EVALUATION OF THE TECHNOLOGICAL CHARACTERISTICS OF A PROTOTYPE ORGANIC FERTILIZER MANUFACTURING PLANT.

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CERTIFICATION.

This is to certify that this work Evaluation of Technological Characteristic Of A Prototype Organic Fertilizer Manufacturing Plant was carried out by **Mohammed Alhassan** in the University Chemical Engineering Laboratory Under a thorough Supervision of **Dr. J. O Odigure** in partial fulfillment of the requirement for the award of masters degree in Petro -Chemical Engineering. F.U.T. Minna.

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ABSTRACT

Conversion of organic waste into useful products such as Organic fertilizer and biogas is important with respect to environmental pollution control, fuel energy problems and food production. This work evaluate the influence of various technological characteristics such as temperature, pH, residence time, feed composition moisture content and microbial activities on the production of organic fertilizer and biogas in a prototype organic fertilizer plant.

Analysis revealed that the rate of production of both the gas and organic fertilizer depend on these technological characteristics. At an environment temperature between 35 and 37.5^{0}C, the optimum operating conditions observed were pH between 7.3 and 7.5, feed moisture content of 13% in case of cow – dung and 42.5 – 54.5% for poultry waste and intermittent mixing. Higher amount of gas was obtained during poultry waste digestion. Final analysis of the organic fertilizer produced showed that the extent of biodegradation was 93.97% in case of poultry waste while 37.87% in cow-dung with a final temperature change in the last 5 days of only 2^{0}C. The designed prototype plant can be used in the local production of organic fertilizer.

CHAPTER ONE

1.0 INTRODUCTION.

Agricultural fertilizer refers to a material added to the soil in order to increase the available chemical elements needed for plant nutrition. Agricultural fertilizer could be organic or inorganic. Organic fertilizer is formed during decomposition of organic material by bacterial under aerobic or anaerobic condition. The gas produced during these process is rich in methane (50 – 80%) and Carbon dioxide (CO_2). The slurry produced at the end of digestion is an excellent source of organic fertilizer containing both macro and microelements needed for healthy growth of plants.

For plants to grow properly, they need close to 60 chemical elements accounting for 90% of a plant dry weight and among these are Carbon, Oxygen and Hydrogen (Horan, 1990). The quality of organic fertilizer or biogas (methane) depends on the amount of nutrient it contains. However the amount of organic fertilizer added to the soil should not exceed the maximum limit to be determine by the extent of digestion, otherwise the crop and the yield level would be impaired.

1.2 ENVIRONMENTAL CONTROL STRATEGIES.

Apart from the excellent benefit derived from fertilizer application agricultural sectors it also serve as one of environmental pollution control strategies. Environmental pollution control has now become an international concern. In developing concept for pollution prevention, it is necessary to address the fundamental causes rather than the symptoms of emissions and waste generation. Odour is one of the obvious characteristics of animal waste. The release of these odourous gases has caused a great deal of concern on animal and human safety, since they are potentially poisonous. A long term solution however requires a change either in the reaction chemistry to prevent the formation of odour causing compounds or their chemical conversion to a less odourous compound.

1.3 THE NEED FOR ORGANIC FERTILIZZER PLANT.

Increase recognition of both the need for technical and economic efficiency in the allocation and utilization of resources and the role that appropriate recycling can play in the waste and sanitary sector has led to the inclusion of organic fertilizer manufacturing plant development in the activities of United Nations International Drinking Water Supply and Sanitation (IDWSS).

Manufacturing activities in Nigeria is very low resulting to large unemployment or under employment of her citizens, and nearly closure of some of its industrial units. Effort should therefore be made to establish new industrial climate by siting up organic fertilizer manufacturing plant in strategic places. The manufacturing process requires low capital investment; couple with the availability of raw material thus making it easy for many Entrepreneur (including unemployed graduates) to venture into the industry.

1.5AIM AND OBJECTIVES

The major aim of this work is to develop a technology for the conversion of organic waste (e.g. cow – dung) into useful material such as fertilizer and biogas via process design / fabrication and evaluation of the technological characteristic of the designed and fabricated plant for the conversion of the waste.

The conceptual framework used for the evaluation of the plant was the application of monode, 1949 and Contoise, 1989 model and the system state description based on the rate of concentration change with time for digestion.

1.6LIMITATION OF THE STUDY.

Due to lack of standard laboratories, the following tests were not conducted on the digested slurry / Biogas.

(i) Burning capacity of the biogas produced.

(ii) C:N ratio of the feed to the digester and solubility of the chemical components of the slurry in water.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION.

Organic fertilizer is formed during the decomposition of organic material. A typical production plant consists of three main units namely the digestion, the treatment and the drying with a subsequent bagging units. Others subsidiary units are the sales and administrative units. Of all these, production unit is the most important unit.

BACKGROUND HISTORY.

For centuries organic fertilizer production is in practice, many Engineers and Environmentalist have expressed interest in the study of anaerobic digestion for the production of organic fertilizer and biogas (Metz, 1981). However the complexity in the intensification of technological parameters and the skills required for optimum selection of size and style of digestion hindered the application of fundamental knowledge to the design and operation of digester to enhance their technological and economic viability. This is because digestion of organic matters requires an understanding of conversion, treatment and refuse disposal (Fry, 1975).

Many researchers have attempted to present a concise review and development of engineering principles, chemistry, microbial and socio cultural aspect of organic fertilizer and biogas production especially as they may be applicable to northern regions of Nigeria due to availability of raw material (Metz, 1981).

Financial projection carried out showed that monetary benefits apart from the sales and reuse of products (methane, CO_2 and organic fertilizer) may include the cost of construction and maintenance. Also, the societal cost of input may include such intangible as improvement in public health, reduced deforestation and reduced reliance on imported fossil fuel. All these can be incorporated to justify the strict financial analysis. (Mohammed, 2000; Charles, 1986).

An inflammable gas from decaying organic matter was first recorded in 1630 by Van Helmont (Charles, 1986). The gas produced was precisely describe by Shirley in 1667 and was put into scientific footing by Volta in 1776 with the conclusion that the amount of gas / slurry produced is a function of volatile solid present in the organic matter (Charles, 1986). In 1804 Dalton established the chemical composition of methane(Charles, 1986). In 1808 Davy established that methane and slurry rich in chemical elements

needed for plant growth were produced from decomposing cattle manure, which may be the first time organic waste were recognized as a sources of energy(Charles, 1986).

Methanogenesis was found to be connected to microbial activities in early 19th century and the organisms were named by Bechamp, a student of Pasteur in 1884. Gayen another student of Pasteur, fermented manure at 35°C obtaining 100 litters of methane per cubic meter of manure (Charles, 1986).

In 1906 Soligen(Charles,1986) was able to enrich for two distinct acetate utilizing Bacteria and found out that formate and hydrogen plus carbon dioxide could act as precursors for methane. This remains the major break through in the microbiology of methane Bacteria for thirty years. Schnellen was the first worker to isolate two methane bacteria in 1947, (methanosarcina barkiri and methano formicium) much of his works are still relevant today. (Charles, 1986).

2.3 OVERALL CONCEPT OF EVALUATING THE PLANT TECHNOLOGICAL CHARACTERISTICS.

Since engineers are concerned with the application of technological principle to satisfy human needs, the essence of engineering should not only be limited to the design process in which resources are transformed in the best way possible into useful products but also

to the evaluation of process designed to see the extent of their perfection (Gael, 1984). The concept of this study is therefore to evaluate the technological characteristic of the prototype organic fertilizer manufacturing plant earlier designed and fabricated. (Mohammed, 1998).

2.4 THE PROTOTYPE ORGANIC FERTILIZER MANUFACTURING PLANT.

Anaerobic digestion of waste requires basic knowledge of the technical and external limitations. This includes capital cost, treatment, efficiency, product yield, operational skills and the technology among others. The technology involved in the designed and fabricated prototype digester is a combination of both fixed dome – shape and batch digester (Mohammed, 1998). The entire plant consist of three main equipment namely:- the digester, extruder and gas collector, all arranged in a way to allow free movement of material in and out of the process plant (Figure 2.0).

The process plant was designed to treat $1m^3$ of feedstock, of cow-dung with density ranges between 950 and 960 kg/m^3. The feed containing 88% total solid and 12% water is prepared and sent directly to the digester to avoid gas loss. The digestion is to proceed to completion with optimum retention time of 22 days. Temperature

between 35 and 37°C, Nitrogen/ Carbon ratio of between 15:1 and 30:1, intent mixing, pH of between 7.0 and 7.3, pressure of between 1.05k and 1.10kN /M^2 with an expected yield of 0.3429m^3 of gas and 0.657m^3 of organic fertilizer per 1m^3 of feed if complete digestion is achieved. If further treatment is required to improve the burning efficiency of the gas produced, the gas should passed through alkaline medium for treatment. The slurry from the digester after de – watering was disinfected and sent to extruder and drying unit respectively (Mohammad, 1998).

2.5.0 BIOCHEMISTRY OF ANAEROBIC DIGESTION.

Organic matter contains complex composition of organic compound with variable concentration such as Carbonhydrates, starch, Nitrogen and phosphorous compound e.t.c. Rate of methane production equal to the rate of manure production for both aerobic and anaerobic digestion of organic matter (Garber, 1975).

2.5.1 MECHANISMS OF REACTION.

The anaerobic conversion of simple molecules of carbon hydrates into manure and methane follows four main path ways namely:

(1) Hydrolysis

(2) Fermentation

(3) Accetogenesis and Accidogenesis

(4) Methanogenesis

Of each of the above steps, methanogenesis is the most important stage. Accidogenesis is regarded as the rate controlling stage in organic waste digestion (Mohammed, 2000). Since the process is organic in nature, the catalyst involved are the microbes, they are enzymatic in nature and are specific to each of the steps:

2.5.2 REACTION MECHANISMS

HYDROLYSIS: This is the first stage in the decomposition of complex organic compound into simpler units, it is believed that Carbonhydrates, lipids and proteins are converted to simpler organic compounds such as glucose, fructose lipids and amino acid by microbes such as hydrogen screating bacterials (consolium of various bacteria) fungi, antinomycetes and proteas e.t.c. (Trevan, 1979).

Mosey, (1971) presented the reaction that takes place by the four main group of bacteria in the following ways:-

$$C_6H_{12}O_6 + 2H_2 \rightleftharpoons 2CH_3COOH \text{ (acetic acid)} + 4H_2 + 2CO \text{----------2.1}$$

$$C_6H_{12}O_6 + 2H_2 \rightleftharpoons 2CH_3CH_2COOH \text{ (propanoic acid)} + 2H_2O \text{----------2.2}$$

$$C_6H_{12}O_6 \rightleftharpoons CH_3CH_2\,CH_2COOH \text{(butyric acid)} + 2CO_2 + 2H_2O \text{-------2.3}$$

FERMENTATION: - Simple organic compounds are fermented to alcohols, hydrogen and carbon dioxide by fermentative bacteria. To develop a global rate of reaction for organic matter degradation. It is necessary to assume that the conversion of substrate proceed straight from hydrolysis to accidogenesis (Mohammed, 2000) in order to simplify the process.

ACCIDOGENIC/ACCETOGENISIS:- Higher fatty acids produced during hydrolysis in equations (2.2) and (2.3) are acted upon by accidogenic bacteria such as colostridium and accetoplastic bacteria and is converted to accetic acid.

From equation (2.2) $2CH_3CH_2COOH + 2H_2O \rightleftharpoons 3CH_3COOH + 2H_2$ ---2.4

From equation (2.3) $CH_3CH_2CH_2COOH + 2H_2O + 2CO_2 \rightleftharpoons 3CH_3COOH$ ------ 2.5

and from equation (2.1) $2CH_3COOH + 2CO + 4H_2 \rightleftharpoons 2CH_3COOH + CH_3COOH + 2H_2$----------2.6

METHANOGENESIS: This is the final stage, accetoplastic bacteria and hydrogen utilizing bacteria convert acetic acid formed in equation 2.4, 2.5 and 2.6 into methane and CO_2.

$9CH_3COOH + 4H_2 \rightleftharpoons 9CH_4 + 9CO_2 + 4H_2$----------2.7

the overall reaction describing the three stages is

$$3C_6H_{12}O_6 + 4H_2 \rightleftharpoons 9CH_3COOH + 4H_2 \rightleftharpoons 9CH_4 + 9CO_2 + 4H_2$$

2.6 MICROBIAL ACTIVITIES OF THE PROCESS.

The degradation of complex organic matters to produce slurry and methane depends on the complex interaction of three groups of bacterials called the accidogenic, accetogenic and methanogenic bacteria. Accidogenic bacteria hydrolysis the complex organic matter to simple compounds such as short chain fatty acids and alcohol, the second group (accidogenic) convert the fatty acids into acetic acids and the final group (methanagenes) convert the intermediate products (CO, H_2O) into methane and CO_2.

It appears that the accetogenes are strongly dependent on the methanogenes to remove hydrogen as quickly as it is produced, otherwise the hydrogen partial pressure will build up and inhibit the breaking down of the substrates. Therefore stable digester operation will require that these bacterial group be in dynamic and harmonic equilibrium. Changes in environmental condition such as temperature variation or shock loading of substrates can affect the equilibrium and result in the building up of toxic substances which will inhibit the overall process. Also since no single organisms is capable of utilizing all of the wide variety of inorganic and organic compounds found in the waste(such as cow – dung) , the exact composition of bacteria community will depend

on the outcome of their composition from a limited and varied nutrient supply. The aim of plant design and operation should therefore be to create favourable conditions such that the desire microorganisms can proliferate. Effective design of organic fertilizer plant and its operation therefore requires a knowledge of the type of micro – organisms which are required for digestion processes and the environmental condition under which they demonstrate their maximum growth- potentials (Charles, 1986).

Omelianskis, (1980) isolated organisms that were responsible for the production of hydrogen, acetic and butryric acids. While Barker, (1956) extensive studies led to the reported isolation of an organism (methanobacterium) Omelianski in 1940 used the organism to oxidize ethanol to acetate and methane.

A major break through occurred in 1967 when (Bryent et. al ,1967) reported that the original M. Omelianski culture contain two bacterial species. One converted ethanol to acetate and hydrogen, and the other converted carbon dioxide and the released hydrogen to methane. It was recognized thereafter that the complete oxidation of simple compound such as ethanol to CO_2 and CH_4 would require contribution, combination and coordinated metabolisms of different kinds of carbon catabolizing anaerobic bacteria species.

Temperature wise, two groups of microbes are involved, namely thermophilic species which are active at temperature of between 45°C and 75°C and mesopilic species which are active at lower temperatures. But methanosarcina may be active in temperature ranging from 20°C to 40°C (Charles, 1986).

Methanogenic bacteria are fragile and slow growing. It is important to maintain optimum environmental conditions such as temperature and pH to enhance their growth. It should also be noted that methanogenis are strictly anaerobes, the presence of molecular sources of oxygen is toxic to these organisms and even the presence of inorganic sources of oxygen for example nitrates may inhibit their growth (Cricton, 1979). Thus successful digester operation requires that oxygen be excluded from the reaction vessels. (Charles, 1986).

2.6.2 PRODUCTION OF BIOMASS [CULTURING].

When micro organism are introduced into nutrient medium which support their growth, initially growth does not occur, and this period is refer to as a log phase and may be considered a period of adaptation. After which they start to growth at a constant rate and to the maximum rate. This period referred to as log or exponential phase. When the nutrient is exhausted, or the toxic metabolite accumulates, the growth rate of the cells is retarded and eventually

ceased. At this stage the cell number begins to decline and the culture enters the death phase as shown in figure (2.2)

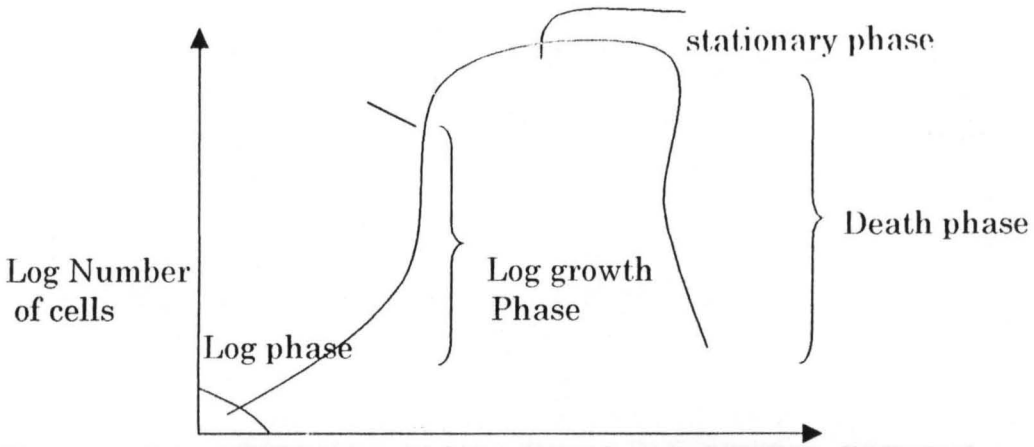


Figure 2.2: TYPICAL BACTERIA GROWTH CURVE.

(Source: Wastewater treatment and utilization second edition by Metcaf. And Eddy(1979).

2.6.3 BATCH AND CONTINUOUS CULTURE.

Continuous culturing provides organic fertilizer and biogas technologist with means of continuous / maintaining a culture in a steady state environment in a controlled physical conditions.

The exponential growth of biomass in batch culture may be prolonged by the continuous addition of fresh feed to medium.If the digester is designed in such a way that the cessation of growth is due to the exhaustion of limited substrate rather than by the accumulation of toxins. However if additional over flow were to be installed in the side of digester such that addition of fresh feed displaces an equal volume of culture, the continuous process of biomass production could be achieved (Trevans 1979).

It is important to appreciate that any component of the

medium may be made the growth limiting nutrient, and that the nature of the limitation will markedly affect the physiological and biochemistry of the cells (Kriton, 1980).

2.6.4 THE SYNTHESIS OF CELL MATERIALS IN METHANOGENES.

Methanogenes do not fix CO_2 autotrophically, it is presumed that similar one carbon carrier to those involved in methanogenesis are used. Two or possible more number of these carriers and one carbon derivatives of vitamins B_{12} which is present in methanogenes in enormous quantity react together to form acetyl coA. This is carbonoxylated to pyrovate which in turn is carbonoxylated to oxocoaccetate. Thus the 3 – carbon and 4 – carbon component required for biosynthesis can be generated.

2.6.5 PROCESS OF METHAN FORMATION.

The path way of methane generation is as shown in fig. 2.3

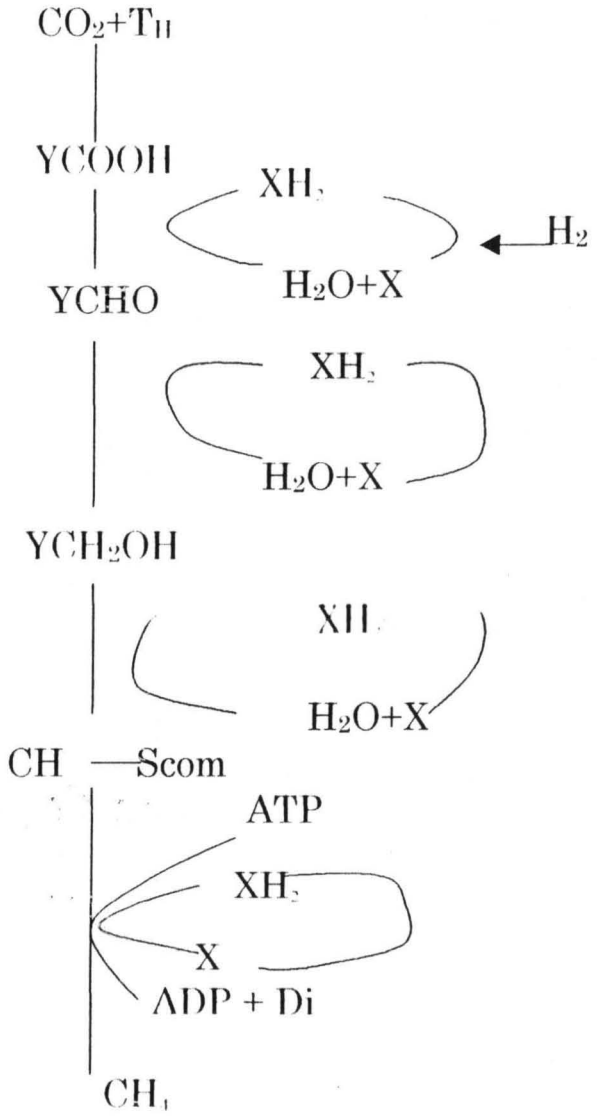


Fig. 2.3: PATH WAY OF METHANE GENERATION

Y is a carrier probably tetrahydro – methamopterine which with CO_2 to form carrier bond XH_2; X – represents one or more electron carrier which can be directly or indirectly reduced by hydrogen and may include COF_{420} and or F_{430} (Trevans, 1979).

2.7 FACTORS AFFECTING ANAEROBIC DIGESTION.

Efficient digester performance depends on maintaining healthy population of the three groups of bacteria, which act together to convert substrate to methane and slurry. The hydrogen removing and methanogenic bacteria are particularly of importance since their activities can inhibit the activities of other groups. The methanogenes are also believed to be the slowest growing organisms and are generally the most sensitive to changes in the environmental condition (Charles, 1986).

2.7.1 EFFECT OF ENVIRONMENT FACTORS ON ANAEROBIC DIGESTION.

pH :- The optimum pH for the production of methane is 7.3 (Agada, 1995) pH below this will inhibit the microbial growth by altering the equilibrium of enzymatic reactions and actually destroying the enzymes. Methanogenes are the most pH sensitive. Two are involved in maintaining pH balance in the digester. They are:

(i) By adjusting the feed rate in and out of the digester.

(ii) The use of chemicals such as $Ca(OH)_2$, NaOH, Na_2CO_3 etc. to raise the pH and H_2SO_4, NH_3 to reduce the pH and provide additional buffer capacity.

TEMPERATURE:- Rate of chemical reaction and metabolic growth rate increases with increasing temperature within a given tolerant limit depending on the thermal stability of the protein molecules synthesized by each particular type of organisms. Microorganisms in the digester are fairly resilient to short temperature upset up to about two – fold and return to their normal activities as soon as the temperature is restored. However experiment has shown that 0.5 to $2^{0}C$ change in temperature can adversely affect mesophilic and thermophilic bacteria respectively (Garber, 1975, 1977).

NUTRIENT: Nutrient is often important in anaerobic digestion, bacteria feed on nitrogen, phosphorous, potassium, magnesium, and cobalt in the substrate. Hence these should be contained in sufficient amount to support bacteria growth. With complex feed stock such as cow – dung this problem is solved but it can become toxic if the concentration of its constituent becomes too great.

TOXICITY EFFECTS:- Toxic compound such as NH_3, heavy metals and volatile acid affect digestion by slowing down the rate of biodegradation at low concentration or by killing or poisoning the organisms at high concentration. The effect of toxic

compound can be dictated when:

(i) There is reduction in methane yield by more than 10% in daily yield at a constant loading rate.

(ii) There is increase in the concentration of volatile acids (acetic acids) and these exceed the normal range of about 250 to 500 mg / liter. NH_3 is rapidly formed during the deamination of protein constituent and its toxicity is often noticed when the ammonia concentration exceed the threshold limit value of 1,500 to 3,000 mg / liter. It is therefore advisable to limit the NH_3 concentration to 80mg / liter (Fiseher et. al, 1979).

VOLATILE ACIDS:- Acids such as acetate, propanoates or butyrates indicate a toxicity effect at high concentration, by lowering the p^{H} below 7.3, at higher concentration of above 1000mg/ liter of propanoates, its inhibitory effect manifest (Hobson and Shaw, 1976).

HEAVY METALS:- The activities of sulphiding group of enzymes lead to the formation of marcaptides, their activation is inhibited by the presence of heavy metal ions due to the formation of their insoluble sulphides or hydroxides under p^{H} conditions in the range found in the digester. Addition of sulphides and removal of

the heavy metal from the feedstock reduces toxicity effect.

INFLUENCE OF CARBON / NITROGEN RATION:-

The presence of nitrogen in the feedstock has two benefits:

(a) It provides an essential element for synthesis of amino acid, enzymes and protoplasma.

(b) It is conveted to ammonia which as a strong base, neutralizes the volatile acids produced and thus maintaining pH condition. Excess of nitrogen in the substrate can result into excessive ammonia formation, which lead to toxic effect. The carbon / nitrogen ratio of feedstock has found to be useful parameter in evaluating the toxicity effect of ammonia. Feed with C/N ratio of 30:1 is recommended (Fry, 1975).

BIODEGRADABILITY OF FEED STOCK:- With the exception of lignin, most waste are degradable, cow – dung is a good example since it is moderately degradable. Other recommended feeds are swan and poultry waste. They give more biogas and better fertilizer per unit weight and at higher rate. Agricultural waste such as wheat and rice straw are also good feeds only that they may require pre – composting and reduction.

MOSITURE CONTENT:- Moisture content greatly affects the conversion of organic waste into end product. Bivad et.al, (1981) found out that by

increasing the moisture content from 61% to 75%, a 10 to 20 fold increase in the rate of conversion was possible over short period of time. Agada,(1995) reported from his laboratory experiment that an optimum moisture content of 91.77% slurry gave an optimum gas yield of 0.3429m^3 and enriched slurry of 0.657m^3 per 1m^3 of cow – dung. Volatile solid is related to moisture content by the following equation:

$$\text{Volatile Solid} = \frac{K}{\text{Moisture content}}$$ where K is approximately equal 545.684(assumed)------(2.9)

Mixing increases gas production contacts and reduces particle size. It also prevents scum formation.

2.8 KINETIC MODELLING

MONODE MODEL:- Monode, (1949) demonstrated that the decrease in growth and the cessation of growth due to depletion of substrate may be describe by the following hyperbolic function:-

$$\mu = \frac{\mu_m S}{K_s + S} \quad \text{----------2.10}$$

Where S = residual concentration of the limiting substrate mass / unit volume.

μ = Specific growth rate t^{-1}

μ_m = Maximum specific growth rate time t^{-1}

K_s =Utilization or substrate concentration when μ = ½ $\mu_{max.}$

2.8.1 VOLUMETRIC GAS / FERTILIZER PRODUCTION.

To obtain theoretical gas / slurry produced, the following relationship is applicable

$$\gamma_{su} = \frac{d_s\, d}{dt} = \frac{-K_s\, dx}{k_s + s_d} = \frac{S^o_d - S_d}{Q_c} \quad \text{----------2.11}$$

$$S_d = \frac{k_s\,(1 + bQ_c)}{Q_c\,(Y_k - b) - 1} \quad \text{----------2.12}$$

$$\frac{1}{Q_c} = \frac{kY S_d}{k_s + s_d} - b \quad \text{----------2.13}$$

$$ST = S^o_T + \frac{k_s\,(1 + b\,Q_c)}{Q_c\,(Y_k - b) - 1} + \frac{1.42Y\,(S^o_d - s_d)\,(1 + 0.2b\theta_c)}{1 + b\theta_c} \quad \text{---------- 2.14}$$

$$\Rightarrow V = \frac{0.35\,(S^o_T - ST)}{Q} \quad \text{----------2.15}$$

(Sources Monode 1947)

Where Y_{su} = substrate utilization rate.

S_d = Concentration of biodegradable substrate in the effluent, mass / unit volume.

S^o_d = Concentration of biodegradable substrate in the influent, mass / unit vol.

ST = Concentration of total substrate in the effluent, mass / unit vol.

$S^{o}T$ = Concentration of total substrate in the influent, mass / unit vol.

K = μ_m / Y = maximum utilization rate coefficient, mass of microorganisms.

Y = Maximum yield coefficient, mass of cells formed per mass of substrate consumed.

Y = Concentration in the reactor of microorganisms utilizing the substrate.

t = time.

Note : Equation 2.15 is valid only for ST expressed as g / l of oxygen demand.

2.8.2 CONTOIS MODEL

Contois,(1959) proposed a modified form of monode expression to account for the effect of decrease in bacteria population per unit increase in the feed substrate concentration as shown below.

$$\mu = \frac{\mu_m s_l}{B S^{o}_l + s_l} \quad \text{----------2.16}$$

Where B = Kinetic coefficient

For Contois model to fit μ_m = 0.31T – 0.129 2.166 where T

is equal to temperature of digester.

Hashimoto (1978) applied the model to the digestion of cow – dung and arrived at the following expression.

$$S_l = \frac{k\, S^o_l}{(\theta \mu_m - 1) + k} \qquad \text{----------2.17}$$

$$\gamma_V = B_o S_l^o \left\{ 1 - \frac{k}{(\theta \mu_m - 1) + k} \right\} \qquad \text{----------2.18}$$

Where k = kinetic coefficient, dimensionless.

Bo = ultimate methane yield coefficient

θ = hydraulic residence time (= Q_c in these case)

For specific conditions of feed stock composition and digester temperature, the kinetic coefficient (μ_m and k) and the gas yield coefficient Bo) have fixed values, S_l and V are then determine purely by Q_c.

Hashimoto et. al (1981b) reported the following values for Bo

Beef manure – Grain ratio, concrete slab = 0.35

Beef manure – Ratio, Dirlot = 0.25(±0.05)

Dairy cattle manure = 0.20 (±0.05)

Pig manure = 0.5 (±0.05)

And using the above values and equation, Hashimoto developed k values for specific fixed stock e.g.

$k = 0.8 + 0.0016 \epsilon^{0.06\, S0}$ for cattle manure----------2.19

and $k = 0.5 + 0.004\epsilon^{0.1\, /S0}$ for pig manure ---------- 2.20

It was observed that the ultimate gas production from beef cattle manure, which is partially dried, is about 70% of the fresh manure value. After two to six month, the volatile solid concentration reduces to 35% of total solid.

2.9 DETERMINATION OF KINETIC COEFFICIENT FOR MONODE MODEL

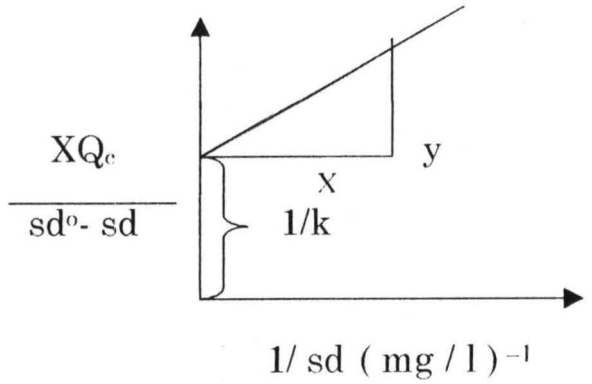
In order to use Monode model to evaluate volume of gas produced at a given time, four kinetic coefficient (Y, b, k and k_s) need to be determined following the steps below :

1. Equation 2.11 is divided by X and taking the inverse of the result will give

$$\frac{XQ_c}{S_d^o - S_d} = \frac{K_s}{k}\,\frac{1}{S_d} - \frac{1}{k} \qquad \text{----------2.21}$$

2. Linear plot of $\left(\frac{XQ_c}{S_d^o - S_d}\right)$ versus $\frac{1}{S_d}$ enable the determination of k_s and k with the Y – intercept equal to $\frac{1}{k}$

(vols / mg COD) and the slope equal to (k_s / k)



from equation (2.11) $\frac{ksd}{ks + sd} = \frac{sd^o - sd}{XQ_c}$

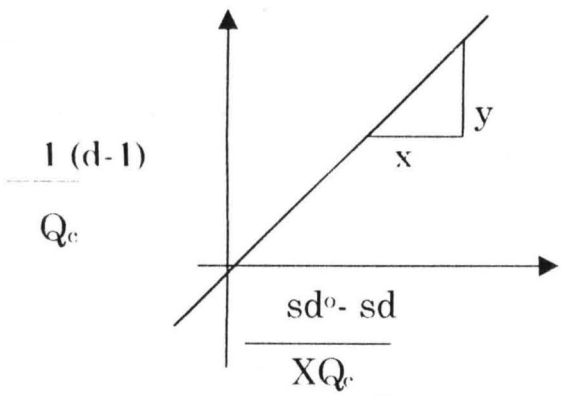
and substituting these in the equation (2.13) the yield can be evaluated:

$$\frac{1}{Q_c} = \frac{Y(sd^o - sd)}{XQ_c} - b \quad \text{----------2.22}$$

Using these equations, a plot of $\left(\frac{1}{Q_c}\right)$ versus the term

$\frac{(sd^o - sd)}{XQ_c}$

Result into a straight line graph with a slope equal to Y (mg, vss / mg liter), the Y intercept equal to (- b) d^{-1}



3. Compute Q_{cm} for a feed concentration by setting sd equal to sd^o in equation (2.13).
4. Effluent concentration sd is calculated using equation (2.12) with

$$Qc = 2Q_{cm} \text{ i.e } sd = \frac{k_s(1 + bQc)}{Qc(Yk - b) - 1}$$

5. Estimate the gas production rate using equation (2.15)

$$\text{i.e } V = \frac{0.25 (ST^o - ST)}{\theta}$$

where $\theta = \theta c = 2\theta_{cm}$ and $ST = Sd$.

CHAPTER THREE

3.0 EXPERIMENT

All experiments were carried out on the prototype plant.

3.1 MATERIALS AND METHODS

The materials used for the experiment include laboratory equipment and reagents.

3.2 EQUIPMENTS:

(1) 2 – liter laboratory sized batch fermenters (Volumetric flask).

(2) Prototype organic fertilizer manufacturing plant in the Chemical Engineering Laboratory F.U.T Minna.

(3) Muffle furnace, Drying oven, stainless dish, petridishes, hand fork.

(4) 100ml evaporating dish, desciator, mortar and pistle.

(5) Top electronic weighing balance, p^{H} meter, autoclave microscope colony, counter machine.

(6) Volumetric analysis equipments, aspirators, blood given set, water / steam bath.

(7) Density bottles, test tube.

3.3 REAGENTS USED.

1 - Distilled water

2 - 0.1M NaOH solution

3 - 0.1M Na_2CO_3 solution

4 - Methyl red solution

5 - Crystal violet solution

6 - Chlorine solution

7 - 5% dilute H_2SO_4

8 - Detergent

9 - Nutrient agar (2g oxoid brand)

10 - Sample (cow – dung, poultry waste, waste water)

11 - Ethanol, acetate, ethyl alcohol, sanfranine.

12 - Peptone crystal, sugar nutrient.

13 - Hydrogen peroxide (H_2O_2)

14 - Blood serum.

15 - IZAL

3.4 METHODOLOGY.

Standard techniques for the analysis was used and the procedures followed accordingly.

3.4.1 DETERMINATION OF DENSITY OF FEED (COW – DUNG)

PROCEDURES:-

1. One dried and empty bottle was weighed and recorded as $(W_1)g$.
2. One – third of the density bottle was then filled with cow dung and weighed again as $(W_2)g$.
3. The remaining two – third was then filled with water and the stopper inserted, excess water was washed away and then weighed $(W_3)g$.
4. The bottle was then emptied rinsed and filled with water and the stopper inserted, it was then wiped, dried and weighed again as $(W_4)g$.

The relative density $$\frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

3.4.2 DETERMINATION OF MOISTURE CONTENTS

PROCEDURES:-

(a) A stainless dish was dried in an oven at 80°C for 1 hour.

(b) It was then cool in a desicator and weighed $(W_1)g$

(c) The sample was then put into the dish and weighed $(W_2)g$.

(d) The dish with the content was then dried in the oven at temperature between 80°C and 150°C for 2 – 4 hours until constant weigh was obtained.

(e) The dish was then transfer to desiccators and allowed to cool and quickly weighed again and that was recorded as (W_3)g. The loss in weight of the sample during drying is the moisture content which was calculated as follows:

$$\text{Moisture Content} = (W_1 - W_2)\text{g}.$$

$$\% \text{ Moisture Content} = \left(\frac{W_2 - W_3}{W_2 - W_1} \right) \times 100$$

The experiment was repeated at 5 – days interval for a period of 20 days and the same procedure was followed for the determination of moisture content for cow – dung and poultry waste digestion.

3.4.3 DETERMINATION OF ASH CONTENT.

PROCEDURE:-

1. Silica dish was dried in an oven at 80°C for 1 hour.
2. The sample was cool in the desiccators and weighted as (W_1)g.
3. The sample was placed inside the dish and weighted (W_2)g.

4. The dish containing the sample was taken and put inside the oven and slowly heated to temperature of between 450°C and 500°C for 2 hours.
5. The furnace was then switch off and the dish immediately taking out and kept in a desiccator for cooling. It was later weighted and recorded (W_3)g.

Ash Content $= (W_2 - W_1)$g.

$$\% \text{ Ash Content dry bases} = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

Volatile solid $= (W_1 - W_2)$g.

$$\% \text{ Volatile solid} = \left(\frac{W_3 - W_1}{W_2 - W_1}\right) \text{g} \times 100$$

This was reported for various samples over the period of digestion at 5 days interval.

3.5 BIOCHEMICAL AND MICROBIAL ANALYSIS

3.5.1 MICROBIAL IDENTIFICATION AND COLIFOR COUNT USING PHYSIOLOGICAL AND BIOCHEMICAL REACTION.

INTRODUCTION:- Strain test specifically selected for isolates were used to classify the bacteria into their generals, this test include primary and secondary identification test, in all the

test media is needed for bacterial inoculation and incubation.

Three basic procedure were used in microbial count and identification and they are:-

(i) Microbial isolation

(ii) Grams staining

(iii) Biochemical characteristic tests.

PROCEDURES

1. 2g of powdered agar (oxoid brand) were weighted into conical flask.
2. A liter of distilled water was then added and the content dissolved by boiling and sneering.
3. The content was sterilized with the aid of autoclave at 120^{0}C for 15 minutes, and allowed to cool to 45^{0}C.
4. The content was then put into sterile petridish containing 1ml of the sample of bacterial cultured obtained from serial dilution.
5. 20ml of Nutrient agar was poured into petridish containing 1ml of the sample and allowed to solidify.
6. Then the sample was incubated for 24hours inside an incubator at 37^{0}C.

3.5.2 SERIAL DILUTION.

PROCEDURES

1. 9ml of distill water was dispensed into each of the test tube labeled A – D and sterilized using autoclave at 121^{0}C for 15minutes and allowed to cool.
2. And a gram of the sample (cow – dung) was put into test tube A and mixed.
3. A mill of the sample mixture from test tube A was taken and transferred B, test tube, after mixing, A mill from test tube B was taken and put into test tube C and mixed as well, after which a mill of the mixture in test tube C was taken and transferred into test tube D.

NOTE: It was the mixture in the D – test tube that was used in coliform count.

3.6 PRIMARY IDENTIFICATION TEST.

3.6.1 GRAMS STAIN TEST.

Grams stain test is always the first stage in the bacteria identification. It provides enough information on the confirmatory test of the organisms.

PROCEDURE:-

(i) A drop of sample (dilute cow – dung) from test "D" of serial dilution was smeared on the glass slide.

(ii) The water was evaporated gently by heating, this process fixed the bacteria to the slide.

(iii) The slide was then washed with a basic dye such as crystal violet. The dye was allowed to stay for 30 seconds to 1 minute and was washed with iodine to fixed the stain. Bacteria took up the dye and thus making them to appear blue under microscope when viewed.

(iv) The slide was then washed with a natural solvent such as tap water, ethanol or acetone and decolourized with absolute ethyl alcohol. This decolourises some species that are not capable of retaining the colour during these processes.

(v) A counter stain of different colour such as safranine was carried out and was allowed to stay for 1 minute.

(vi) The slide was washed with distilled water and allowed to air – dry.

(vii) The slide was then placed under x 100 objective lens in the binocular microscope. The bacterial that retain the stain appeared blue and are termed gram positive while those that were decolourised during step 4 above and are counter stained in step 5 appeared red and are

termed gram negative.

3.6.2 BACTERIAL MORPHOLOGICAL TEST.

SHAPE IDENTIFICATION.

After gram staining, the shape identification experiment was performed. Bacterial are believed to be limited to four basic shapes when view under light microscope; namely;

(1) Straight rod (E.coli, zooglea, Salmonella)

(2) Curved rod

(3) Spiral e.g. spyrillum

(4) Sphere e.g. Cocci.

The result obtained when different sample of cow – dung from different area was viewed under microscope for morphological test is presented in table 4.11

3.7 BIOCHEMICAL REACTIONS (CHARACTERISTICS TESTS) CONFIRMATORY TEST FOR EACH SPECIES OF BACTERIAL IDENTIFIED DURING GRAM STAINING USING LACTOSE, SUCROSE, GLUCOSE AND FRUCTOSE BROTH.

Species of bacteria are believed to feed on organic substrate; with each species capable of utilizing specific nutrient in the organic substrate. Thus feeding habit is used for their confirmatory test.

3.71 MEDIA PREPARATION

PROCEDURE:-

1. 1g of each sugar were dissolved in 100ml of distilled water.
2. 2g of peptone was dissolved in the solution of (1)
3. 2ml of red indicator were then added to the mixture and the whole solution was sterilized at 121°C for 15 minutes after dispensing 10ml into test tube.

3.7.2 CATALYSE TEST TO CONFIRM THE PRESENCE OF BASILLUS SPP AND STAPHYLOCOCI SPP.

PROCEDURE:-

1. A drop of 3% H_2O_2 was mixed with a loop full of bacteria from each sample inoculated.
2. Gas production was observed on the glass slide, this confirms the presence of basillus spp and staphylococci aureus in different samples tested.

3.7.3 COAGULASE TEST

CONFIRMATORY TEST FOR STAPHYLOCOCCUS AREUS.

PROCEDURE:-

1. A loop full of bacteria culture was mixed with blood serum on glass slide.
2. The mixture was observed for coagulation.

NOTE: If the mixtures coagulates on mixing, then the test is positive. This test was to differentiate between staphylococcus Aureus and Basillus spp. It is only staphylococcus Aureus that respond positively to the test.

3.7.4 CONFIRMATORY TEST FOR E.COLI(METHYLRED TEST).

PROCEDURE:

1. A 24 hours old culture of bacteria was placed in a solid agar.
2. It was then flooded with gram iodine and the colour change was observed. This test confirms the presence of Bacillus.

NOTE: - It is believed that only Bacillus can digest starch.

3.7.5 SUGAR TEST (SECONDARY TEST)

CONFIRMATORY TEST FOR BACILLUS SPP.

STARCH HYDROLYSIS.

1. A 24 hours old culture of bacteria was placed in a solid agar.
2. It was then flooded with gram iodine and the colour change was observed. This test confirms the presence of Bacillus.

NOTE:- It is believed that only Bacillus can digest starch.

3.7.6 BACTERIAL COUNT.

(A) After the incubation of the sample obtained during the media preparation as in (3.5.2) the sample was then placed under counting machine called coliform count machine.

(B) The counting was done by observing the Bacterial colony under the magnifying glass incorporated to the counting machine and punching the colony one by one. As the punching proceed, the machine count the number of vibration caused by punching and these correspond to the number of bacteria colony observed.

(C) Number of colonies on the agar media equal to the number of cells in 1 mill of suspension. The number of

colonies was multiplied by the dilution factor to obtain total number of colonies in the original suspension as shown in table 4.9 and 4.10.

(D) The estimated growth was determined by finding the differences in the cell mass between successive incubation period as shown in table 4.7 and 4.8.

3.8 DEODOURISATION OF DIGESTED SLURRY USING HYDROGEN PEROXIDE.

PROCEDURE:-

1. 25mls of digested slurry were measured into a volumetric flask.
2. Appreciable amount of H_2O_2 was put into burrete
3. H_2O_2 was titrated against the digested slurry until no odour was smell from the slurry and the volume of H_2O_2 used is tabulated on table 5.3.

CHAPTER FOUR

4.0 RESULTS, DATA AND MODEL ANALYSIS

4.1 RESULTS:

In this chapter, results of various experiments are presented in table 4.1 to 4.13. It covers characteristic such as composition of parameter in cow – dung and poultry waste digestion, microbial count and identification, results of deodorization / disinfections and mathematical modelings.

TABLE 4.1 : Composition of various parameters in Cow – dung digestion.

Residence Time(days)	*Weight of The Sample Before Drying(g)*	*Moisture Content (g)*	*Ash Content(g)*	*Volatile Component (g)*	*Volatile Solid(g)*	*Volatile Solid removed (g)*
0	19.56	2.64	10.40	9.16	6.52	0.00
5	19.56	3.35	10.69	8.37	5.52	1.00
10	19.56	3.36	11.04	8.52	4.96	0.56
15	19.56	4.24	11.30	8.26	4.02	0.94
20	19.56	4.44	11.20	8.36	3.92	0.10

TABLE 4.2 : Percentage composition of various parameters in Cow – dung digestion.

Residence Time	*Moisture Content (g)*	*% Volatile Solid(%)*	*% Ash Dry Basis*	*%Total Solid Wet Basis*	*%Volatile Solid removed (%)*
0	13.50	38.53	61.47	86.50	0
5	17.13	31.05	65.15	82.87	15.34
10	18.20	31.00	69.00	81.80	10.15
15	21.68	28.24	73.76	78.32	18.92
20	22.70	25.93	74.07	77.30	2.49

TABLE 4.3 : Percentage Changes in the various parameters in Cow – dung digestion.

Residence Time(days)	*%Change in Moisture Content*	*%Change in Total Solid*	*% Change in Volatile Solid(g)*	*%Change in Ash Content*
0	0.00	0.00	0.00	0.00
5	26.90	4.20	15.30	2.30
10	34.80	5.40	32.90	6.20
15	60.60	9.40	38.30	8.60
20	68.20	10.60	39.90	9.56

TABLE 4.4 : Composition of various parameters in Poultry waste digestion.

Residence Time(days)	*Weight of The Sample* ($W_2 - W_1$) (g)	*Moisture Content (g)* ($W_2 - W_3$) (g)	*Ash Content(g)* ($W_5 - W_1$) (g)	*Volatile Component(g)* ($W_2 - W_5$) (g)	*Volatile Solid(g)* ($W_3 - W_5$)= W_1 (g)	*Volatile Solid removed (g)*
1	19.56	8.33	0.16	19.40	11.07	0
2	19.56	9.02	0.67	18.87	9.87	1.2
3	19.56	9.71	1.52	18.01	8.33	1.54
4	19.56	9.71	1.52	18.04	8.33	0
8	19.56	11.60	4.28	15.28	3.68	4.65
16	19.56	11.64	4.30	15.26	3.62	0.06
20	19.56	11.64	4.30	15.26	3.62	0
24	19.56	13.81	5.09	14.47	0.66	2.96

TABLE 4.5 : % Composition of various parameters in Poultry waste digestion.

Residence Time(days)	*Weight of The Sample(g)*	*% Moisture Wet Content Basis*	*% Ash Content Dry Basis*	*% Volatile Content Wet Basis*	*%Volatile Solid Dry Basis*	*% Volatile Solid removed Dry Basis*
1	19.56	42.59	1.43	99.18	98.58	0
2	19.56	16.12	6.36	96.59	93.64	10.48
3	19.56	19.64	15.43	92.23	84.57	15.60
4	19.56	19.64	15.43	92.23	84.57	0
8	19.56	59.30	53.77	78.12	46.23	55.80
16	19.56	59.53	54.29	78.02	45.64	1.63
20	19.56	59.53	54.29	78.02	54.64	0
24	19.56	70.60	88.52	73.98	11.50	81.77

TABLE 4.6 : % Change in composition of various parameters in Poultry waste digestion.

Residence Time(days)	*Weight of The Sample(g)*	*% Change in Moisture Content*	*% Change in Ash Content*	*% Change in Volatile Content*	*%Change in Volatile Solid*	*% Change in Volatile content removed*
1	8.5	0	0	0	0	0
2	8.5	8.29	314.29	-2.61	-11.02	∞
3	8.5	7.65	127.59	-4.51	-15.42	24.53
4	8.5	0	0	0	0	0
8	8.5	19.43	181.82	-15.31	-0.55	∞
16	8.5	0.40	0.54	-0.15	-56.39	-48.52
20	8.5	0	0	0	0	0
24	8.5	18.58	18.18	-5.13	-81.53	∞

TABLE 4.7 : % Bacterial changes for anaerobic digestion of Cow – dung.

S/N	*Residence time (days)*	*No of Bacteria in 1g of the sample.*	*Bacterial population change.*	*%Biomass Change*
1	1	1.19×10^6	0	0
2	2	2.17×10^6	98	82.35
3	3	1.274×10^7	1057	487.10
4	4	5.69×10^6	- 705	55.30
5	5	1.02×10^6	-167	29.35
6	6	7.75×10^6	373	92.79
7	12	3.75×10^6	-400	51.61
8	18	3.86×10^6	11	2.93

TABLE 4.8 : % Bacterial changes for Aerobic digestion of Cow – dung.

S/N	*Residence time (days)*	*No of Bacteria in 1g of the sample.*	*Biomass change.*	*%Biomass Change*
1	1	1.19×10^6	0	0
2	2	5.36×10^6	417	350.42
3	3	8.10×10^6	274	51.11
4	4	4.76×10^6	- 334	41.23
5	5	6.51×10^6	175	36.75
6	6	5.03×10^6	-148	22.73
7	12	3.55×10^6	-148	29.42
8	18	3.65×10^6	10	2.82

Table 4.9: Initial coliform count on the experimental samples

Sample	*Dilution factor*	*Number of coliform in the plate*	*Number of coliform In 1g of samples*
A	10^{-1}	79	79×10^{1}
B	10^{-1}	111	111×10^{1}
C	10^{-1}	129	129×10^{1}
D	10^{-1}	68	68×10^{1}
E	10^{-1}	16	46×10^{1}

Table 4.10 : Initial Bacterial count on the experimental samples.

Sample	*Dilution factor*	*Number of coliform in the plate*	*Number of coliform In 1g of samples*
A	10^{-1}	319	319×10^{1}
B	10^{-1}	276	276×10^{1}
C	10^{-1}	196	196×10^{1}
D	10^{-1}	156	156×10^{1}
E	10^{-1}	119	119×10^{1}

NOTE: See the table under the Physiological and Biochemical test result for the definitions of letter A – E.

Table 4.11: Physiological and Biochemical test result.

Sample	*Gram Stain*	*Shape*	*Catalyse Test*	*Coagu -late Test*	*Methy- lred Test*	*Lactose Test*	*Glucose Test*	*Suc- rose Test*	*Fruc- tose Test*	*Organism confirm*
A	-	Short rod	-	-	+	+	+	+	-	E. Coli
B	+	Long rod	+	-	-	-	+	+	+	Bacillus Spp.
C	+	Cocci	+	+	-	+	+	+	+	Staph. aureu
D	+	Long Rod	+	-	-	-	+	+	+	Bacillus Spp.
E	-	Short rod	-	-	-	+	+	+	-	E.coli

* it is only Bacillus Spp that is positive to starch hydrolysis

KEYS:- A = Sample taking from Agriculture farm F.U.T Minna.

B = Sample taking from Abatour Tunga Minna.

C = Sample taking from Bosso, Abubakar Kawu road, Minna.

D = Sample taking from Animal farm, Tunga ,Minna.

E = Sample taking from Keteren Gwari, Minna.

Table 4.11b: Volume of H_2O_2 and Izal used to deodourized the slurry.

Volume of Slurry cm³	*Volume of* H_2O_2	*Volume of IZAL cm³*
20.00	6.28	0.20

RESULTS OF MATHEMATICAL MODELS.

Kinetic coefficient for contoise model along with the gas generated at interval of 5 day is presented in table 4.12 :-

Table 4.12: Kinetic coefficient for contoise model.

HRT	*Volatile Solid removed*	*Bo*	*K*	μ_m	*VolumeOf gas GeneratedM³x10⁻³*
5	1	0.2	0.802	0.261	0.011
10	0.56	0.2	0.802	0.261	0.006
15	0.91	0.2	0.802	0.261	0.101
20	0.1	0.2	0.802	0.261	0.101

Predicted volume = 0.05479

Volume generated (practical) = 0.028

Table 4.13: Kinetic coefficient for monode model.

K	*Ks*	*B*	*Y*	Q_c	S_d	*Volume Of ga GeneratedM³x1*
0.1949	3.277	0.01	45.71	0.3373	0.3373	0.011

CHAPTER FIVE

5.1 DISCUSSION OF RESULTS.

A detail investigation and modeling of organic waste degradation had been performed under natural and prevailing environmental conditions. The results obtained are presented in table 4.1 to 4.13 and calculation as shown in appendix B.

In table 4.2 and 4.5 it can be deduced that about 39.87% total solid dry basis of Volatile Solid had been removed within the first twenty days, during cow-dung digestion, while for poultry waste, 93.97% of volatile solid were removed within the same (retention) time. This is in agreement with the results presented by Sturkey,(1979) and Van Soest,(1979) for poultry and cow-dung. The highest mass was removed on the 8^{th} day for the poultry waste while for cow-dung it was within the first 5-days. (Odigure, 1998; and Charles 1986).

Table 4.2 and equation 2.9 shows that % Moisture content is inversely proportion to the % Volatile solid with constant of proportionality approximately equal to 545.684 for aerobic digestion of cow-dung (Mohammad 1998, Agada 1995). From table 4.2, the moisture and ash content increased with increase in residence time while volatile solid decreased.

Agada,(1995) and Odigure,(1999) reported similar observation; however, the pattern of the parametric change in poultry waste digestion is different to ascertain. The increase in moisture and ash content is as a result of continuous production of water by fermentation bacteria and in concentration of non-biodegradable material per unit volume (Charles1986, Harshimoton 1981a). These increases in both moisture and ash content have a sinusoidal pattern. It was observed that within the 1st and 2nd day there was increase in moisture and ash content, between the 3rd and 4th day there was no increase in both ash and moisture content, but between 8th and 16th day there was a sharp increase, and within 16th and 20th day no increase at all. Finally these parametric change increase slightly between the 20the and 24th day (Odigure 1999; Agada 1995 and Charles 1986).

From table 4.7 and 4.8, it can be observed that on the 3rd day bacteria had their maximum multiplication (1.274×10^7 and 8.10×10^6) for anaerobic and aerobic digestion of cow – dung respectively; and a subsequent decrease in population on the 4th day (5.69×10^6 and 4.76×10^6) respectively. However between 12th and 18th day there was sluggish increase in biomass population i.e. 3.75×10^6 to 3.65×10^6 for aerobic and 3.55×10^6 to 3.65×10^6 for aerobic (Metcaf, 1978). Comparison between the biomass population in

both aerobic and anaerobic digestion of cow – dung showed that maximum biomass population occurred on the 3rd day (table 4.7 and 4.8). Result of digestion showed that bacteria population was about 1.27 x 107 per gram of sample for anaerobic as against 8.10 x 10^6 for aerobic digestion. The reported low biomass population in the case of aerobic digested slurry was due to the presence of molecular oxygen in the digester which inhibit the growth of methanogenes (Omelianski, 1980).Since the digestion was carried out under environmental conditions(Winter). The temperature range in the digester was maintained between 35 and 37^{0}C. This may have accounted for the slow rate of gas production observed as compared to that reported by Ward (1984) where the temperature range was between 40 – 47^{0}C. Comparisons between table 4.7 and 4.12 showed that the rate of production of gas and slurry depend on the biomass population i.e. when the biomass population was 4.02 x 10^6 the gas produced was 0.011 x10^{-3} m^3 and when the biomass population dropped to 3.75 x 10^6 the gas produced was 0.006 x $10^{-3}m^3$ with optimum biomass and gas production expected on the 3rd day in both aerobic and anaerobic digestion of cow – dung (U.S.E.P.A, 1979 and Rourk 1968).

The expected maximum gas production is 0.05479 x $10^{-3}m^3$ between 1st and 24th day

and minimum of 0.01 x $10^{-3}m^3$ (Contoise 1959, Monode 1949) corresponding to maximum and minimum conversion of substrate in the digester according to Bernard (1987). This could not be ascertain in this experiment due to poor conditions of facilities. In table 4.1 the highest volatile solid was removed within the first 5 – days of digestion of cow – dung (Odigure 1999; Agada 1995; Benard 1987) while in the case of poultry waste, on the 8^{th} day.

Among the species of bacteria identified (isolated) from the digested slurry were staphylococus Aureus, Basillus spp and Escherichecolli (table 4.11). The Basillus spp appears to be predominant, this is evident by the spore formation on the nutrient agar (Bryant et. al 1967, Metcaf 1979). However pathogenic, gram positive cocci of the general staphylococcus and streptococcus are commonly pyogenic i.e. pus formation is a major aspect of their effect on the human host. The organisms are characteristics favour transformation from organic fertilizer (if not properly treated) to plants and Animals (Horan 1990, Eugene 1983).

Gram – negative rod like E.colli causes travelers diarrhea, meningitis, urine and other infectious diseases and are also resistance to dryness and other penicillin treatment. Gram positive Bacillus spp of

the general corynebacterium, bacterium diphtheria, clostridium tetani and clostridium butulinum causes botulism and often fatal disease characterized by severe paralysis, while clostridium titanic causes tetanus (luck jaw) respectively (Horan 1990, Eugen 1983).

Preliminary analysis conducted on the deodourization and the disinfections of the digested slurry showed that for every $20cm^3$ of the digested slurry an average volume of $6.28cm^3$ of H_2O_2 and $0.02cm^3$ of IZAL is needed to deodourized and to completely disinfect it. However the cost for these treatments is negligible to be considered as a factor militating against the application of organic fertilizer (digested slurry) produced in this way to farmlands, and the product is safe to handle. Model equations relating volume of gas produced and HRT that can satisfactorily predict the performance of the digester was obtained. The results obtained. The Hence the prototype plant is viable to be used in the production of organic fertilizer.

A lot has been achieved. In this research work various species of bacteria responsible for digestion were identified and compared with the ones expected, optimum operating and technological parameter of the prototype plant were determine. Conclusions were drawn as to viability of the prototype plant to

the purpose to which it is designed for.

CHAPTER SIX

6.1 CONCLUSION

The following deduction can be made on the performed experiment.

1 - It is apparent that rate of production of both the gas and slurry depend on the composition, age of the digested material, percentage moisture content, and biomass population.

2 - The highest percentage volatile solid was removed (93,97% total volatile solid dry basis) in poultry waste as against 39.87% in cow – dung.

3 - The study showed that the optimum technological condition for the prototype plant operating at room temperature and intermitted mixing are: p^H between 7.3 and 7.5, Hydraulic retention time of 24 days and more, moisture content of between 13 and 15% of the total slurry in cow – dung , 42.5 – 54.5% in poultry waste digestion, 6.28cm^3 of H_2O_2 and 0.02cm^3 IZAL is needed to deodourised and completely disinfects 20cm^3 of 24 days old digested slurry, and the organic fertilizer produced after these treatment is safe to handle.

6.2 RECOMMENDATION:

Conversion of organic waste into useful organic fertilizer and its associate biogas is not easy to achieve. Some of the problems encountered during the course of these research works is the slow – rate of digestion, variation in environmental condition and epileptical power supply throughout the period of the research.

In line with the level of research work on this subject, and coupled with the problem encounter during the course of this research work. I hereby recommend the following area for further researcher.

1) During the course of this research work, justification as to gas production was made because gas was really seen produced but no attempt was made to test the quality of gas and fertilizer produced for their commercial use due to lack of enough technical aid.
2) Equilibrium relationship have been established between odour arising from a 24 days old slurry and volume of H_2O_2 and IZAL needed to de-odorize and disinfect it, however no attempt has been made to test the efficiency of other deodorant which may be more effective than H_2O_2

3) Investigation carried out also shows that residence time can be reduced from 22 to less than that by bacteria seeding. I therefore recommend to any interested researcher to investigate the viability of this statement

4) And finally although attempts have been made as to seeding and odour removal, no attempt has been made on the removal of organic matter (usually the halogen compound) that inhibit gas and quality of fertilizer produced.

APPENDIX A

RESULTS OF THE VARIOUS EXPERIMENTS.

TABLEA1: Composition of various parameters in cow – dung digestion.

Residence Time (days)	Weight of Empty Dish W_{ED}	Weight of dish + Sample Before Drying (W_2)	Weight of Dish + Sample After Drying (W_3)	Weight of Dried Sample (W_4)	Weight of Dish + Sample After Ashing (W_5)
0	1.20	20.76	18.12	16.92	11.60
5	1.20	20.76	17.41	16.21	11.89
10	1.20	20.76	17.20	16.00	12.24
15	1.20	20.76	16.52	15.32	12.50
20	1.20	20.76	16.32	15.12	12.40

TABLEA2: Composition of various parameters in poultry waste digestion.

Residence Time (days)	Weight of Empty Dish W_{ED}	Weight of dish + Sample Before Drying (W_2)	Weight of Dish + Sample After Drying (W_3)	Weight of Dried Sample (W_4)	Weight of Dish + Sample After Ashing (W_5)
1	1.20	20.76	12.43	11.23	1.36
2	1.20	20.76	11.74	10.54	1.87
3	1.20	20.76	11.05	9.85	2.72
4	1.20	20.76	11.05	9.85	2.72
8	1.20	20.76	9.16	7.96	5.48
16	1.20	20.76	9.12	7.92	5.50
20	1.20	20.76	9.12	7.92	5.50
24	1.20	20.76	6.95	5.75	6.29

DENSITY OF COW- DUNG

Mass of empty bottle (W_1) = 11.92g

Mass of bottle + cow-dung (W_2) = 20.776g

Mass of bottle filled with water + cow-dung (W_3) = 64.723g

Mass of density bottle filled with water only (W_1) =65.092g

∴ Mass of cow-dung =(W_2 - W_1)g = 8.856g

Mass of water filling the bottle (W_1 - W_1) = 53.172g

Mass of water filling the space left by cow-dung (W_3 -W_2)

= 43.947g

Mass of water having a volume equal to that of solid =

$(W_1 - W_1)g - (W_3 - W_2)g = 9.225g$

The relative density is calculated as

$$\frac{\text{Mass of substance}}{\text{Mass of equal volume of water}} = \frac{W_2 \quad W_1}{(W_1 - W_1)g - (W_3 - W_2)g} \times 1000 = 960 kg/m^3$$

TABLEA3: Volume of H_2O_2 used to deodorized 20ml of the slurry.

Burette reading (cm^3)	Rough	1st	2nd	3rd	4th	5th
Final burette reading (cm^3)	43.50	15.70	50.06	35.00	36.30	36.00
Initial burette reading (cm^3)	29.90	13.50	15.70	27.00	33.30	30.00
Volume of H_2O_2 used (cm^3)	13.60	2.20	1.9	8	3.00	6.00

Volume of digested slurry used = $20cm^3$

Average volume of H_2O_2 used =$6.28cm^3$

TABLESA4: Bacteria count for anaerobic digestion of cow – dung.

Retention time (days)	Dilution Factor	Number of Bacteria in the plate	Number of Bacteria 1g of samples
1	10^4	119	1.19×10^6
2	10^4	217	2.17×10^6
3	10^4	1,274	1.274×10^7
4	10^4	569	5.69×10^6
5	10^4	102	1.02×10^6
6	10^4	775	7.75×10^6
12	10^4	375	3.75×10^6
18	10^4	386	$3.88 \times 10^{4}{}^{6}$

TABLE A5: Bacteria count for aerobic digestion of cow – dung.

Retention time (days)	Dilution Factor	Number of Bacteria in the plate	Number of Bacteria 1g of samples
1	10^4	119	1.19×10^6
2	10^4	536	5.36×10^6
3	10^4	810	8.10×10^6
4	10^4	176	1.76×10^6
5	10^4	651	6.51×10^6
6	10^4	503	5.03×10^6
12	10^4	355	3.55×10^6
18	10^4	365	3.65×10^6

TABLE A6: Volume of IZAL Used To Disinfect The Slurry.

	Rough	1st	2nd	3rd
Initial Volume(cm^3)	50	10.1	50.0	11.0
Final Volume (cm^3)	40	30	40.0	29.00
Volume of the IZAL solution used(cm^3)	40	10.1	10.0	10.0
Presence of bacteria after treatment	none	none	none	none

The solution is 1cm^3 of IZAL to 50cm^3 of water

=> every 10cm^3 of solution contain 0.2cm^3 of IZAL concentration.

THE DESIGNED OPTIMUM TECHNOLOGICAL CHARACTERISTIC OF THE PROTOTYPE PLANT WAS BASED ON THE FOLLOWING OBTAINED EXPERIMENTAL DATAS ON COWDUNG DEGRADATION. MOHAMMED,1998.

TABLE: A7: Influence of pH on degradation of cow dung

		SAMPLES				
		A	B	C	D	E
PH	Initial	6.50	7.00	7.5	8.0	8.5
	Final	6.53	7.18	7.61	7.98	8.43
Total Solid	Initial	9.99	9.99	9.99	9.99	9.99
	Final	8.96	8.52	8.42	8.86	9.47
	%Charge	10.31	14.71	15.71	11.31	5.41
Moisture	Range	89.88	89.88	89.88	89.88	89.88
Content%	Initial	105.1	82.72	83.09	94.31	102.01
	Final	16.93	- 7.93	-7.55	4.93	13.49
Volatile	%Change	8.28	8.28	8.28	8.28	8.28
solid%	Initial	7.25		6.71	7.16	7.60
	Final	12.22	18.97	13.52	8.21	
	%Change					

Residence time = 20 days

Temperature = 37.4°C

TABLE A8: Influence of residence time on cow-dung degradation

PARAMETER	0	5	10	15	20	25	30	35	46	40
Total Solid	8.47	7.78	7.27	6.73	6.47	6.40	36.27	6.13	6.07	6.07
Moisture content%	91.30	83.33	74.67	81.20	80.66	80.67	81.87	80.47	80.96	80.96
Volatile Solid%	7.0	6.15	5.8	5.2	4.93	4.87	4.73	4.67	4.6	4.6
%change	0	12.45	17.14	25.71	29.57	30.42	32.43	33.36	34.29	34.27

Temperature = 35.56, $p^{H} = 7.45$

TABLE A9: Effect of concentration on cow-dung degradation.

$p^{H} = 7.7$, Residence Time = 20 days

		SAMPLES				
		I	J	K	L	M
Total Solid	Initial	18.78	15.49	11.86	8.28	5.12
	Final	17.23	14.61	10.38	7.16	4.77
	%Charge	8.24	5.67	12.5	13.51	6.87
Moisture	Initial	81.22	84.5	88.13	91.29	94.88
Content%	Final	83.44	76.20	75.92	78.54	91.08
	%Change	-2.73	- 9.87	-13.8	-14.54	- 4.0
Volatile	Initial	16.09	14.13	9.86	6.83	4.57
solid%	Final	14.63	13.19	8.01	5.44	4.19
	%Change	8.96	6.67	18.76	20.4	8.34

TABLE A10: Effect of temperature on cow-dung biodegradation

		Temperature.^{0}C					
PARAMETER		25.3	30.4	37.32	40	45	50
Moisture	Initial	91.11	91.11	91.11	91.11	91.11	91.11
content%	Final	76.88	73.28	74.66	72.09	72.72	73.4
% change	Initial	8.89	8.89	8.89	8.89	8.89	8.89
	Final	6.84	6.44	6.40	6.48	6.60	6.68
Total Solid%		23.05	27.56	27.97	27.08	25.76	24.36
%change							
Volatile Solid	Initial	7.19	7.19	7.19	7.19	7.19	7.19
	Final	5.19	4.71	4.70	4.70	4.09	4.94
% change		29.07	34.06	34.58	33.98	21.83	31.28

Time = 20 days

$p^H = 7.55$

TABLE A11: Influence of mixing on cow-dung biodegradation intermittent mixing of 2 days interval residence time of 20 days

	0	5	10	15	20
Total Solid %	8.54	8.19	7.59	7.28	6.85
Moisture content%	91.46	92.69	85.93	03.58	79.04
Volatile Solid %	6.89	6.50	5.94	5.55	5.17
% change	0	5.66	13.79	19.45	24.96
B: DAILY MIXING					
Total solid%	8.54	8.3	7.77	7.52	7.31
Moisture content%	91.46	71.80	66.56	64.2	-
Volatile Solid%	6.89	6.61	6.12	5.89	5.66
% Change	0	4.06	11.18	14.50	17.85
C: NO MIXING					
Total solid%	8.54	8.46	8.23	7.88	7.77
Moisture content%	91.46	90.68	89.03	85.65	85.62
Volatile Solid%	6.89	6.75	6.43	6.22	6.12
% Change	0	2.03	6.68	9.72	11.17

Average Temperature = 35^0C; p^H = 7.52

APPENDIX B

SAMPLE CALCULATIONS

1) Weight of sample before drying = Weight of the dish + Sample before drying (W_2)

Weight of dish(W_2)

=20.76 –1.2 = 19.56g

2) Moisture content = Weight of the sample + dish before drying (W_2)g Weight of sample + dish after drying (W_3) = 20.76 – 18.12 = 2.64g.

3) % Moisture content = $\frac{\text{moisture content}}{\text{mass of the slurry.}} \times 100$

$$= \left(\frac{W_2 - W_3}{W_2 - W_1}\right) \times 100$$

$$\frac{2.64}{19.50} \times 100 = 13.5\%$$

4. Ash Content = Weight of the sample + dish after ashing (W_5)g – Weight of dish (W_1) = 11.06 – 10.40 g.

5. % Ash Content = $\frac{\text{Ash Content}}{\text{Weight total solid}} \times 100$

6. Volatile Component = Weight of the dish + Sample before drying(W_2) - Weight of dish + Sample after drying (W_3) g = 20.76 – 11. 60

= 9.16g.

7. % Volatile Component (dry basis) = $\frac{\text{Volatile Component}}{\text{Weight of dried sample}} \times 100$

$= \frac{W_6}{W_1} \times 100 = \frac{6.52}{16.92} \times 100$

= 38.53%

8. Volatile Solid = Weight of dish + Sample after drying (W_3) g

Weight of dish + sample after ashing (W_5) g

= 18. 12 – 11.,6 = 6. 52g

9. % Volatile solid = $\frac{\text{Weight of Volatile Solid}}{\text{Weight of the dried sample}} \times 100$

$= \left(\frac{W_6}{W_1}\right) \times 100 = \frac{6.52}{16.92} \times 100$

= 38%.

10. Volatile Solid removed = Volatile Solid inlet -- Volatile solid out

= 6.52 – 5.52 = 1.0g.

11. % Volatile solid removed = $\frac{\text{Volatile solid removed}}{\text{initial volatile solid in}} \times 100$

$$= 1 \quad x \quad \frac{100}{6.52} \quad = \quad 15.34\ \%$$

12. % Moisture $\quad$ K $\quad$ where k 545.684(assumed).

Volatile Solid

13. From table 4.2 when Moisture Content = 13.5

$$\%\ \text{Volatile Solid} = \frac{545.684}{13.5} = 40\%$$

MATHEMATICAL MODELING SAMPLE CALCULATION

DETERMINATION OF KINETIC COEFFICIENTS

From table: A1 the following table is generated

TABLE B1: Composition of parameters in cow – dung digestion.

HRT = QC	S o	S	V. Solid removed
5	6.52	5.52	1
10	5.52	1.96	0.56
15	1.96	1.02	0.94
20	1.02	3.92	0.1

CONTOIS MODEL:-

The following Kinetic coefficient need to be determine before Contois Model can be applied to predict the amount of gas

produced; K, μm, V, Bo (see Numenclature for definition).

Recall from equation 2.16a, 2.16b, 2.19, 2.20 and taking

Bo = 0.2 for Diary Cattle ∴

$$K = 0.8 + 0.0016\ \epsilon^{0.061S_0}$$

$$\mu m = 0.\ 0.131 - 0.129$$

$$V = \left(\frac{B_o S_o}{HRT}\right) \left\{1 - \frac{k}{\{(HRT.)\mu m\} + k - 1}\right\}$$

$B_o = 0.2.$

The following table is generated.

TABLE B2: Kinetic coefficient using contois.

HRT (days)	S_o (g)	S (g)	V.S. removed (g)	B_o	K	μm	Volume of gas generated.
5	6.52	5.52	1.00	0.2	0.802	0.261	0.011
10	5.52	4.96	0.56	0.2	0.802	0.261	0.006
15	4.96	4.02	0.91	0.2	0.802	0.261	0.010
20	4.02	3.92	0.10	0.2	0.802	0.261	0.001
							0.028

MONOD MODEL.

In order to use Monod Model four – kinetic coefficient must be evaluated and are Y, b, k, and ks.

Recall from equation 2.24 through equation 2.30, and using

TABLE B3: Composition of parameter for monode model.

= RT	X106 Number of bacterial in lg of the shape	S d	Sd	Number of the bacterial in the sample x10⁶	XQc x 10⁶	S d – Sd (g)	XQc x10⁵ / S d Sd	S d – Sd / XQc X10 ⁻⁵	1 x 10⁻³ / sd	1 / Qc	Log {XQc / S d – Sd}
0	7.76	6.52	6.52	0	0	0	1 / 0	0	0	0.158	0
5	1.02	6.52	5.52	26.21	131.05	1.00	13.105	7.63	0.18	0.2	8.12
10	5.1	5.52	1.96	28.15	281.5	0.56	50.268	1.12	0.20	0.1	8.70
15	3.53	1.96	1.02	17.51	262.65	0.94	27.942	3.36	0.25	0.07	8.45
20	3.9	1.02	3.92	15.68	313.6	0.10	313.6	0.32	0.26	0.05	9.50

To determine ks and k; linear plot of $\left(\frac{XQc}{S^{\circ}d - Sd}\right)$ against $\frac{1}{Sd}$ yield

Y intercept $= \frac{1}{k}$ and the slope is equal to ks/k as shown on

Figure 8. From the graph.

Intercept = 5.13

$\Rightarrow k = \frac{1}{5.13} = 0.1949$

$$\text{Slope} = \frac{4.37}{0.26} = 16.81$$

$ks = k \times \text{slope} = 3.277$

from equation 2.25 and 2.26 i.e

$$\frac{ksd}{ks + sd} = \frac{s^{\circ}d - sd}{XQc} \quad \text{---------- 2.25}$$

$$\frac{1}{Qc} = \frac{Y(s^{\circ}d - sd)}{XQc} - b \quad \text{---------- 2.26}$$

Using these equations, a plot of $\frac{1}{Qc}$ against $\frac{s^{\circ}d - sd}{XQc}$ give a

Straight line with Y – intercept = (- b) and slope y equal to Y

2-. From figure (9)

$$\text{slope} = \frac{0.128}{2.8} = 45.71$$

Intercept = - 0.01

$Y = - b$

$b = 0.01$

3. Using equation 2.27

$$\frac{1}{Qcm} = \frac{kYs^{\circ}d}{ks + s^{\circ}d} = \frac{0.1949 \times 45.71 \times 6.52}{3.277 + 6.52} = 5.929$$

$Qcm = 0.1687$

$\Rightarrow Qc = 2Qcm = 0.3373.$

4. $$sd = \frac{ks\,(1 + bQc)}{Qc\,(Yk - b) - 1} = \frac{3.277\,(1 + 0.01\,(0.3373)}{0.3373\left\{(45.71)(0.1949)0.01\right\} - 1}$$

$$= 1.6427$$

5. To estimate the gas produced at the end of the digestion

$$V = \frac{0.35\,(S^{\circ}T - ST)}{Q} = \frac{0.35(s^{\circ}d - sd)}{Qc}$$

$$= \frac{0.35\,(6.52 - 1.6427)}{0.3373} = 5.0609$$

$$= 0.01 m^3/$$

APPENDIX C : GRAPHS

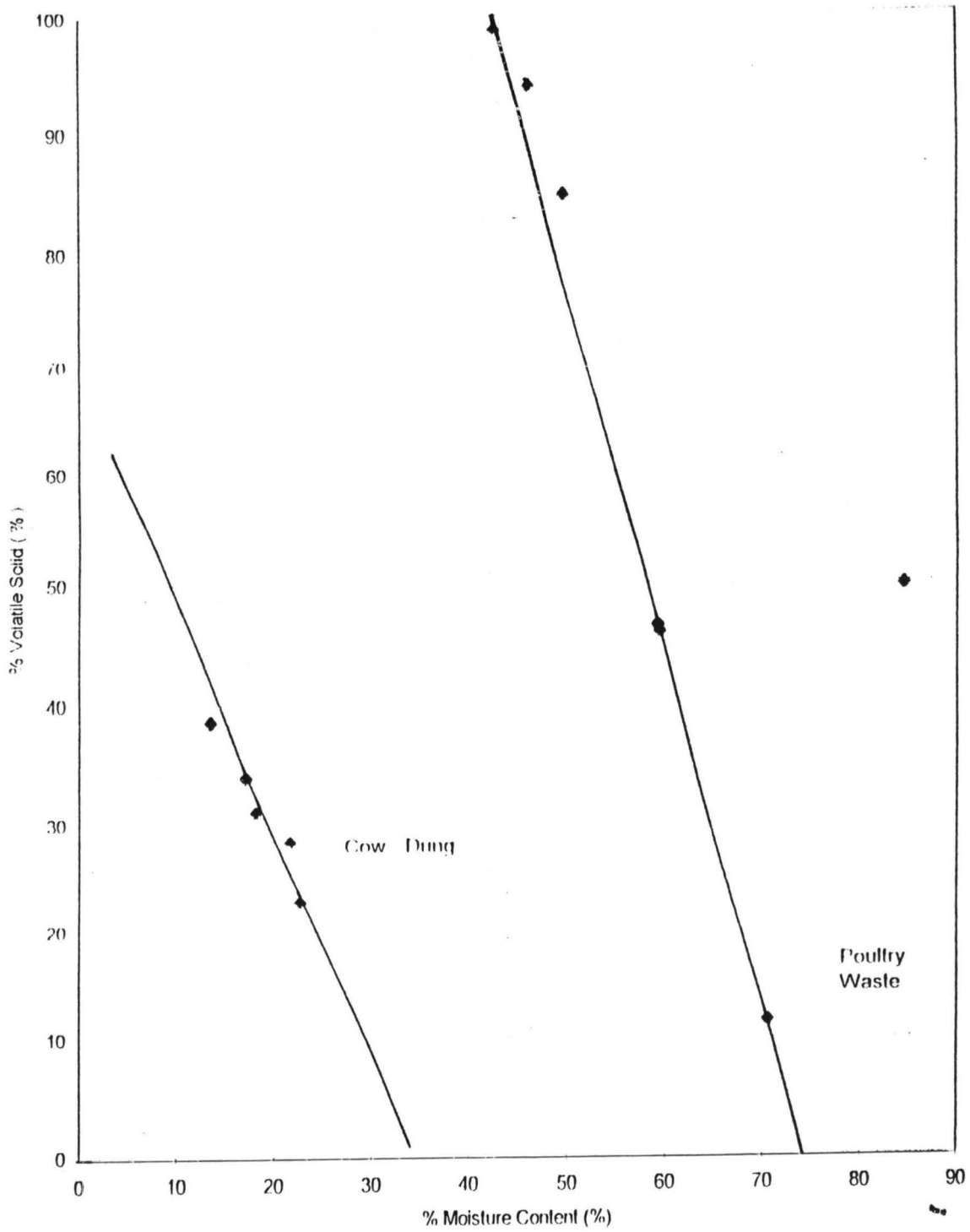


Fig.1 Graph Of % Volatile Solid Against % Moisture Content

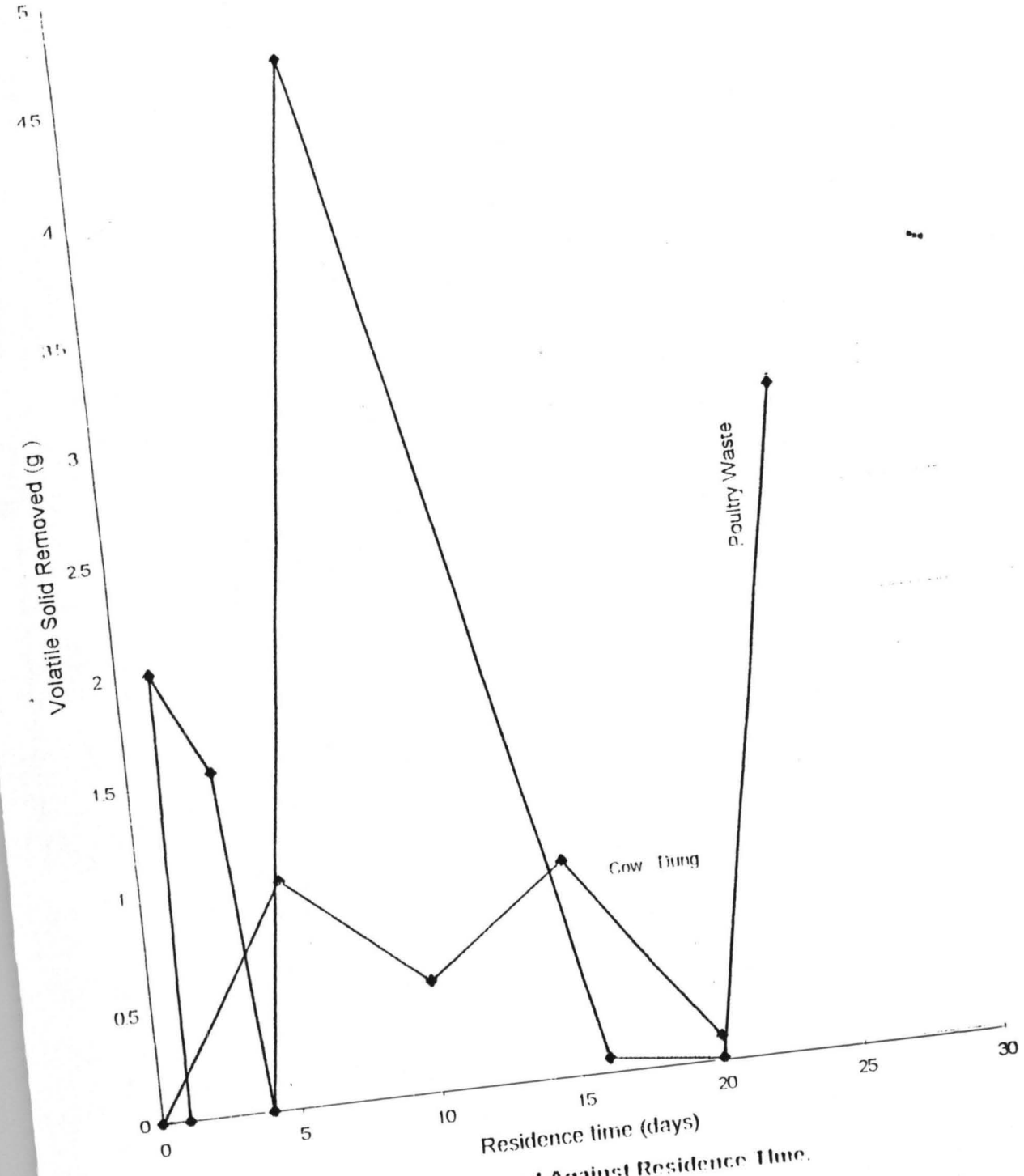


Fig 2 Graph Of Volatile Solid Removed Against Residence Time.

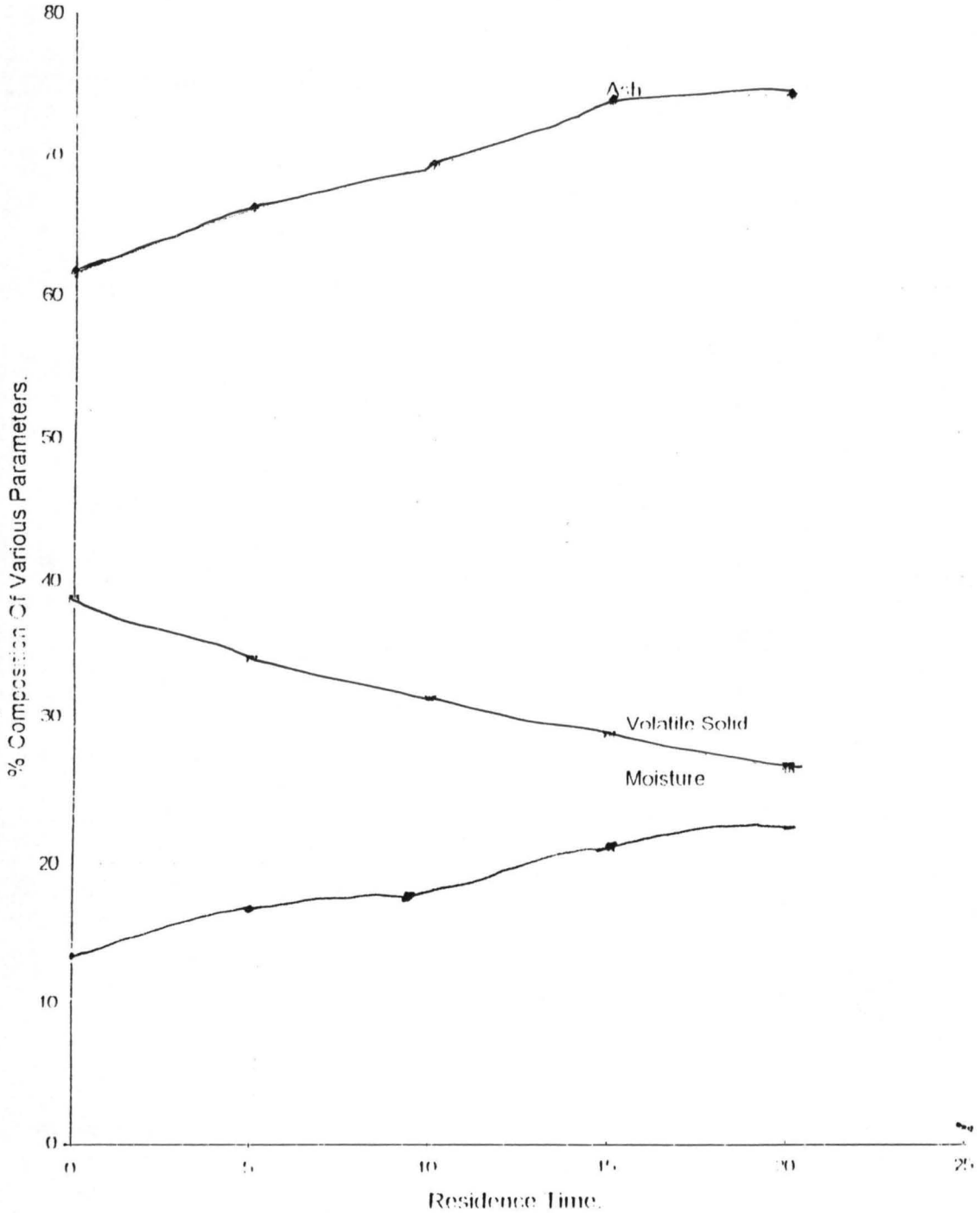


Fig.3 Graph Of Composition Of Various Parameters In Cow - Dung Digestion Against Residence Time.

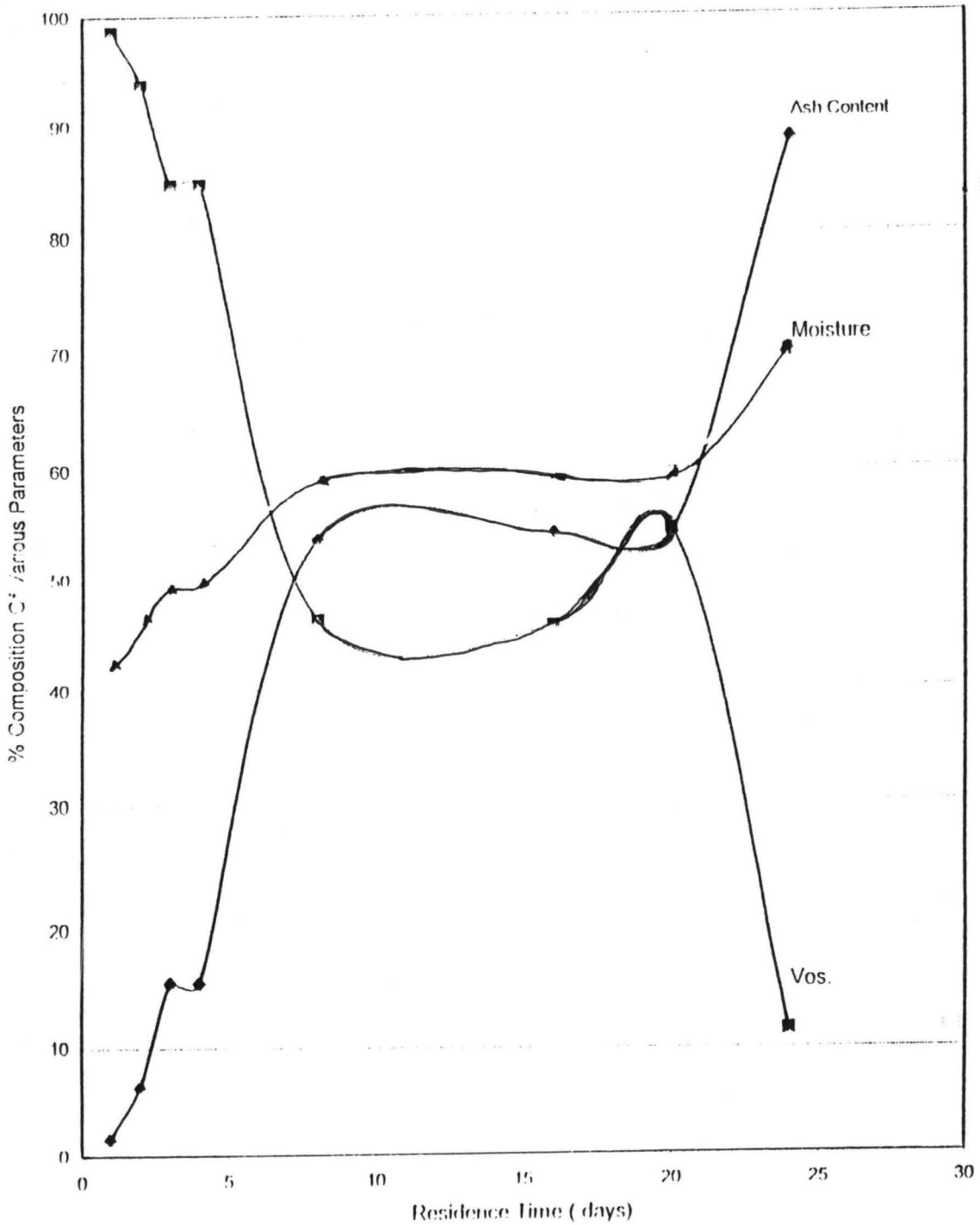


Fig.4 Graph % Composition Of Various Parameters In Poultry Waste Digestion Against Residence Time (Days)

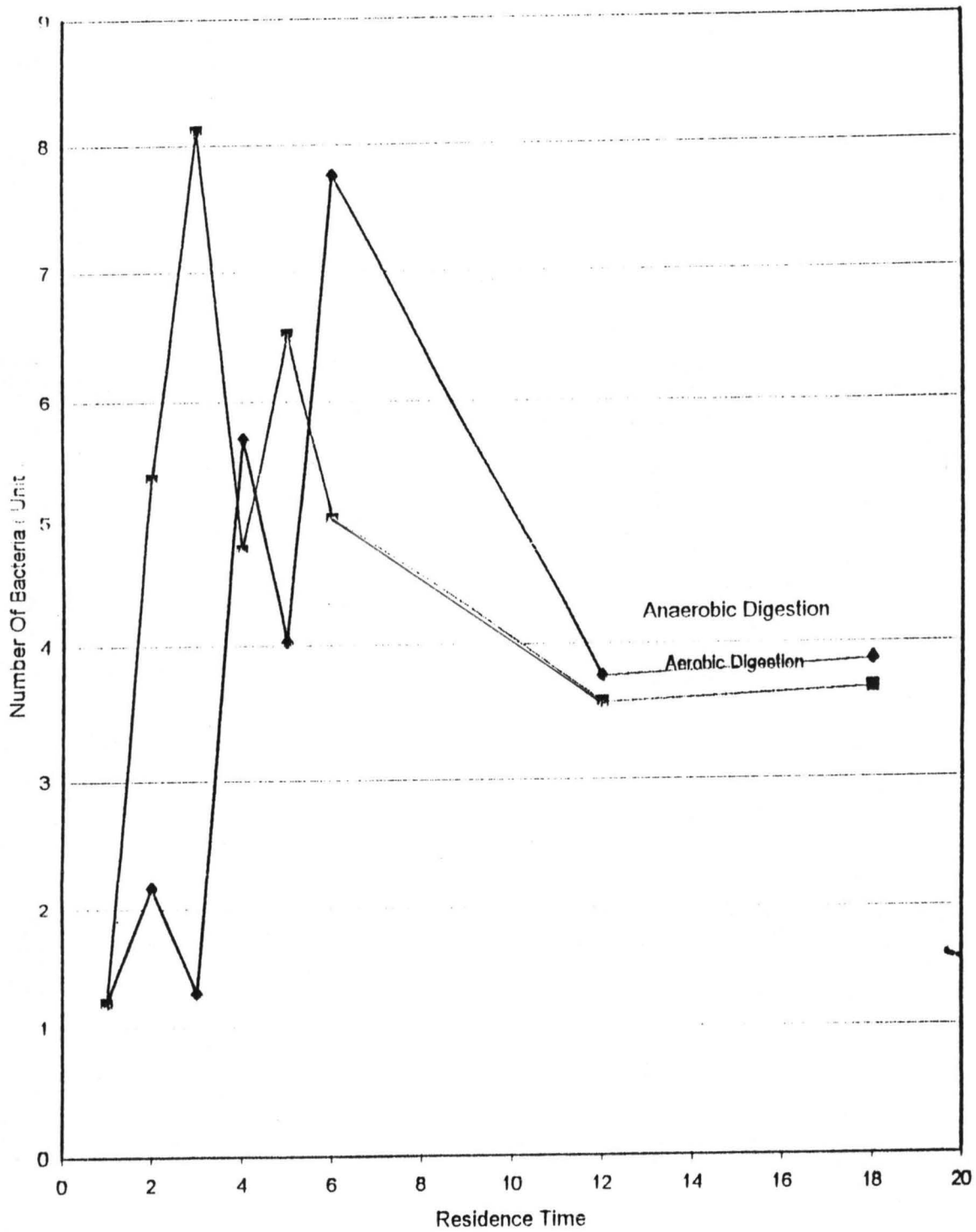


Fig.5 Graph Of Number of Bacterias (Unit) Against Residence Time (days) For Anaerobic And Aerobic Digestion Of Cow - Dung

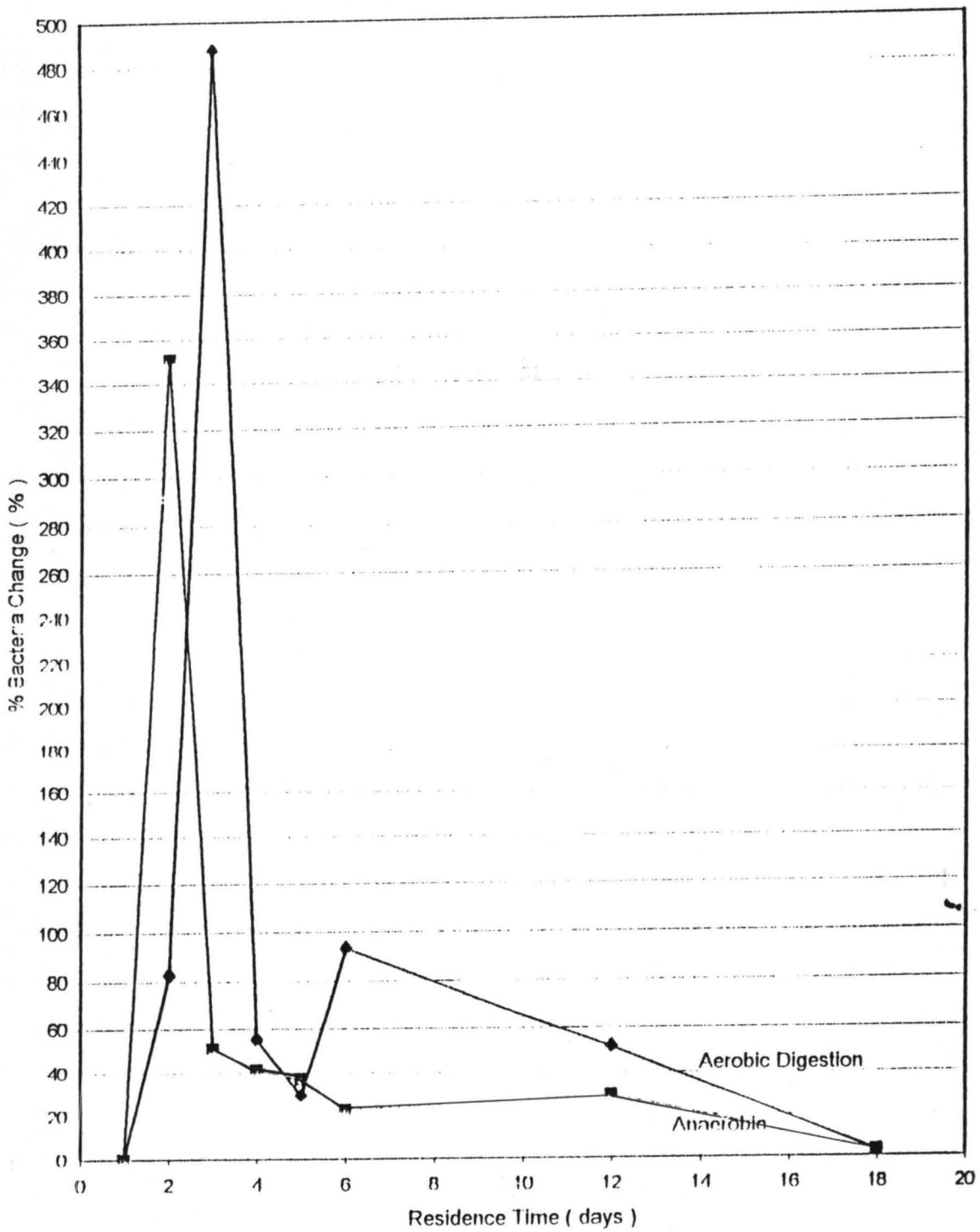


Fig.6 Graph Of Percentage Bacteria Change (%) Against Residence Time (days) For Both Aerobic And Anaerobic Digestion Of Cow - Dung.

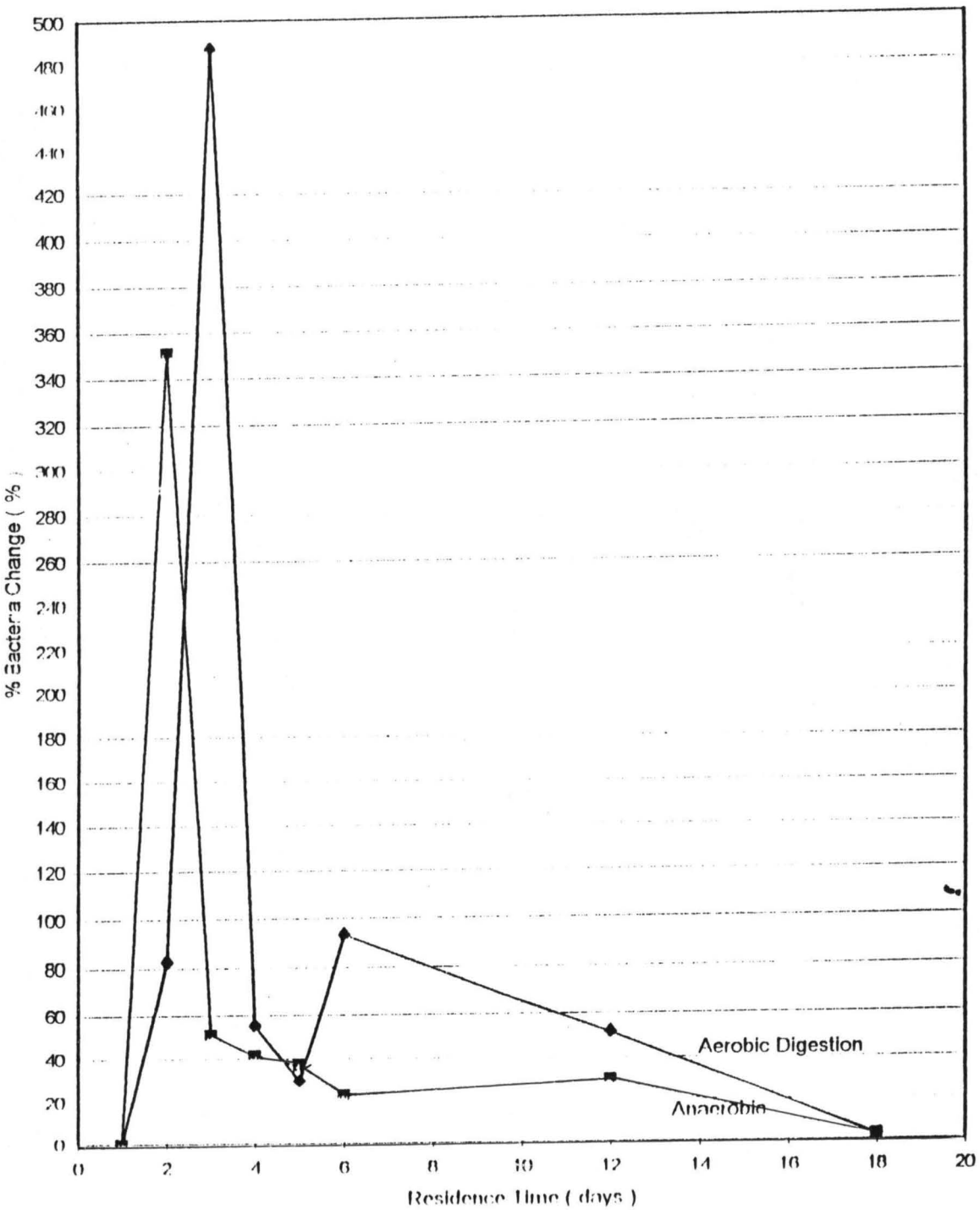


Fig.6 Graph Of Percentage Bacteria Change (%) Against Residence Time (days) For Both Aerobic And Anaerobic Digestion Of Cow - Dung.

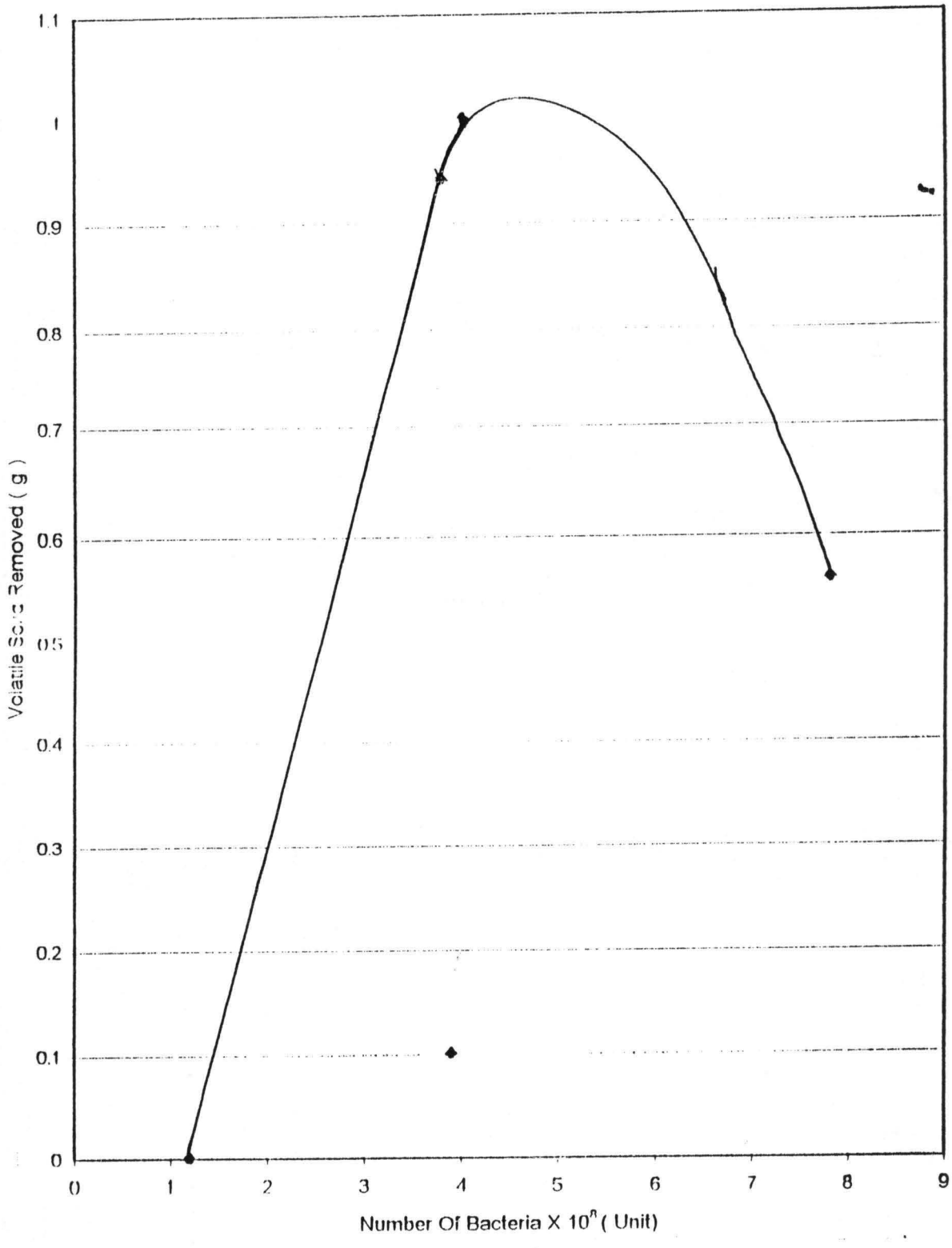


Fig.7 Graph Volatile Solid Removed Against Number Of Bacteria(Unit)

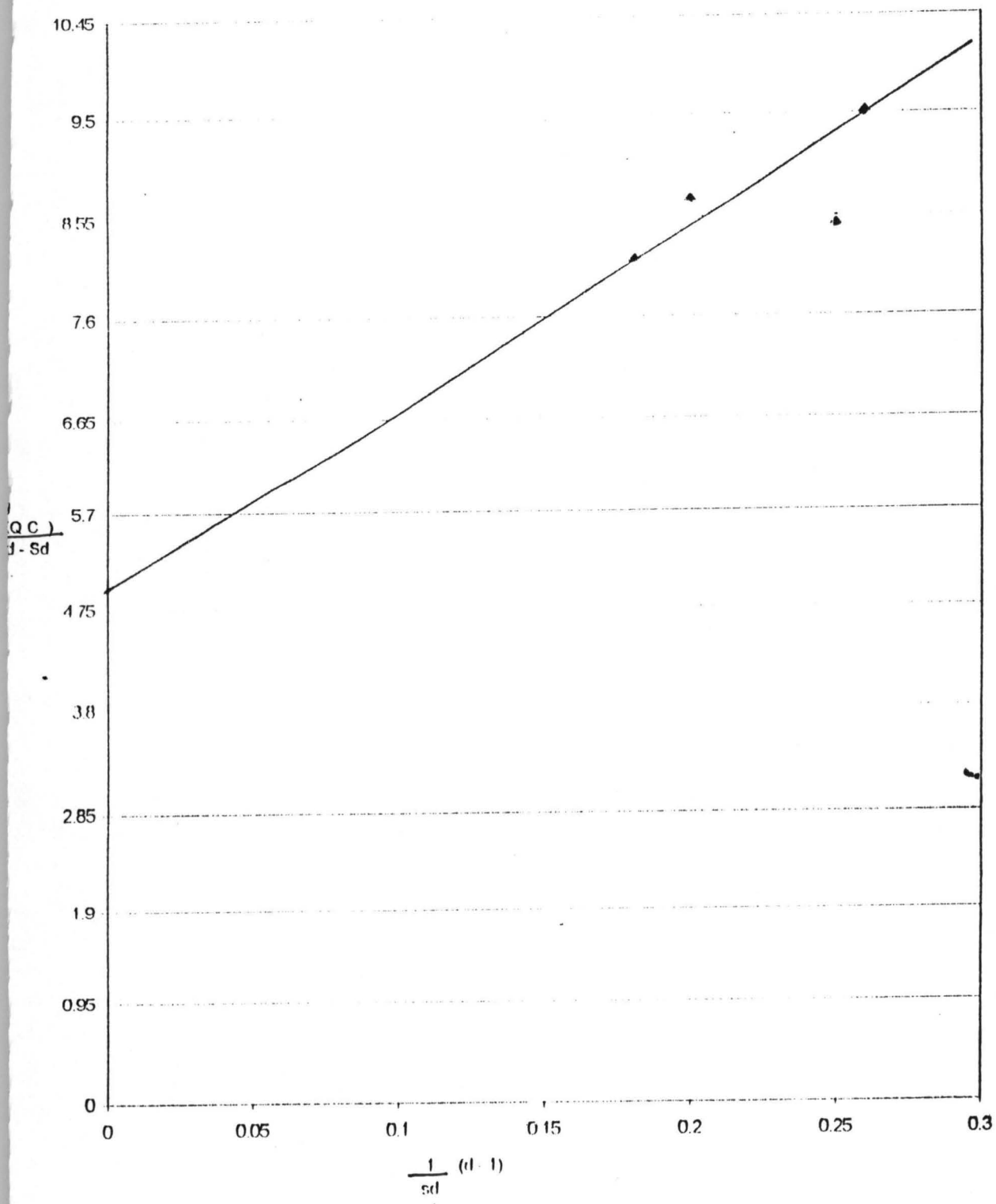


Fig 8 Graph Of Log (XQC) Against (1)
S d - d Sd

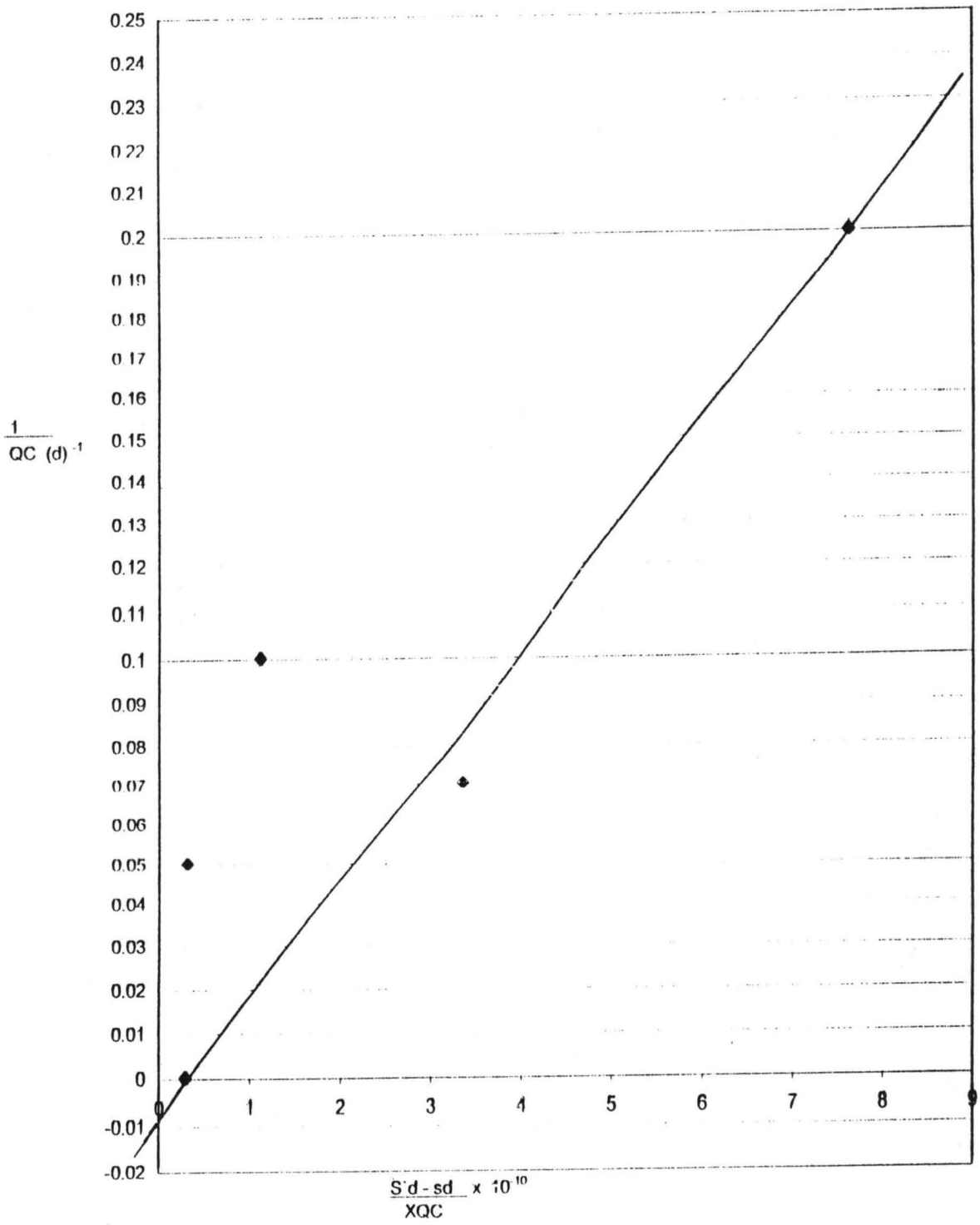


Fig.9 Graph Of Log (1 / QC) Against (S'd - sd) / XQC

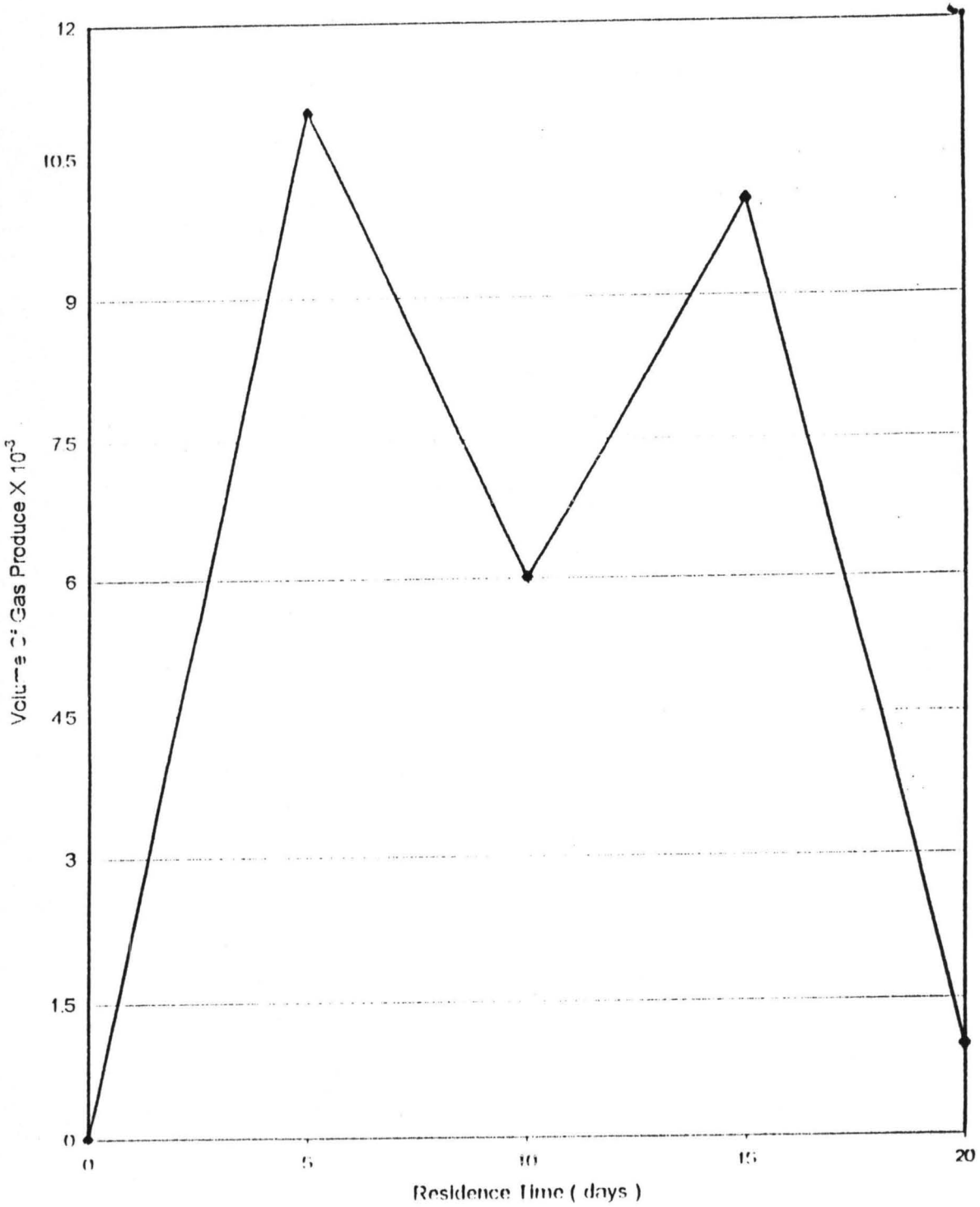


Fig.10 Graph Of Volume Of Gas Produced Against Residence Time For Anaerobic Digestion Of Cow - Dung Using Contois Model

NOMENCLATURE

HRT ---------- Hydraulic retention time (days)

γS_u ---------- Substrate Utilization rate, mass/unit volume-time

sd ---------- Concentration of biodegradable substrate in the influent, mass/unit volume.

$s^{\circ}d$---------- Concentration of biodegradable substrate in the influent.

ST ---------- Concentration of total substrate in the influent, mass/ unit volume.

$S^{\circ}T$ ---------- Concentration of total substrate in the influent mass/ unit volume.

$S^{\circ}\gamma$---------- Concentration of refractories substrate in the influent, mass/ unit volume.

t---------- time.

k---------- μm/y maximum utilization rate of coefficient, mass of substrate consumed per mass of micro organisms.

Y---------- Maximum yield coefficient, mass of cells formed per mass substrate consumed.

X---------- Concentration in the reactor of microorganisms utilizing substrate, mass/ unit volume.

b---------- Endogenous decay coefficient, (time) $^{-1}$.

θ---------- Hydraulic detention time (time).

Qc---------- Mean cell (solids) residence time (time).

δv---------- Volumetric gas production rate, volume of methane per time per volume of reactor.

S---------- Essential nutrient(or Substrate) concentration, mass/unit volume.

μm---------- Maximum specific growth rate, time^{-1} (at large s).

Ks---------- "half – rate" coefficient (i.e concentration of s at which the rate is one-half the maximum, or $\mu = 1/2\mu m$), mass/unit volume.

V---------- Methane production rate, at (S.T.P) L/d

Vs---------- Specific yield (volumetric methane production rate in cubic meters per day per cubic meter of digester.

Bo---------- Ultimate methane yield in cubic meters of methane per kilo- gram of volatile solids added.

So---------- Influent volatile solids concentration in kg/m^3.

k---------- A dimensionless kinetic coefficient.

GLOSSARY.

ACID FORMING BACTERIA:- The group of bacteria in a digester that produce volatile acid as one of the by-products of their metabo- lism.

AEROBIC:- In the presence of free oxygen.

ANAEROBIC:- In the absence of free oxygen.

AEROBES:- Bacteria which live and repro- duced in environment containing oxygen which is available for their respiration such as atmospheric oxygen or dissolved oxygen.

ANAEROBES:- Bacteria which live and repro- duced in an environmental contai- ning no oxygen which is available for their respiration, such as atmo- spheric or dissolved oxygen.

ANAEROBIC CONTACT PROCESS:- An anaerobic digestion process, in which the micro

organism are separated from the influent slurry by sedimentation or other means and returned to the digester to increase the rate of stabilization.

ANAEROBIC DIGESTER:- A reactor that is constructed to aid the degradation of organic matter by anaerobic bacteria.

BIOGAS:- A mixture of gas, predominantly methane and carbon- dioxide produced by anaerobic fermentation.

BUFFER CAPACITY:- A measure of the capacity of water or waste water for offering to change in PH.

CARBON /NITROGEN RATIO(C/N RATIO) :- The ratio of organic Carbon to that of total Nitrogen.

COLIFORM:- A rode-shaped bacterium found in intestinal tracts of most animals, which is often used as

an indicator to detect feical contamination.

DEGRADATION:- The breakdown of substances by chemical, physical and / or biological action.

DETENTION TIME:- The theoretical period of resistance in a given volume or unit it is normally calculated by dividing the active volume of the unit by the rate of flow of the liquid through it's.

DIGERSTER : - The unit in which anaerobic digestion take place, which maybe constructed so as to store the gas produced by anaerobic digestion.

EFFLUENT (FERTILIZER) :- The sludge or spent slurry from a continuous – feed digester.

ENZYME :- A complex organic substance (protein) produced by living cells and having the property of accelerating transformation

such as digestion processes.

FACULTATIVE:- The ability of micro – organism to live under either aerobic or anaerobic conditions.

INOCULANT (INOCULUM):- Any material such as previously digested feed stock, that is added to a newly started digester to hasten the degradation of organic matter and the production of methane.

MESOPHILIC :- Within a moderate temperature range normally 30 – 40°C.

METHANE (CH_4):- A colourless, odourless, flammable gas and the main constituent of natural gas, coal gas and biogas.

NIGHT SOIL :- Human facets and urine collected by buckets or vacuum trucks.

PATHOGEN :- Disease Causing Organisms.

RETENTION TIME :- The number of days that organic matter or bacteria remain in the

digester.

SLUDGE:- The slurry of settled particles resulting from the process of sedimentation.

SUPERNATANT :- Liquid removed from a sludge. Supernatant commonly refers to liquid between the sludge in the lower portion and the scum on the surface of an anaerobic digester.

THERMOPHILIC :- Of a relatively high temperature, normally in the range of $50^0 - 80^0C$.

TOXICITY :- A condition that will inhibit or destroy the growth or function of an organisms.

TOTAL SOLID :- The sum of dissolved and suspended constituents in a sample , usually started in milligrams per liter.

VOLATILE ACIDS :- Short chain ($C_1 - C_{12}$) fatty acids which are produced by

acid forming bacteria. They are soluble in water and are reported to be equivalent to acetic acid.

VOLATILE SOLIDS:- The solids that volatilizes and therefore are lost on ignition of a sample of dry solids at 80°C . Representing the organic matter in the sample of the volatile solids and are expressed as a percentage of the total solids.

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