturtechnik und Flurbereinigung, 22: 262-268 (From Soils and Fertilizers, 45: p176, 1982).
- Balakhonov, S.I. and Drozdova, T.A., 1981, A comparison of the effectiveness of two techniques using straw and animal excrement as fertilizer. Agrokhimiya, No.4: 83-89 (From Soils and Fertilizers, 45: p842, 1983).
- Balasubramanian, A., Shantaram, M.V., Sardeshpande, J.S. and Rangaswami, G., 1972, Studies on certain microbiological properties of the old permanent manurial plots at Coimbatore, Tamil Nadu. Madras agric. J., 59: 443-448.
- Bartholomew, H.V., 1965, Mineralization and immobilization of nitrogen in the decomposition of plant and animal residues. In Soil Nitrogen. (Eds.) W.V. Bartholomew and F.E. Clark, Agronomy series No.10, American Soc. of Agronomy, Madison, Wisc., pp285-306.
- Bunt, J.B. and Rovira, A.D., 1955, The effect of temperature and heat treatment on soil metabolism. J. Soil Sci., 6: 129-136.
- Buswell, A.M. and Neave, S.L., 1930, Laboratory studies on sludge digestion. Illinois state water survey Bulletin, 30: 35-87.
- Chellamuthu, S. and Kodandaraman, G.V., 1980, Effect of FYM and ammonium sulphate on the yield of ragi. Mysore agric. Sci., 14: 294-296.
- Colom, J. and McCalla, T.M., 1952, The decomposition of partridge pea and its influence on nitrification. Soil Sci. Soc. Amer. Proc., 16: 208-210.

- Cooney, L.C. and Wise, L.O., 1975, Thermophilic anaerobic digestion of solid waste for fuel gas production. Bioeng. Biotechnol., 17: p1119.
- Datta, M. and Gupta, R.K., 1983, Response of leguminous crops to press mud and lime in Nagaland. J. Indian Soc. Soil Sci., 31: 635-637.
- Desai, S.V. and Biswas, S.C., 1945, Manure and gas production by anaerobic fermentation of organic wastes. Indian Eng., 6: 67-76.
- Deshpande, P.S., Sharnaik, S.H. and Godboy wagle, P.M., 1975 Use of water hyacinth as an additive in biogas production. Current science, 48: 490-492.
- Diaz, L.F., Kurz, F. and Trezek, G.J., 1974, Methane gas production as part of a refuse recycling system. Compost science, 15: 7-13.
- Duggan, J.C. and Wilas, C.C., 1976, Effects of municipal compost and nitrogen fertilizers on selected soils and plants. Compost science, 17: 24-31.
- Epstein, E., Keane, D.B., Meisinger, J.J. and Legg, J.O., 1978, Mineralization of nitrogen from sewage sludge and sludge compost. J. Environ. Qual., 1: 217-221.
- Esteban, P., Move, A., Ovtega, M. and Sanz, A.M., 1980, Nitrification of pig slurry in an agricultural soil. Anales del Instituto Nacional de Investigaciones Agrarias, No.13: 13-31 (From Soils and Fertilizers, 45, p175, 1982).
- Feilden, E.H.N., 1981, A note on the temperature for maximum net gas production in an anaerobic digester system. Agricultural wastes, 3: 75-79.
- Fisher, J.R., Ianmotti, E.L. and Fulbage, C.D., 1983, Production of methane gas from combinations of wheat straw and swine manure. Trans. ASAE., 26: p546.

- Fisher, J.R., Iannotti, E.L. and Sievers, O.M., 1981, Anaerobic digestion of manure from swine fed on various diets. Agricultural wastes, 3: 201-214.
- Flowers, T.H. and O'Callaghan, J.R., 1983, Nitrification in soils incubated with pig slurry or ammonium sulphate. Soil. Biol. Biochem., 15: 337-342.
- Fowler, G.J. and Joshi, G.W., 1923, Studies on anaerobic fermentation of cellulose. I. Indian Inst. Sci. Bangalore., 3: 39-49.
- Fujita, M., Scharew, J.M. and Moo-Young, M., 1980, Effect of corn straw addition on the anaerobic digestion of swine manure. Agricultural wastes, 2: 177-184.
- Furrer, O.J., 1977, Influence of high rates of sewage sludge and pig slurry on plant yields and soil properties. Land wirt schaftliche Forschung Sonderheft, 33: 249-256 (From Soils and Fertilizers, 41: 631, 1978).
- Galiano, F. and Rodriguez, E., 1963, Organic fertilizer from town refuse applied to horticulture. Technologia, 5: 15-23 (From Soils and Fertilizers, 30: 294, 1967).
- Gautham, R., Datta, R., Sood, M.L. and Kalva, T.S., 1984, study of bacterial population of soil under different levels of fertilizer application. J. of Indian Soc. Soil Sci., 32: 178.
- Glenn, C.W. Aures, 1976, Can organic manures improve crop production in southern India. Compost Sci., 17: 7-11.
- Grammes, L.C., Polkowski, L.B. and Witzel, S.A., 1971, Anaerobic digestion of farm animal wastes. Trans. of ASAE., 14: 7-13.
- Guha, B.R., 1976, Fuel gas and compost manure from water hyacinth. Khadigramodyog., 22: 483-486.
- Gupta, K. and Sinha, J.P., 1974, Study of the manurial value of super compost reinforced with single superphosphate. Indian J. agric. Chem., 7: 25-30.

Hashimoto, A.G., Chen, Y.R., Varel, V.H. and Priar, R.L., 1981, Anaerobic fermentation of agricultural residues. In: Utilization and recycle of agricultural wastes and residue., (Eds). Micheal shruber, Bocaroton, CRC press, p135-196.

Hashimoto, A.G., Varel, V.H. and Chen, V.R., 1981, Ultimate methane yields from Beef cattle manure, effect of temperature, ration constituents antibiotics and manure age. Agricultural wastes, 3: 241-256.

Hashimoto, A.G., 1983, Thermophilic and Mesophilic anaerobic fermentation of swine manure. Agricultural wastes, 6: 175-191.

Hawkes, F.R., Floyd, J.R.S. and Hawkes, D.L., 1980, Operation of a laboratory scale plug flow type of digestion on pig manure. Energy from Biomass, 1st E.C. conference, (Eds.) A. Shrub, P. Chartier and G. Sheleser, pp378-405.

Hawkes, F.R. and Young, B.V., 1980, Design and operation of laboratory scale anaerobic digestion: operating experience with poultry litter. Agricultural wastes, 2: 119-133.

Hills, D.J., 1979, Effects of carbon: Nitrogen ratio on anaerobic digestion of dairy manure. Agricultural wastes, 1: p267.

Hills, D.J., 1980, Biogas from a high solids combination of dairy manure and Barley straw. Trans. ASAE., 23: 1500-1504.

Hills, D.J., 1983, Design parameters and operating characteristics of animal waste anaerobic digestion system, Beef cattle. Agricultural wastes, 3: 205-218.

Hills, D.J., 1983, Design parameters and operating characteristics of animal waste anaerobic digestion systems, Dairy cattle. Agricultural wastes, 3: 219-230.

Hills, D.J. and Roberts, W., 1981, Anaerobic digestion of dairy manure and field crop residues. Agricultural wastes, 3: 179-189.

- Hiltbold, A.E., Bartholomew, M.V. and Werkman, C.H., 1951, The use of tracer techniques in the simultaneous measurement of mineralization and immobilization of nitrogen in soil. Soil Sci. Soc. Amer. Proc., 15: 166-173.
- Hindin, E. and Gilbert H. Dunstan., 1960, Effect of detention time on anaerobic digestion. J. of water poll. con. fed., 22: p930.
- Hobson, P.N. and Shaw, B.G., 1973, The anaerobic digestion of waste from an intensive pig unit. Water Res., 10: 849-852.
- Heish, Y.P., Douglas, A.L. and Harry, L.M., 1981, Modelling sewage sludge decomposition in soil. II. Nitrogen transformation, J. Environ Qual., 10: 59-64.
- Huang, J.J.H. and Sterusbeyer, S.C., 1981, Biogas production from different livestock wastes. From: Proc. of 2nd International seminar on energy conversion and use of renewable energies in the bio-industries., p376-383.
- Idnani, M.A. and Chawla, O.P., 1969, Improve the performance of your biogas plant in winter. Indian Eng., 6: 37-38.
- Idnani, M.A. and Varadarajan, S., 1974, Preparation of fuel gas and manure by anaerobic fermentation of organic materials. ICAR Tech. Bull., 46: 60.
- Indiraraja, M. and Raj, D., 1979, Effect of press mud application on physical, chemical and biological characters of some common soils. Madras agric. J., 66: 538-545.
- Indiraraja, M. and Raj, D., 1980, A note on the influence of press mud application on ragi yield in an alkali soil: Madras agric. J., 67: 204-206.
- Jackson, M.L., 1973, Soil chemical analysis: Prentice Hall, New Delhi.

- Jain, M.K., Singh, R. and Tauro, P., 1982, Biochemical changes during anaerobic digestion of animal wastes. Water Res., 16: 411-415.
- Jain, M.K., Singh, R. and Tauro, P., 1983, cattle waste anaerobic digestion in a semi continuously and a batch type digester. Agricultural wastes, 7: 251-259.
- Janson, S.L., and Clark, F.E., 1952, Losses of nitrogen during decomposition of plant material in the presence of inorganic nitrogen. Soil Sci Soc. Amer. Proc., 16: 330-334.
- Jensen, H.L., 1931, The microbiology of farm yard manure. I. changes in microflora and their relation to nitrification. J. agric. Sci., 21: 38-80.
- Jones, J.C. and Stafford, D.A., 1955, Influence of Industrial wastes and retention time on methane production from sewage sludge digestion. Effluent water treat. J., 15: 288-291.
- Joseph, A.R., 1977, Effect of nitrogen source on nodulation, nitrogen fixation and mineral content of soybean in solution culture. Madras agric. J., 64: 211-217.
- Juste, C., Dureau, P. and Lassene, M., 1981, Effect of methane digestion on the fertilization value of various organic wastes. Rendus des seances de l'Academie d'Agriculture de France, 67: 782-790 (From Soils and Fertilizers, 45: p175, 1982).
- Kanfuran, R., Sutter, K. and Wellinger, A., 1982, Low temperature methane generation from animal manure. Proc. of 2nd International Seminar on energy conservation and the use of renewable energies in bio-industries, pp405-417.
- Kelling, K.A., Walsh, L.M., Keeney, D.R., Ryan, J.A. and Peterson, A.E., 1977, A field study of the agricultural use of sewage sludge. 2. Effects on soil N and P. J. Environ. Qual., 6: 345-352.

- Kiefer, C.E. and Kourtz, H., 1934, The digestion of garbage with sewage sludges. Sewage works J., 6: 14-23.
- King, L.D., Rudgers, L.A. and Webber, L.R., 1974, Application of municipal refuse and liquid sewage sludge to agricultural land. I. Field study. J. Environ. Qual., 3: 361-366.
- King, L.D. and Vick, R.L., 1978, Mineralization of nitrogen in fermented residue from citric acid production J. Environ. Qual., 7: 315-318.
- Klass, D. and Ghosh, S., 1979, Methane generation by anaerobic digestion of Bermuda grass. In Sym. "Biomass as a non-fossil fuel source," (Ed.) P.L. McCarty, American Chem. Soc./Chem., Honolulu.
- Knol, W., Host, M.M. and Waart, J., 1978, Biogas production by anaerobic digestion of fruit and vegetable waste. A preliminary study. J. of Sci. of food and agriculture, 29: 822-830.
- Kuster, E. and Williams, S.T., 1964, Selection of media for isolation of streptomycetes. Nature, 202: 926-929.
- Kuszelewski, L. and Jagiela, Z., 1973, Evaluation of the fertilizer value of slurry from intensive pig fattening farms. Part II. Field experiments Roelnik: Nauk Rolniczych, 99: 133-148 (From Soils and Fertilizers, 38: 1103, 1975).
- Lang, F., 1980, Whey - Potential source of energy milk indu. Agricultural wastes., 82: 30-31.
- Laura, R.D. and Idnani, M.A., 1971, Increased production of biogas from cow dung by adding other agricultural waste materials. J. Sci. food and agriculture, 23: 164-167.
- Laura, R.D. and Idnani, M.A., 1972, Mineralization of nitrogen in manures made from spent slurry. Soil Biol. Biochem., 4: 239-243.

- Lettinga, G., 1980, Energy from biomass. Proceedings of 1st International conference on biomass, (Eds.) W. Pais, P. Chartier and D.O. Hall, Applied Sci. Pub. Limited. London. pp265-278.
- Magdoff, F.R. and Amadon, J.F., 1980, Nitrogen availability from sewage sludge. J. of Environ. Qual., 2: 431-435.
- Makawi, A.A.M., 1982, Local organic manures and their effect on soil microflora on wheat yield. FAO soils Bull. No.45: 144-148.
- Martin, J.P., 1952, Use of acid, rose-bengal and streptomycin in a plate method for estimating soil fungi. Soil sci., 60: 215-232.
- Mathers, A.C. and Stewart, B.A., 1974, Corn silage yield and soil chemical properties as affected by cattle feedlot manure. J. of Environ. Qual., 3: 143-149.
- Mazur, T., Koe, J. and Ciecko, Z., 1979, Comparison of the fertilizing value of slurry with that of FYM and mineral nitrogen in pot experiments. Roczniki aleboznawcze, 30: 57-72 (From Soils and Fertilizers, 43, p.437, 1980).
- Moo-young, M., 1978, Bio-conversion of agricultural wastes into animal feed and fuel gas. Bioeng. Biotechnol. 8: 205-208.
- Nelson, C.H., Strake, R.P. and Maxlerine., 1939, Anaerobic decomposition and gassification of corn stalk by thermophiles. Iowa State Coll. J. Sci., 14: 233-25
- Niklowski, M., Kalembasa, S. and Kania, R., 1979, The first year of field experiment on the effectiveness of solid pig manure. Roczniki Nankowe Zootechniki Monografie i Rozprawy, No.14, 171-182 (From Soils and Fertilizers, 45, p50, 1982).
- Nommick, H., 1961, Mineral nitrogen immobilization and carbondioxide production during decomposition of wheat straw in soil as influenced by temperature. Acta. agric. Scand., 12: 81-94.

- Norman, A.G., 1924, Anaerobic decomposition of organic wastes. Biochem. J., 29: 502-520.
- Odeyemi, O., 1982, Biogas generation from cassava leaves compared with two animal manures and sewage sludge. Proc. of 2nd International Seminar on energy conservation and the use of renewable energies in the bio-industries., pp338-359.
- Pain, B.F., Phipps, R.H. and Richardson, S.J., 1977, The effects of cattle slurry and inorganic fertilizer nitrogen on the yield and mineral composition of forage maize. Results of preliminary experiments. J. Sci. Ed. Agric., 28: 694-698.
- Parker, C.F. and Sommers, L.E., 1983, Mineralization of nitrogen in sewage sludge. J. Environ. Qual. 12: 150-156.
- Patha, P.P., Alone, B.Z., Titus, S.K. and Shide, A.D., 1977, Seasonal variation in performance of anaerobic digestion of city refuse. Indian J. Environ Health. 19: 340-345.
- Patrick, O. Aino and Ewreka Egolun, 1979, The effect of cattle feedlot manure and inorganic fertilizer on the improvement of subsoil productivity of soil. Soil and Fertilizers, 43: p151.
- Peery, W.J. and Norman, A.N., 1948, Influence of composition of plant materials on properties of the decomposed residues. Soil sci., 65: 209-226.
- Perra-cabriales, J.J. and Alexander, M., 1983, Growth of Rhizobium in soil amended with organic matter. Soil Sci. Soc. Amer. J., 47: 241-245.
- Pfeffer, J.T., 1974, Temperature effects of anaerobic fermentation of domestic refuse. Bioeng. Biotechnol., 16: 771-787.
- Pfeffer, J.T. and Khan, K.A., 1976, Microbial production of methane from municipal refuse. Bioeng. Biotechnol., 18: 1179-1191.

- Polesko, Yu.A., Brazhnik, S.P. and Kolesnikova, Z.M., 1974, the role of mineral fertilizers in the mobilization of the nitrogen in the plant residues of winter wheat. Agrokimiya, 2: 8-14 (From Soils and Fertilizers, 35, 1104, 1975).
- Prasad, C.R., Gulati, K.C., Idnani, M.A. and Desai, R.S., 196 Studies on biogas production/methane fermentation of some carbohydrates. Proc. Nat. Acad. Sci. India 38: 179-184.
- Quastel, J.H. and Scholesfield, P.G., 1951, Biochemistry of nitrification in soil. Bact. Rev., 15: 1-53.
- Raj, R. and Sinha, J.P., 1977, Study of the rate of mineralization of nitrogen in town-compost mixed with different soils of Bihar. Indian J. agric. Chem., 10: 195-199.
- Rajasekharan, P., 1980, Microbiological changes accompanying degradation of water hyacinth in an anaerobic digest. Madras agric. J., 67: 39-41.
- Rajasekharan, P., 1981, Effect of fish and chicken wastes on the microbial population and biogas generation. Madras agric. J., 68: 444-449.
- Rajasekharan, P., Manian, R. and Kamaraj, S., 1982, Groundnut shell and composite mixture of weeds; A good feed stock material for biogas production. Madras agric. J., 69: 801-808.
- Ramaswami, P., Raj, D. and Selvaraj, K.V., 1979, Effect of continuous application of manure and fertilizers on some of the physico-chemical and microbiological properties of soil under irrigated conditions. Mysore J. agric. Sci., 13: 167-170.
- Ravikumar, V. and Krishnamoorthy, K.K., 1980, Influence of soil amendments on the physical properties of black soil and yield of ragi. Madras agric. J., 67: 177-182.
- Ravikumar, V. and Krishnamoorthy, K.K., 1980, Effect of soil amendments on the chemical properties of verticoll and yield of finger millet. Madras agric. J., 67: 369-371.

- Robbins, J.E., 1979, Methane production from cattle waste and delignified straw. Infection and Immunity, 39: p175.
- Robinson, R.G., 1983, Yield and comparison of field beans and Adzuki bean in response to irrigation, compost and nitrogen. Agron. J., 75: 31-35.
- Rothwell, D.F. and Hortenstine, C.C., 1969, Composted municipal refuse: Its effect on carbon dioxide, nitrate, fungi and bacteria in Arrendonte fine sand. Agron. J., 61: 837-840.
- Ryan, J.A., Keeney, D.R. and Walsh, L.M., 1973, Nitrogen transformations and availability of an anaerobically digested sewage sludge in soil. J. Environ. Qual., 2: 489-492.
- Sabey, B.R., Agbim, N.N. and Markstrom, D.G., 1975, Land application of sewage sludges III. Nitrate accumulation and wheat growth resulting from addition of sewage sludge and wood wastes on soils. J. Environ Qual., 4: 388-393.
- Sanyasi Raju, M., Kuppaswami, S.V. and Subramaniam, T.R., 1957, The effect of compost on some south Indian crops. Andhra agric. J., 4: 121-128.
- Sathianathan, M.A., 1975, Biogas-Achievements and challenges. A.V.A.R.D., New Delhi.
- Shenmughan, K. and Ravikumar, V., 1980, Effect of organic residue on physical properties of soil and yield of sorghum. Madras agric. J., 67: 272-276.
- Sharma, N., Srinivastava, L.L. and Mishra, B., 1983, Studies on microbial changes in soil as a result of continuous application of fertilizer, FYM and lime. J. Indian Soc. soil Sci., 31: 202-206.
- Sheila Bousfield, Hobson, P.N. and Summers, R., 1979, A note on anaerobic digestion of cattle and poultry wastes. Agricultural wastes, 1: 161-164.

- Shiva shanker, K., Vlassak, K. and Livens, J., 1976, A comparison of the effect of straw incorporation and CO₂ enrichment on the growth, nitrogen fixation and yield of soybeans. J. agric. Sci. Camb., 87: 181-185.
- Shivashankar, K. and Vlassak, K., 1978, Influence of straw and CO₂ on nitrogen fixation and yield of field grown soybeans. Plant and soil, 49: 259-266.
- Shivashankar, K. and Shantharam, M.V., 1980, Nodulation, growth and yield of soybeans as affected by paddy straw application to soil. Z. pflanzen. Bodark., 143: 68-73.
- Sievers, D.M. and Brine, D.E., 1978, C/N ratio and anaerobic digestion of swine wastes. Trans. of ASAE., 21: 537.
- Sims, J.T. and Boswell, F.C., 1980, The influence of organic wastes and Inorganic sources on soil nitrogen, yield and elemental composition of coon. J. Enviro Qual., 9: 512-518.
- Singh, R., Jain, M.K. and Tauro, P., 1981, Press mud as an additive to increase biogas production from cattle wastes. Current science, 50: 640-643.
- Singh, R., Jain, M.K. and Tauro, P., 1982, Production of biogas from cattle waste supplemented with poultry waste and saw dust. Maryana agricultural University J. Res., 11: 207-213.
- Singh, R., Jain, M.K. and Tauro, P., 1982, Rate of anaerobic digestion of cattle wastes. Agricultural wastes, 4: 267-272.
- Singh, R., Jain, M.K. and Tauro, P., 1983, Predigestion to improve production of biogas from cattle waste. Agricultural wastes, 4: 167-174.
- Subbaiah, S. and Sree Ramulu, V.S., 1979, Influence of sewage wastes addition on the soil characteristics. III. The effect on germination percent, dry matter yield and macro nutrient uptake by sorghum seedlings. Madras agric. J., 66: 379-387.

- Sundaram, S.P., 1979, Effects of application of nitrogen fertilizer on nodulation and nitrogen fixation in Bengal gram. Madras Agric. J., 66: 344-345.
- Tam, P.K. and Magistad, O.C., 1936, Chemical changes during decomposition of pineapple trash under field conditions. Soil Sci., 41: 315-327.
- Tester, C.F., Sokora, L.J., Taylor, J.M. and Parr, J.F., 1977, Decomposition of sewage transformation. J. Environ. Qual., 6: 459-463.
- Updegraff, D.M., 1969, Semi-micro determination of cellulose in biological materials. Anal. Biochem., 32: 420-424.
- Vander Berg, L., 1977, Effect of temperature on growth and activity of a methanogenic culture utilising acetate. Can. J. Microbiol., 23: 898-902.
- Vasil'ev, V.A., 1981, Technology of the preparation of liquid manure in relation to crop yields. Part 4. Effect of methane fermentation of litterless manure on changes in its chemical composition and manurial value. Agrokhimiya, No.9: 100-104 (From Soils and Fertilizers, 45, p363, 1982).
- Vogel, A.I., 1961, A text book of qualitative inorganic analysis. Longmans and Green Co. limited, pp1054-1093.
- Volz, M.G. and Heichel, G.H., 1979, Nitrogen transformation and microbial population dynamics in soil amended with fermented residue. J. Environ. Qual., 8: 434-439.
- Weil, R.R. and Kroontze, W., 1979, Organic decomposition in soil heavily amended with poultry manure. J. Environ. Qual., 8: 582-588.

APPENDICES

APPENDIX-1

Soil extract agar medium composition

K_2HPO_4	-	0.40 g
$MgSO_4 \cdot 7H_2O$	-	0.05 g
$MgCl_2 \cdot 6H_2O$	-	0.10 g
$(NH_4)_2HPO_4$	-	0.50 g
$FeCl_3$	-	0.01 g
$CaCl_2$	-	0.10 g
Peptone	-	1.00 g
Yeast extract-		1.00 g
Agar	-	18.00 g
Water	-	750 ml

To this, 250 ml of soil extract prepared as mentioned below was added. The pH of the medium was adjusted to 7.2 to 7.4 and was sterilized by autoclaving at 15 lbs pressure for 15 minutes.

Preparation of soil extract: One kg of soil in one litre of water was autoclaved for 30 minutes at 15 lbs pressure was allowed to stand overnight and filtered through whatman No.1 filter paper. The filtrate was used as soil extract.

APPENDIX-II

Martin's Rose bengal agar medium composition

Glucose	-	10.0 g
Peptone	-	5.0 g
MgSO ₄ ·7H ₂ O	-	0.5 g
Rose bengal	-	0.033 g
Agar	-	18.0 g
Water	-	1000 ml

The pH was adjusted to 6.0 and autoclaved at 15 lbs pressure for 15 minutes. Just before use, to the medium 3 ml of Streptomycin sulphate (containing 6 ug per ml of Streptomycin sulphate) was added per litre of medium.

APPENDIX-III

Kuster's agar medium composition

Starch	-	10.0 g
Casein	-	0.3 g
KNO ₃	-	2.0 g
NaCl	-	2.0 g
MgSO ₄ ·7H ₂ O	-	0.5 g
FeSO ₄	-	0.01 g
CaCO ₃	-	0.2 g
K ₂ HPO ₄	-	2.0 g
Agar	-	18.0 g
Water	-	1000 ml

The pH of the medium was adjusted to 7.0 and autoclaved at 15 lbs pressure for 15 minutes.

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