PRODUCTION OF BIOGAS FROM POULTRY MANURE

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ABSTRACT

The objective of this research is to determine the extent of anaerobic biodegradation of raw manure, co-digested manure with bran, and co-digested manure with grass (as the substitute for rice straw) at 10% TS w/v each, and to establish methane yields from these treatments. The anaerobic digestion of high solids raw manure and also co-digested manure were conducted in a 4 L batch anaerobic tank which operated under mesophilic conditions at ambient temperature. The co-digestion with grass (as substitute for rice straw) and bran were carried out to determine whether any of these two materials inhibited or promote the greater production of biogas. This co-digestion of high solids raw manure were conducted with a ratio of total solid of chicken manure to co digested material of 90:10 for both co-digestion. The result shows that, the anaerobic digestion of 10% TS w/v of chicken manure (without co-digestion) have 3 major phases that is the phase 1 or the lagging phase, that was believed to be the hydrolysis phase of the manure, which occurred in about 14 days, phase 2, the exponential phase that was believed to be the methanogenesis phase of the manure, which occurred about 49 days later, and phase 3, the end phase, that was believed to shows the last phase that is usually inhibited by ammonia and VFA concentration . The result shows that the co digestion with bran is more feasible which produce high yield of methane and lowest yield of hydrogen sulphide in biogas produce. The recommendation have been made to optimize the methane production by two stages of anaerobic digestion and also by inoculate to start the process.

ABSTRAK

Tujuan kajian ini adalah untuk menentukan tahap biodegradasi anaerob tahi ayam mentah, campuran tahi ayam dengan dedak, dan campuran tahi ayam dengan rumput (sebagai pengganti jerami padi) pada kadar pepejal total 10% berat per isipadu, dan untuk mengukur penghasilan gas metana hasil dari prosess ini. Pencernaan anaerobik dengan kadar pepejal total yang tinggi ini dilakukan dalam tangki anaerobik 4 L yang dikendalikan di bawah keadaan mesofilik pada suhu bilik. Proses biodegradasi dengan campuran tahi ayam dan rumput dan dedak dilakukan untuk menentukan sama ada dua bahan menghalang atau meningkatkan penghasilan biogas. Nisbah jumlah pepejal total antara tahi ayam dengan campuran (rumput atau dedak) adalah 90:10 untuk kedua-dua proses biodegradasi ini. Keputusan kajian menunjukkan bahawa pencernaan anaerobic bagi tahi ayam mentah mempunyai 3 tahap utama iaitu fasa 1, fasa tertinggal yang diyakini tahap di mana proses hidrolisis berlaku, yang berlaku di sekitar 14 hari, fasa 2, fasa eksponen yang diyakini fasa penghasilan gas methana (methanogenesis), yang berlaku di sekitar 49 hari kemudiannya, dan tahap 3, tahap akhir, yang diyakini menunjukkan tahap terakhir yang biasanya dihambat oleh konsentrasi ammonia. Keputusan kajian untuk menunjukkan pencernaan anaerobik dengan combinasi tahi ayam mentah dengan dedak menunjukkan proses yang sesuai untuk dijalankan memandangkan kadar penghasilan metana adalah tinggi dan hidrogen sulfida adalah rendah dalam biogas yang terhasil. Beberapa cadangan penambahbaikan untuk penyelidikan seterusnya telah disarankan untuk meningkatkan kadar penghasilan gas metana yang lebih tinggi iaitu dengan menggunakan dwi peringkat dalam proses pencernaan anaerobik dan juga dengan menggunakan inoculum dari tahi yang telah lama dicerna.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of study

In recent year, the demand of broiler (chicken meat) and chicken eggs had arisen. From the Malaysia Poultry and Products Annual report, Malaysia been said to be one of the highest per capital consumption rates in the world for chicken at 35 kg. The report also said that the country also has a high per-capita egg consumption level of 280 eggs per person per year. This industry is regarded as the most successful segment of the livestock sector and perhaps has the highest output value per worker in the agriculture sector. The record in the report said, until 2005, there are about 2,500 broiler farms producing over 400 million birds (Jacelyn, 2005).

The factor of the rising in demand for broiler is because chicken meat is the most popular and cheapest source of meat protein among Malaysians, largely because there are no dietary prohibitions or religious restrictions against chicken consumption, unlike pork and beef for the minority Hindu population and pork for the majority Malay Muslim population. Besides that, quick service restaurants (QSR) such as Kentucky Fried Chicken (KFC), McDonald’s, A&W, Kenny Rogers, Nando’s Chickenland (a South-African based chain) have propelled the growth of chicken consumption in Malaysia.

Due to the rapid development of chicken farm in Malaysia, the yield of chicken manure has also increased dramatically year by year. The untreated chicken manure has the potential to create human and animal health problem (Fan *et. al.*, 2000), unpleasant odours problem, and environmental problem as well. However, chicken manure can be a beneficial commodity if been used wisely.

The excessive nitrate concentration in waters and greenhouse gas emissions cause by the untreated feedstock, may be overcome by apply anaerobic digestion treatment which will leads to the reduction of nitrogen pollution via the nitrification/denitrification process plus produce methane (biogas) which can be use as energy source. The presence of bacteria which can be consider high in manure will help in play role in anaerobic digestion process.

In the meantime, while waiting for anaerobic digestion, there is also occurrence of degradation from high molecule to lower molecule structure. This degradation is important to produce fertilizer from manure. Without proper degradation, the manure/compost will bring bad effect if been apply immediately toward any plant. The immature compost applied to soil would cause nitrogen starvation (Bernal *et. al.*, 2009), phyrotoxic effects, and presence of harmful microbes (Fang *et. al.*, 1999). Only the mature compost can improve soil fertility and plant growth (Haga, 1999).

The fresh and treated dried chicken manure are high in nitrogen, phosphorus, and potassium content if been compared with other type of manure. Table 1.1 shows that even in fresh manure or treated dried manure, the nitrogen content which is always needed in relatively large amounts to make all plant proteins, in the manure is still high.

Table 1.1 : Nutrient content in different type of manure

FRESH MANURE	Nitrogen (N), %	Phosphorus (P_2O_5), %	Potassium (K_2O), %	Organic matter, %	Moisture content, %
Cattle	0.5	0.3	0.5	16.7	81.3
Sheep	0.9	0.5	0.8	30.7	64.8
Poultry	0.9	0.5	0.8	30.7	64.8
TREATED DRIED MANURE					
Cattle	2	1.5	2.2	69.9	7.9
Sheep	1.9	1.4	2.9	53.9	11.4
Poultry	4.5	2.7	1.4	58.6	9.2

* *data obtain from"Manure is an Exellent Fertilizer"from www.ecochem.com/t_manure_fert.html*

1.2 Problem statement

The increment of chicken farm have creates some problem and issues regarding the environmental problem and public community. In Berita Harian dated 14 Mei 2010, the Government of Selangor, has directed the Lay Hong Farm at Batu 20, Sungai Buloh, to stop their organic fertilizer production from chicken manure because of the unpleasant odour has disturbed the nearby community. This is a serious matter to be overcome quickly. By the proper treatment of chicken manure its hope to slightly reduce or clear this problem and issues forever. In order to overcome this problem, anaerobic digestion is suggested as the alternative way beside just wait for the chicken manure to mature before it can be used and sell as fertilizer. It is more environment friendly, cost effective, and generates more incomes. The most important things is that it is waste to wealth method.

1.3 Research objectives

The objective of this research is to determine the extent of anaerobic biodegradation of raw manure, co digested manure with bran, and co digested manure with grass (as the substitution of rice straw) at 10% TS w/v each, and to establish methane yields from these treatments.

1.4 Research scope

In order to achieve these objectives, the following scopes have been identified:

i. The biogas production yield by anaerobic digestion of raw manure.
ii. The biogas production yield by anaerobic digestion of co digested manure with bran.
iii. The biogas production yield by anaerobic digestion of co digested manure with grass.
iv. The analysis of methane production yield by anaerobic digestion of raw manure.
v. The analysis of methane production yield by anaerobic digestion of co digested manure with bran.
vi. The analysis of methane production yield by anaerobic digestion of co digested manure with grass.

1.5 Rational and significant

The study of production of biogas production from poultry manure may contribute and beneficial a lot for environment and society. These are several benefits which are:

i. Use the commodity of waste to be converted to wealth.
ii. Preserving and protecting environment by reducing pollution especially air and water pollution.
iii. Find another source of energy that required less cost.

CHAPTER 2

LITERATURE REVIEW

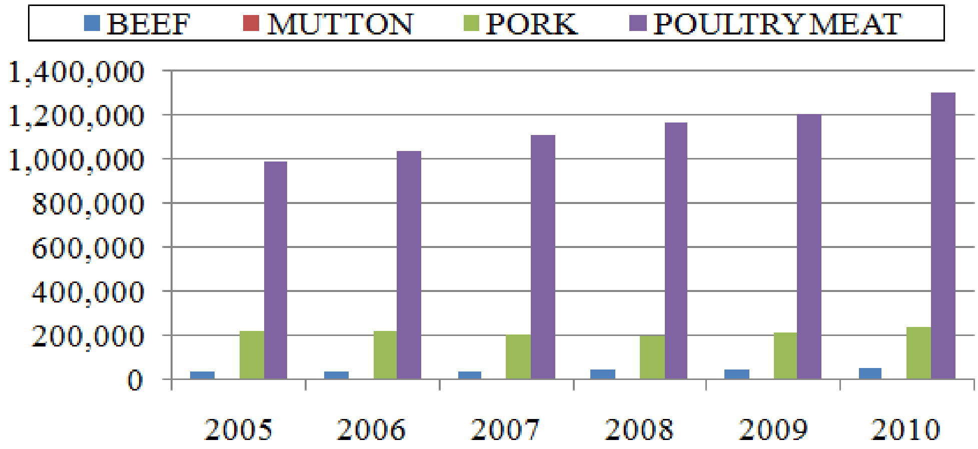
2.1 Poultry Demand in Malaysia

Nowadays, the demand of poultry meat has increase time by time. In Malaysia, many multinational poultry enterprises company grow actively such as Sin Mah, Leong Hup, PPNJ and QSR to fit with the demand.

In the past 5 years, the consumption of poultry in Malaysia and in many other countries has been on the increase, reaching more than 35 kg per capita in Malaysia in 2005 to 2010 (Malaysia : Per Capita Consumption of Livestock Products, 2000-2010, Jabatan Perkhidmatan Veterinar, Figure 1)

The increased concentration of poultry enterprises on relatively small land areas have resulted in the production of large amounts of poultry manure. This creates a problem for the poultry producers as well as for the general public. Moreover in the long run, the success of many poultry operations may depend on the efficiency of the management and utilization of waste.

a)



b)

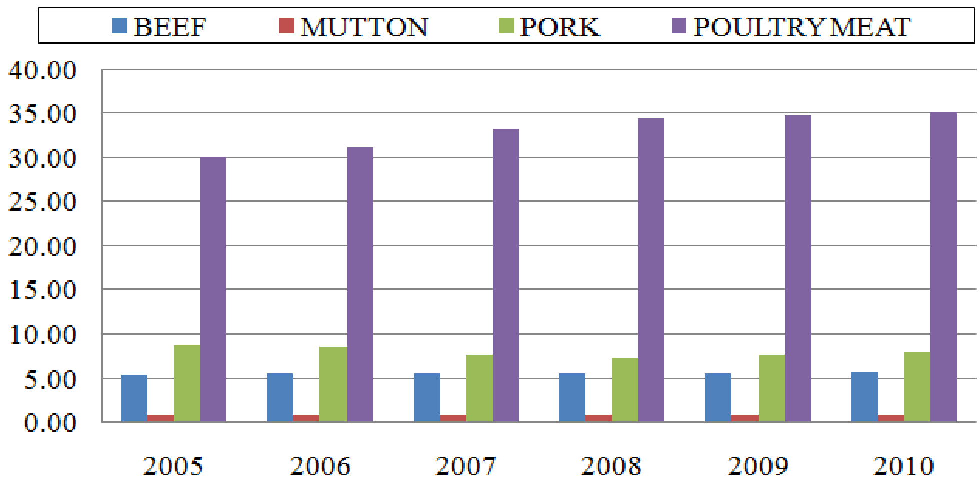


Figure 2.1 : Beef, mutton, pork, and poultry meat consumption. (a) In Malaysia from 2005 to 2010. (b) Per capita consumption in Malaysia in 2005 to 2010 (Jabatan Perkhidmatan Veterinar, 2010)

2.2 Poultry manure characteristic

Little literature is available on the characteristics and quantification of organic solid by-products and wastes from poultry farming, though such information is needed to evaluate treatment options for these materials. This characteristics is summarized in Table 1.

Table 2.1: Quantities and characteristics of organic solid wastes produced in poultry farming

Characteristic	**Manure**
TS (%)	20 – 47[a,d]
VS (% of TS)	60 – 76 [a,d]
Kjeldahl-N (% of TS)	4.6 – 6.7 [a,d]
Protein (% of TS)	Na
Lipids (% of TS)	1.5 – 2.1[b]
Methane potential (m^3/kg VS_{added})	0.2 – 0.3[a,c]
Methane potential (m^3/kg wet weight)	0.04 – 0.06[a,c]

Na: Not available

[a] Huang and Shih (1981).

[b] Mackie *et al.* (1991).

[c] Safley *et al.* (1987).

[d] Webb and Hawkes (1985).

2.3 Conventional method of chicken manure treatment

Agroindustries like poultry farming produce high quantities of organic wastes which are typically rich in nutrients and which can well be used in agriculture to conserve and recycle nutrients and to reduce waste discharge and use of chemical fertilisers (Marchaim *et al.*, 1991; Shih, 1987). However, without sufficient treatment these wastes may pose severe health risks, odour, environmental pollution, and visual problems, or their use may be legally banned altogether. Treatments may help to improve the physical and chemical properties of the waste and reduce its phytotoxicity (Marchaim *et al.*, 1991; Sudradjat, 1990; Vermeulen *et al.*, 1992). This manure is usually treated either by incineration, or by composting. But this two conventional method both have bad impact toward environment. Therefore, development of an alternative method for managing chicken manure is required.

2.3.1 Incineration

Incineration refers to technologies of thermal destruction, apparently among the most effective methods for destroying potentially infectious agents (Ritter and Chinside, 1995). Air-dried chicken manure is a proven combustible solid fuel with a gross calorific value of about 13.5 GJ per tonne, about half that of coal (Dagnall, 1993), whereas materials having a high moisture content have little or no energy value. In incineration, the air emission, process conditions, and the disposal of solid and liquid residues need to be strictly controlled. The Commission of the European Communities is currently preparing a new Directive on waste incineration. However, incineration at low temperature produces dioxins, which belong to a class one human carcinogen declared by IARC (1997), and also causes air pollution.

2.3.2 Composting

Composting is an aerobic biological process to decompose organic material, where it is carried out in either windrows or reactors. It is a common method to treat chiken manure wastes. Composting reduces pathogens, and composted material may be used as soil conditioner or fertiliser (DeBertoldi *et al.,* 1983; Senesi, 1989). However, wastes with a high moisture and low fibre content need considerable amounts of moisture-absorbing and structural support to compost well (Tritt and Schuchardt, 1992). In addition, emission to air, water, and land may present a problem, especially in windrow composting, and this may also reduce the nitrogen (fertilising) content in the compost (Tritt and Schuchardt, 1992). Large-scale composting, on the other hand, emits greenhouse gases, which contribute to global warming (Ginting *et al.* 2003; Peigne and Girardin 2004; Turnell *et al.* 2007). Composting, moreover, releases nitrogen through ammonia volatilization, which reduces the agronomic value of the composts (Delaune *et al.* 2004; Kelleher *et al.* 2002; Tiquia and Tam 2002).

2.3.3 Summary of Advantages and Disadvantages of Incineration and Composting

Table 2.2 : Summary of advantages and disadvantages of incineration and composting

	INCINERATION	COMPOSTING
ADVANTAGES	• effective methods for destroying potentially infectious agents (Ritter and Chinside, 1995) • proven high combustible solid fuel about half that of coal (Dagnall, 1993)	• reduces pathogens, and composted material may be used as soil conditioner or fertiliser
DISADVANTAGES	• air emission, process conditions, and the disposal of solid and liquid residues need to be strictly controlled • incineration at low temperature produces dioxins	• wastes with a high moisture and low fibre content need considerable amounts of moisture-absorbing and structural support to compost well (Tritt and Schuchardt, 1992) • emission to air, water, and land may present a problem and this may reduce the nitrogen (fertilising) content which reduces the agronomic value of the compost (Tritt and Schuchardt, 1992) • Large-scale composting, contribute to global warming (Ginting et al. 2003)

The advantages and disadvantages of the two conventional method to treat poultry manure as been discuss before been summarized in Table 2.2.

2.4 Anaerobic Digestion

Anaerobic digestion is a biological process in which organic matter is degraded to methane under anaerobic conditions. Methane can then be used for energy to replace fossil fuels and thereby to reduce carbon dioxide emissions. Anaerobic digestion reduces pathogens and odours, requires little land space for treatment, and may treat wet and pasty wastes (Braber, 1995; Shih, 1987, 1993). In addition, any releases to air, water, and land from the process can be well controlled (Braber, 1995; Shih, 1987, 1993). Most of the nutrients also remain in the treated material and can be recovered for agriculture or feed use (Salminen *et al.*, 2001; Shih, 1987, 1993; Sundradjat, 1990; Vermeulen *et al.*, 1992). Chicken manure has a higher proportion of biodegradable organic matter than the excrements of any other livestock. So, anaerobic digestion is the most suitable method for treatment of this municipal solid waste.

2.4.1 Degradation pathways

A diversity of microorganisms are involved in the many steps of anaerobic degradation of complex substrates, such as solid chicken farming waste (Figure 2.1), any of which may be rate-limiting, depending on the waste being treated as well as process conditions and operation (Pavlostathis and Giraldo-Gomez, 1991). Solid chicken farming waste contains high amounts of different proteins and lipids.

Fermentative bacteria, particularly the proteolytic Clostridium species, hydrolyse proteins to polypeptides and amino acids, while lipids are hydrolysed via β-oxidation to long-chain fatty acids (LCFAs) and glycerol

(Koster, 1989; McInerney, 1988; Zinder, 1984) and polycarbohydrates to sugars and alcohols (Koster, 1989; Pavlostathis and Giraldo-Gomez, 1991; Zinder, 1984, Figure 2.1). After that, fermentative bacteria convert the intermediates to volatile fatty acids (VFAs), hydrogen (H_2), and carbon dioxide (CO_2) (Koster, 1989; McInerney, 1988; Zinder, 1984).

Ammonia and sulphide are the by-products of amino acid fermentation (Koster, 1989; McInerney, 1988; Zinder, 1984). Hydrogen-producing acetogenic bacteria metabolise LCFAs, VFAs with three or more carbons, and neutral compounds larger than methanol to acetate, H_2, and CO_2 (Figure 2.1). As these reactions require an H_2 partial pressure of ca. 10^{-3} atm, they are obligately linked with microorganisms consuming H_2, methanogens, and some acetogenic bacteria (Dolfing, 1988; Zinder, 1984).

Methanogens ultimately convert acetate, H_2 and, CO_2 to methane and CO_2 (Figure 2.1) (Vogels *et al.*, 1988; Zinder, 1984). In the presence of high concentrations of sulphate, H_2 consuming acetogenic bacteria and sulphate reducing bacteria compete with methanogens for H_2 (Widdel, 1988; Zinder, 1984).

Anaerobic digestion has been shown to destroy pathogens. Thermophilic being usually more effective than mesophilic digestion (Shih, 1987). This pathogenic bacteria, parasites, and viruses may constitute a serious risk to animals and public health if untreated poultry slaughterhouse waste is to be recovered for agriculture or animal feed (Marchaim *et al.*, 1991; Shih, 1987, 1993).

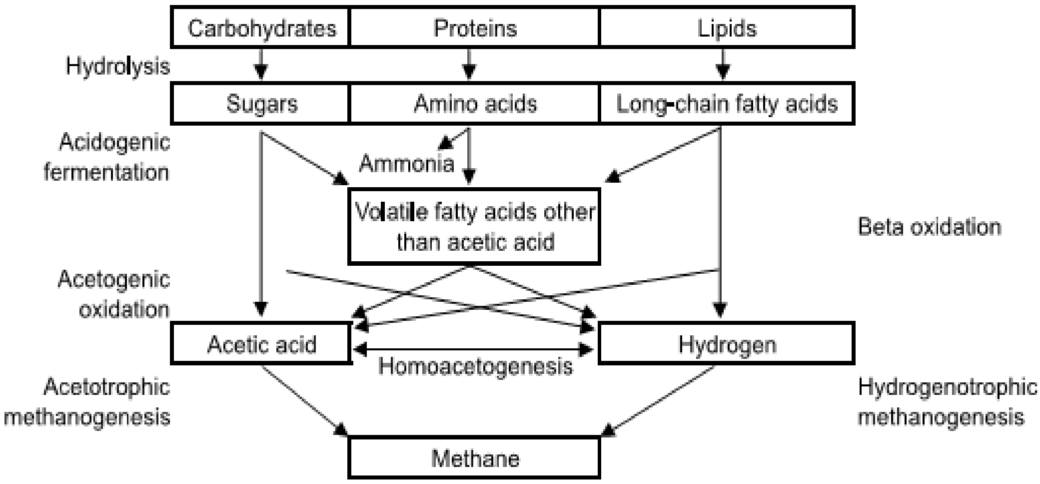


Figure 2.2: Degradation pathways in anaerobic degradation (previously reviewed by Koster, 1989; Pavlostathis and Giraldo-Gomez, 1991; Zinder, 1984).

A complete eradication of fecal coliforms and salmonellae was observed in a thermophilic digester (50 °C), whereas a comparable mesophilic digester (35 °C) destroyed them only partially (Shih, 1987, 1993). The oocysts of Eimeria tenella, a pathogenic protozoan causing chicken coccidiosis, were inactivated 99.9% in a thermophilic digester and 90–99% in a mesophilic digester, whereas thermophilic and mesophilic conditions reduced the counts of excreta-born fungal spores by 99–100% and 94–98%, respectively (Shih, 1987, 1993).

Viruses may tolerate the conditions in an anaerobic digester considerably better than bacteria (Turner and Burton, 1997), yet thermophilic treatment (at 55 °C) with an appropriate holding time may destroy many of the viruses present in wastes. Anaerobic treatment at 50 °C has been shown to destroy Marek's disease virus (Shih, 1993).

Besides temperature, the destruction of pathogens in anaerobic digestion depends also on several other factors. For example, increasing the hydraulic retention time (HRT) may increase bacterial and viral destruction (Kun *et al.*, 1989). A two-phase anaerobic digestion reduced the number of pathogens even more than the conventional one-phase digestion (Kun *et al.*, 1989). However, unstable performance or incomplete anaerobic digestion may, in fact, lower the ability of the process to reduce pathogens (Marchaim *et al.*, 1991)

2.4.2 Concentration of total solid in anaerobic digestion of poultry manure

A common approach of total solid concentration relies on dilution of the manure to 0.5-3.0% total solids (TS) thereby eliminating ammonia inhibition of the digestion. The resulting large volume of the waste to be processed makes this method economically unattractive.

There have been some efforts made to treat the manure in its semi-solid state. Converse *et al.* (1981) operated a farm poultry digester fed with 11.4% TS manure; however high volatile acid content of the digestate and low volatile solids (VS) reductions obtained indicated the need for optimization of the digester's biogasification efficiency.

Hill (1983), Jewell & Loehr (1977), and Morris *et al.* (1975) previously in their research said that when poultry manure anaerobically digested at its original solids content of 20-25%, can cause a reduction of process performance caused by ammonia accumulation.

Safley *et al.* (1985) reported better performance of their full-scale digester, though at a lower solids level (5.9% TS). Jantrania and White (1985) attempted a laboratory-scale digestion of poultry manure at 30-35% TS.

Apparent build up of hydrogen sulphide to inhibitory levels in most of the reactors and overall reduced conversion efficiency with very long retention times employed pointed out the limitation of the application. Webb and Hawkes (1985) tested a broad range of solids from 1 to 10% TS and showed optimum substrate bioconversion to methane at 4-6% influent TS.

They suggested a two-phase operation with the first hydrolysis/acidogenesis phase and the second methanogenic phase, already pre-adapted to high levels of ammonia, as an alternative to a single-stage design. The above experiments were carried out within the mesophilic temperature range (30-38ºC).

Huang and Shih (1981) conducted a thermophilic (50ºC) digestion of diluted manure at different solids concentrations and retention times and concluded that maximum CH_4 production can be obtained at 6% VS and 4 day retention.

This previous research on total solid concentration of poultry manure been used in anaerobic digestion have been summarized in Table 2.3

Table 2.3 : Summary of previous research on total solid concentration of poultry manure for anaerobic digestion

Total Solid	Author	Result
Total solids content of 20-25%	Hill, 1983; Jewell & Loehr, 1977; Morris et al., 1975	reduction of process performance caused by ammonia accumulation
Farm poultry digester fed with 11.4% TS manure	Converse et al. (1981)	high volatile acid content of the digestate and low volatile solids (VS) reductions obtained indicated the need for optimization of the digester's biogasification effciency
5.9% TS	Safley et al. (1985)	reported better performance of their full-scale digester
different total solids levels; 21.7 %, 10%, 5%.	Bujoczek et al. (2000)	The highest solids at which the digestion was still feasible was around 10% total solids.

Poultry manure at 30-35% TS	Jantrania and White (1985)	hydrogen sulphide to inhibitory levels in most of the reactors and overall reduced conversion efficiency very long retention times employed pointed out the limitation of the application
Broad range of solids from 1 to 10% TS	Webb and Hawkes (1985)	showed optimum substrate bioconversion to methane at 4-6% influent TS
Diluted manure at different solids concentrations	Huang and Shih (1981)	maximum CH4 production can be obtained at 6% VS

2.4.3 Co-digestion with poultry manure

Many research using chicken manure to be co-digested with other materials. Callaghan *et. al.* (2002) have done research of co-digestion of chicken manure and cattle slurry. This result shows that chicken manure was not as successful as a co-digestate. As the amount of chicken manure in the feed and the organic loading was increased, the volatile solid reduction deteriorated and the methane yield decreased. This appeared to be due to the concentrations of free ammonia present in the liquors.

Zhang *et. al.* (2010) have done research on the anaerobic digestion of dairy and poultry waste. In the research, poultry waste was characterized as an organic/nitrogen-rich substrate. Supplementing dilute dairy waste with poultry waste for anaerobic co-digestion resulted in improved biogas production.