CHAPTER 1

INTRODUCTION

When finding alternatives to oil as a source of fuels and chemicals, the anaerobic digestion represents one of the possible technologies that produces a useful energy product in the form of methane gas (biogas). The biogas product may be converted directly to electrical power, as a medium BTU fuel in internal combustion engines, or may be upgraded by reducing the carbon dioxide content to produce synthetic natural gas. Cellulosic wastes, including agricultural wastes, food processing wastes, wood wastes, and municipal wastes, are the main sources for biogas production, plentiful, and offer the most immediate promise for economic utilization in Thailand.

Among the cellulosic wastes mentioned above, paper wastes are the most easily obtained and recycled in the paper-making industry. Rivard, Adney, and Himmel (1991) estimated the materials discarded into the municipal waste stream during 1970-2000 shown in Table 1.1. These data indicate that the majority of this waste is biodegradable. Usually, newspaper, wood, and cardboard can be recycled. On contrary, the so-called "paper waste", which are mainly used toilet paper, facial tissue, and napkins, are discarded into the environment without further proper treatment causing pollution. They are generally left in the disposal sites and landfills producing landfill gases, or burned in the incinerators producing carbon dioxide to the atmosphere. Of course, it is expensive to dispose these wastes without undue pollution.

Nearly all paper waste contains more than 70% of cellulose in its content. This should be a must to use paper waste before discarding into the environment to cover the cost of cellulose. The use of biotechnological knowledge for converting paper waste by microbial degradation into industrial substrates, like biogas, is an alternative. This biotechnological potential is clean and specific, although expensive.

Table 1.1 Materials discarded into the municipal waste stream 1970-2000.

	1970		1986		2000	
	mill.ton/yr	%	mill.ton/yr	%	mill.ton/yr	%
Paper & paperboard	36.5	32	50.1	36	66.0	39
Yard waste	32.2	21	28.3	20	32.0	19
Food waste	12.8	11	12.5	9	12.3	7
Glass	12.5	11	11.8	8	12.0	7
Metals	13.5	12	12.6	9	14.4	9
Plastics	3.0	3	10.3	7	15.6	9
Other	11.0	10	15.2	11	16.5	10
Total	121.5	100	140.8	100	168.8	100

Source: Rivard, Adney, and Himmel (1991)

To date, most anaerobic digestion has been run at mesophilic temperatures, but there is much interest and potential in adopting a thermophilic system (Bragger *et al*., 1989; Brock, 1978). Many investigations have been made in the past decades on the use of thermophilic bacteria in cellulosic degradation and biogas production (Ahring and Westermann, 1987; Bhat and Maheshwari, 1987; Brenner and Johnson, 1984; Ferguson and Mah, 1983; Hormeyer *et al*., 1988; Hudson, Morgan, and Daniel, 1990; Jones, Nagle, and Whitman, 1987). Most of the effective cellulolytic and methanogenic thermophiles are usually found at temperature ranging from 50 to 60°C (Zinder, Anguish, and Cardwell, 1984) and having made remarkable results in cellulolysis and methanogenesis (Ng and Zeikus, 1981). In addition, there are many advantages using a thermophilic system, i.e., faster rates of conversion of organic matters to CH_4 which, in turn, means reduced retention times of the solids, increased output and improved efficiency, and resulted in rapid rise in volatile acids (Rintala and Ahring, 1994; Sorensen, Nielsen, and Ahring, 1991).

In Thailand, researches in this area are extensive, but all are emphasized on environmental factors, e.g., temperature, loading, agitating, physical factors, retention times, etc. (Alivio, 1968; Biogas plant system integrated management and technology at Sisaket Province, Thailand, 1988; Centeno, 1974; Chaipaksa, 1979; Chanthaworaphab, n.d.; Chitcharoongkiat, 1986; Kunawanakit, 1986; National Energy Administration, 1984; Opasawatchai, 1983; Pattamapirat, 1980; Tanticharoen, 1986; Tongkasame, 1968). In addition, there are also some studies on biogas production by mixed cultures (Dhavises, Vongkiatkachorn, and Oi, 1986; Kemavuthanon, 1994). The study of microorganisms in the digester is still limited, especially cellulolytic thermophiles and thermophilic methanogens. In 1984, Sribenjalux and Vejjanukroh isolated pure cultures of mesophilic cellulolytic bacteria and methanogens and used the techniques of coculturing to produce methane successfully for the first time in Thailand. They also convinced that paper waste, which is mainly cellulose, is the best carbon source for cellulolytic bacteria and methanogenic bacteria in biogas production.

To define further the efficiency of biogas technology and paper waste treatment in Thailand, this thesis was conducted at a thermophilic (55°C) laboratory scale. Two from 123 strains of pure thermophilic cellulolytic bacteria and three from 147 strains of thermophilic methanogens were selected and chosen for coculturing in biogas production from cellulose and paper waste.

1.1 Objectives

1) To select pure cultures of thermophilic cellulolytic bacteria and thermophilic methanogenic bacteria.
2) To investigate the feasibility to treat paper waste by anaerobic thermophilic digestion.

1.2 Scope of the Study

In this thesis, at least 5 brands of unused toilet paper and facial tissues were ground into small pieces, mixed together, and used as paper waste throughout the study. Newspaper, paperboard, and so on, were excluded due to their availability for recycling process. Besides, 50 samples of bacterial sources were chosen.

1.3 Anticipated Benefits

1) The use of thermophilic coculture in biogas production from paper waste could be an alternative and beneficial way for paper waste treatment.
2) The selected thermophilic strains could be used and applied to other thermophilic digesters effectively.

1.4 Components of the Thesis

This thesis comprises five chapters including this introduction. Chapter 2 gives the literature survey concerning the anaerobic digestion, the biogas production, the biology of anaerobic thermophiles, cellulolytic and methanogenic bacteria, and the use of thermophily. In Chapter 3, the materials and methodology in anaerobic works are discussed. The results could be found in Chapter 4. Chapter 5 is the discussion which summarizes the biogas production from cellulose and paper waste by thermophilic bacterial cocultures and some useful suggestions.