TWO-STAGE DRY ANAEROBIC DIGESTION

OF MUNICIPAL SOLID WASTE

BY

CHING LIN AGATHA YU

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
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ABSTRACT

Research on high-solids anaerobic co-digestion of solid wastes with sewage sludge has thus far only been accomplished for a one-stage mesophilic and/or thermophilic process. In this study, a series 21d mesophilic followed by a 7d or 14d thermophilic process was developed and compared to a one-stage 28d mesophilic process for a 33% solid-state anaerobic co-digestion of a synthetic high-paper-content solid waste with waste secondary sludge.

Seven mesophilic (M1 through M7) and two thermophilic (T1, T2) digesters were monitored for pH, volatile acids, ammonia, Total Kjeldahl nitrogen, biogas productivity, methane content, and their composts examined for coliforms and cumulative oxygen consumption. M2 and M4 were operated as the one-stage 28d process while M6 and T2 made up the 21d mesophilic and 14d thermophilic reactors in the series process. Reactor $T1_{7d}$ failed as a dry anaerobic digester.

Biogas productivity for the series process was 13.2 L BG/kgTSrc.d compared to 9.1 L BG/kgTSrc.d for the one-stage process and methane content were 60.1%($M6_{21d}$), 55.3%($T2_{14d}$) and 38.7%($M4_{28d}$). Volatile solids removal of 52.3% and 20.5% were respectively reported for the series and one-stage process. No practical coliform removal was achieved in either processes. Cumulative oxygen consumption of 142.3 and 141.5 mg O_2/gTS.10d, respectively for the one-stage and series composts were lower than the 150-160 mg O_2/gOM obtained in an independent aerobic windrow composting process (De Wilde, 1990).

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LIST OF ABBREVIATIONS

BG	-	Biogas
CH_4	-	Methane
CO_2	-	Carbon Dioxide
COC	-	Cumulative Oxygen Consumption
CV	-	Coefficient of Variation (%)
DAD	-	Dry Anaerobic Digestion
g	-	Gram
kg	-	Kilogram
kW	-	Kilowatt
HAc	-	Acetic Acid
HProp	-	Propionic Acid
MPN	-	Most Probable Number
MRT	-	Mass Retention Time
MSW	-	Municipal Solid Waste
OFMSW	-	Organic Fraction of Municipal Solid Waste
OM	-	Organic Matter
SOC	-	Soluble Organic Carbon
TS	-	Total Solids
VFA	-	Volatile Fatty Acid
VOA	-	Volatile Organic Acid
VS	-	Volatile Solids
WSS	-	Waste Sewage Sludge

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1. INTRODUCTION & SCOPE

With increasing uncertainties pertaining to future landfill space availability, alternate energy source, production costs and fuel market prices, solid waste management using controlled biological decomposition of the organic fraction of municipal solid waste (OFMSW) is receiving increased attention (Cecchi et al. 1988; De Baere et al. 1986). This means that increasing quantities of OFMSW will be diverted from landfills and recycled for use as raw materials for the production of compost and energy.

Anaerobic digestion of OFMSW is not a new process, but perfecting the process is still an ongoing research. High-solids anaerobic digestion up to 40 percent total solids (TS) have been demonstrated by Jewell (1979). Since then, this process has been further investigated by Chynoweth et al. (1990) at 60%-80% TS, Logsdon (1990), and Poggi et al. (1990) at 25%-40% TS.

High-solids anaerobic digestion offers high volume reduction of up to 90 percent for uncompacted OFMSW by converting the biodegradable organics to useful biogas and biomass in the reactor (Kayhanian et al. 1991). Methane (CH_4), a quality fuel gas, and carbon dioxide (CO_2) are the principal gases constituting biogas.

There is, however, an upper limit to the total solids that can be applied to the high-solids anaerobic digestion process. Jewell (1979) found that a TS content higher than 32.5% decelerated the digestion rate. To increase the digestion rate, Six and De Baere (1988) co-digested MSW with waste sewage sludge. Poggi et al. (1990) also confirmed the technical feasibility of this co-digestion technology for a typical high-paper content North

American MSW with WSS at 30 to 35% TS.

Other attempts to accelerate anaerobic digestion of organic solids by Pfeffer (1973), Cecchi et al. (1988), and Graindorge et al. (1989) included elevating digestion temperature, lowering the total solids content, and/or increasing the nutrient supply.

All research pertaining to dry anaerobic digestion (DAD) conducted thus far dealt only with either a one-stage mesophilic or a one-stage thermophilic batch or continuous DAD process. Work by Poggi et al. (1990) demonstrated the instability of some single-stage thermophilic reactors fed with a mixture of North-American solid waste and sewage sludge.

It was then thought that a two-stage (herein referred to as series) DAD process could benefit from both the stability of a mesophilic (35°C) digester and the microbial thermal "kill" advantage of a thermophilic (55°C) digester. To the knowledge of the author, no work has yet been done for a series DAD process.

The goals of this study were therefore to investigate the technical feasibility of a sequential DAD process and to compare the series to a single-stage DAD process, in terms of reactor performances and the quality of the ultimate compost.

The variables to be investigated include (1) temperature, (2) mass retention time and (3) type of DAD process : one-stage or series. Comparison between the one-and two-stage DAD processes were to be based on responses including (1) biogas production and composition, (2) volatile solids removal efficiency, (3) Volatile Fatty Acid (VFA) concentration, (4) pH, (5) pathogen indicator removal, and (6) cumulative oxygen consumption.

2. LITERATURE REVIEW

The following literature review is intended to give an overview of the developments in anaerobic digestion and presentation of the state of the art of Dry Anaerobic Digestion (DAD) of MSW with WSS. A definition of DAD and its applications in solid waste management will be presented. Important environmental and operational considerations relating to an in-vessel anaerobic digestion process such as pH, temperature, nutrients, retention time and total solids will also be presented. General discussions pertaining to the microbiology and biochemistry of anaerobic digestion have already been covered extensively in the literature (Stronach et al, 1986; Parkin and Owen, 1986; Pfeffer, 1979) and will therefore not be repeated in this review.

2.1 Definition of Anaerobic Composting

Anaerobic digestion or composting involves a controlled biological decomposition of the organic fraction of a waste stream in the absence of air or oxygen to give an environmentally friendly humus-like product which can be handled, stored, or used for soil amendment purposes. While intermediates formed during aerobic composting are in the oxidized state, those from anaerobic composting are in the reduced state. That is why, all anaerobic processes should be followed by an eventual aerobic stage to stabilize the residual intermediates. Careful process and operational design, can accelerate the anaerobic process to the extent comparable to aerobic composting (Golueke, 1991a).

2.2 Advantages of Anaerobic Digestion of Solid Wastes

The prospect of using anaerobic digestion in future solid waste management is becoming a promising management option with the confirmation of high-solids anaerobic digestion technology by researchers like Shulze (1958), Jewell (1979), Chynoweth (1991), De Baere et al. (1985).

The principal advantages of dry anaerobic digestion of municipal solid waste include:

1) recovery of methane (CH_4) which can be used for energy production (Kayhanian et al. 1991)
2) production of a stable compost that can be used as soil amendment and/or boiler fuel (Kayhanian et al., 1991)
3) less expensive to dewater than a slurry (Chynoweth, 1991)
4) smaller reactor size can be used (Molnar et al., 1989)
5) liquid waste stream requiring further treatment is minimized (Molnar et al., 1989)
6) volume reduction of up to 90% is possible for uncompacted OFMSW by bioconversion to biogas and biomass (Kayhanian et al, 1991)

2.3 Environmental Factors Affecting DAD

Because DAD is a biological process, biological reactions determining the efficiencies of volatile solids removal, biogas productivity, and reactor performances are highly dependent on a favorable environment for the myriad of heterogeneous microorganisms residing in the digesters.

2.3.1 Effects of pH and VFA

Since the pH in an anaerobic digester is controlled by the "interaction of weak and strong acid-base systems, which are either present in the waste or released during the anaerobic process" (Cecchi et al. 1991), constant buffering is necessary to maintain the optimum microbial pH of 7.0. An increase in volatile fatty acids due to increased hydrolysis and acidogenesis results in the decrease of pH in the digester. An "unbalanced" reactor results, meaning, the risk of inhibiting the methanogenic step. Researchers like Le Roux et al. (1978), Buivid et al. (1981) recommended the addition of the chemical buffers like lime, $Ca(OH)_2$ and $CaCO_3$. According to Molnar & Bartha (1989), Buswell also used $Ca(OH)_2$.

Calcium carbonate was found to be ineffective as a buffer by Jewell et al. (1981) and Ten Brummeler et al. (1988). Sodium bicarbonate, also known as soda ash, gave the best results. While more expensive, $NaHCO_3$ can eliminate problems related to calcium carbonate precipitation (Gunnerson et al., 1986). Buffering is therefore recommended for maintaining a pH around neutrality to avoid VFA build-up in the digester which might lead to eventual process inhibition due to organic acids toxicity.

2.3.2 Effects of Temperature

The van't Hoff-Arrhenius rule of doubling reaction rates with every $10^{o}C$ increase in temperature holds true only up to a maximum temperature when excessive heat denatures the enzymes and can destroy the organism (Peavy et al., 1985). The functions of temperature are two fold in anaerobic composting. Optimum temperature is important to enhance process efficiency, and to effect thermal kill on the pathogens to assure a hygienic compost. Two temperatures commonly employed are in the mesophilic (35°C) and thermophilic (55°C) range.

Hashimoto et al. (1981) working with cattle manure at a mass retention time (MRT) of 4-5 days with 8-10% volatile solids (VS) concluded that thermophilic digestion gave a higher net production of energy per unit of capital cost than the mesophilic digesters.

Shelef et al. (1980) working with a 12% total solids (TS) cattle manure at 6d MRT, found that given the same MRT, a thermophilic digester could tolerate a higher organic loading than the mesophilic digester. Volumetric gas yields of 5.5 was obtained for the thermophilic digester while only 3.0 was obtained under the mesophilic conditions.

Converse et al. (1977) however, reported the superiority of a 10.4d MRT mesophilic digesters over a 6.2d MRT thermophilic digesters when dealing with a 15.8% TS dairy manure at 6.2d MRT. Mesophilic cultures were found to generate a higher methane yield per pound of VS added (Schellenbach, 1980).

Some thermophilic digesters were found to be rather unstable by Schellenbach (1980), Garber (1954, 1975, 1977) and Poggi et al. (1990). Garber also demonstrated that full scale mechanically stirred systems required that temperature variations of ± 0.5°C and ± 2°C be maintained for the thermophilic and mesophilic systems, respectively.

Hartz et al., (1982) and Mata-Alvarez et al. (1986) reported 41°C and 42°C, respectively, as the optimum operating temperatures reported using landfilled MSW with 39 to 57% TS. By digesting a 4-10% TS landfill slurry at an extended MRT of 30 days, Pfeffer (1973) found that the thermophilic digesters outperformed the mesophilic ones by 60%. Cooney and Wise (1975) experimenting with a 5% landfill slurry at 30d MRT, observed a 50% greater biogas production in the thermophilic digesters. Kimchie et al. (1988) had 30% more biogas production from the thermophilic digestion of a 3-18% TS piggery and dairy wastes at an MRT of 6 days.

In handling a 40% TS batch digestion of OMSW, Kasali and Senior (1989) demonstrated the inhibition of biogas and methane and accumulation of solvents under the thermophilic conditions. The 55°C was claimed to have a bactericidal effect on the methanogens. Heinrichs (1990) found that thermophilic digesters at 21d MRT had the highest removal efficiencies and biogas production while thermophilic digesters at 15d MRT were unstable.

For a loading rate between 14.3 to 17.2 kg COD/m^3.d, De Baere et al. (1985) obtained a similar biogas production of 6.2 m^3/m^3r.d for both the mesophilic and thermophilic digesters operating between 30 to 35% TS. However, at loadings greater than 17.2 kg COD/m^3.d, efficiency swayed in favor of the thermophilic regime. Gas production dropped by 10% in mesophilic digesters when the loading rate was increased to 18.6 kg COD/m^3.d. Thermophilic digestion at 21.4 kg COD/m^3.d demonstrated increased gas production to 8.5 m^3/m^3r.d.

Where the quality of the compost is concerned, temperatures ranging from 55° to 60°C are important for compost pathogen control. McKinley et al. (1989), in handling aerobic composts, reported a dramatic decrease in microbial activity in aerobic compost with an increase in temperature from 45° to 55°C. Temperatures beyond 60°C were known to incapacitate the bacteria responsible for composting, by cell protein denaturation.

Exposure time and temperature are intimately related. The higher the temperature, the shorter the time required to achieve pathogen destruction and vice versa. With 20d MRT, Garber (1977) demonstrated pathogen kill rates of 10^2 and $>10^4$ for *Salmonella* and *fecal streptococci* in wastewater sludge at mesophilic and thermophilic temperatures, respectively.

Using the DRANCO process, De Wilde et al. (1990) claimed to have obtained a dry and pathogen free compost (0 fecal streptococci and 0 fecal coliform), called *Humotex*, by subjecting the compost to an anaerobic thermophilic (130°F) condition for 3 weeks. Thermal kill points vary between pathogenic organisms (Golueke, 1991). De Bertoldi et al. (1991) reported that coliforms and Salmonella in aerobic composts were more sensitive to temperature than the streptococci (45-48°C). In the same study, the researchers found that Salmonella disappeared before the coliform level dropped to 5×10^2, and streptococci dropped to 3×10^3. Although much research has been done to determine the effects of temperature on anaerobic digestion efficiency, no conclusive results could be attained. The DAD process requires further optimizzation.

2.4 Operational Considerations for DAD

2.4.1 Effects of Mass Retention Time (MRT)

Progress in anaerobic treatment technologies of wastewater and solid wastes came about with the realization of severe premature washout of the microorganisms due to short mass retention time (Lawrence & McCarty 1970). Hill (1982) could not achieve optimum degradation for dairy manure in the digesters operating at short MRT. Parkin and Owen (1986) working with sludges also stressed the importance of a high design SRT for anaerobic process stability.

De Baere & Verstraete (1984) working with a high-solids European substrate emphasized the importance of optimizing MRT to ensure maximum gas production and a higher degree of degradation. A degree of degradation ensures a more stable ultimate compost which may be safely used as a soil conditioner.

Hills (1980a) working with anaerobic digestion of dairy manure and barley straw found a considerable drop off in digester efficiency for MRT below 15d. The 30.2% COD reduction observed at 25d MRT dropped to only 23.4% at 10d MRT. A decrease in methane content from 62.5% to 57.4% was also observed with a corresponding decrease in retention time from 25d to 10d (Hills, 1980b). The efficiency of digesters with MRT greater than 20d remained fairly constant throughout the experimental run.

When digesting a 6% TS slurry of OMSW with primary sewage sludge, Cecchi et al. (1988) found that a retention time of 15 days was required to give the most economical and efficient degradation. A retention time less than 15d resulted in a wash-out of bacteria.

Dry anaerobic digestion of a synthetic high-paper-content OMSW with waste secondary sludge between 30 and 35% TS, carried out at the University of Manitoba (Poggi et al., 1990) showed that digester performance was better at 21d than at 15d MRT. Digesters at 21d MRT exhibited the highest efficiencies.

Chynoweth and Legrand (1988), using the systems analysis approach, determined the optimum economical MRT for high-solids anaerobic digestion to be around 3 weeks. Optimum MRT may vary between 15 to 25d, depending on the temperature, total solids content and the biodegradability of the waste. Graindorge et al. (1989) recommended a 25% TS content and 17d MRT when working with a high-paper content OMSW (42% paper and cardboard). Results from the literature seemed to suggest a minimum retention time of 15 days when dealing with a high-paper content waste (i.e. less degradable).

2.4.2 Effects of Total Solids (TS)

Total solids (TS) in the original feedstock, TS content for optimum process efficiency and for producing a stable compost are not the same thing. TS in the feedstock is usually higher than that in the reactor contents because the decomposition process remove some of the solids as biogas, biomass and water vapor. Total solids content of a waste or substrate has a great bearing on the degree of substrate degradation that can be achieved.

High-solids anaerobic digestion studies on farm organic wastes and crop residues by Jewell (1979) showed a decrease in process efficiency with an increase in TS content above 35%. A similar efficiency decreasing trend was observed by Wujcik and Jewell (1988) in high-solids digestion of manure substrate. Methane content dropped sharply when the total solids of the substrate was increased from 30% to 35%. However, total solids up to 30% could be used reliably without any inhibition by the VFA.

Schulze (1958) digesting a mixture of air-dried sewage sludge and actively digesting sludge as the feed for a batch reactor, concluded that methane production could be achieved at 40% TS. However, problems of volatile fatty acids accumulation was encountered at such a high-solids content.

Graindorge et al. (1989) demonstrated that a concentration greater than 25% TS was unsuitable for digesting a high-paper-content (40% paper plus cardboard) waste. On the other hand, the Valorga process was reporting a 35% TS for a highly fermentable waste. De Baere et al. (1985) using the DRANCO process successfully digested a highly fermentable organic MSW at a total solids content between 30 to 35%. Research by Poggi et al. (1990) also demonstrated optimum removal efficiency and maximum biogas production between 30-35% TS in the feedstock.

Where pathogen removal is concerned, thermal kill was more effective at relatively low total solids (i.e. high moisture content) because moisture has the "technical effect of increasing the conductivity of the exposed mass to the thermophilic temperatures" (De Bertoldi et al, 1991). However, following digestion, a high TS is essential to ensure a stable compost. De

Bertoldi et al. (1991) showed that TS > 70% discouraged pathogen regrowth in the compost. Summarizing the information on TS reported in the literature, it appears that the digestion solids level should be at 30 to 35% TS for optimum process efficiency and that a level of 65 to 70% TS is required for compost stability.

2.5 Applications for the Composted Material

Diverting compostable materials from landfills for anaerobic composting is but the beginning of the environmental benefits for solid waste digestion (Kashmanian et al, 1991). Other benefits are derived from the use of the composting end product. Composts from the co-digestion of OMSW with sewage sludge have found several applications as a soil conditioner.

Marchaim and Creden (1981) reported the successful application of digested piggery and dairy wastes as a fodder and as an agricultural fertilizer. Maynard (1989) and Brinton (1985) when applying the compost to land, found the organic content remaining in the compost to have the ability to reduce pollutant carrying runoff and leachate, which provided surface and ground water quality benefits.

The maturity and stability of the finished compost critically determines its point of application (Inbar et al, 1991). If the compost is to be used as a soil conditioner, Price and Cheremisinoff (1981) recommended the carbon to nitrogen ratio (C/N) to be between 10 and 20. A low C/N ratio promoted the formation of high and toxic ammonia concentrations in the compost (De

Vleéschauwer et al., 1981; Zucconi et al., 1981; Chanyasak et al., 1983). Higher C/N ratio has been shown to promote the production and therefore accumulation of toxic organic acids in the compost (Inbar et al. 1991).

Oxygen consumption rates expressed as mg O_2/g volatile organic matter were reported by Schulze (1960) as one of the most accurate indicators for the activity of the composting process. This is because oxygen is consumed as a result of microbial metabolic respiration (Haug et al., 1991). Cumulative oxygen consumption (COC) of the compost was also used by researchers like Haug (1991) in measuring compost substrate degradability and Graves et al (1991) in determining the biodegradation of organic contaminants in soil and water.

According to Schulze (1960), the oxygen consumption rates for the finished compost should be lower than those measured during the active phases of organic substrate decomposition, since the purpose of composting is to convert all the organic fraction of a waste into more stable compounds. De Baere et al. (1986), working with a highly fermentable European substrate (35-40% TS) reported a COC in the range of 250-300 mg O_2/g OM (organic matter). In the same study, composts which underwent 6 weeks of aerobic windrow composting consumed 150-160 mg O_2/g OM.10 days. Composts subject to 3 weeks of dry thermophilic anaerobic digestion reported a COC as low as 50-60 mg O_2/g OM.10 days, indicating higher stability.

Hazardous materials, of importance, heavy metals and slowly degradable toxic organic compounds are major causes for concern in composts. Certain heavy metals are toxic to anaerobic organisms, even at low concentrations because these ions "inhibit metabolism and kill the organisms by inactivating the sulfhydryl groups of their enzymes in forming mercaptides" (Mosey et al., 1971).

Theis and Hayes (1979) found that toxicity effects are affected by the solubilities of heavy metals under various digester conditions because it is the soluble fraction that is toxic. Pretreatments of solid wastes should be emphasized in order to restrict the composting of toxic organic fraction and limit the transfer of heavy metals into the compost (Zucconi et al., 1991).

To minimize the solubilization effects of heavy metals, Cayrol et al. (1988) demonstrated a 45 to 55% heavy metal reduction by pre-sorting the MSW prior to composting. Heavy metal contamination may also come from waste sewage sludge co-digested with OFMSW. Pretreatment of the contaminated wastewater should therefore be emphasized if waste sewage sludge is to be composted. Insuring the production of a high quality, marketable compost is critical to successful composting because without markets, contaminated compost would end up eventually in the landfill (Richard, 1991).

Biogas is another valuable end product in composting. One cubic meter of methane at standard temperature and pressure has a heating value of 35,800 kJ/m^3 (Metcalf & Eddy, 1991). Biogas from co-digestion of OFMSW with sewage sludge was found to contain 50 to 65% methane content (De Baere et al., 1987).

2.6 Concluding Remarks

Composting provides a solution to the increasing solid waste problem. Diversion of the OFMSW from landfills also minimizes the risk of groundwater contamination by leachate from the landfill. A viable environmental and economic solution to solid waste management and leachate contamination of the underlying groundwater (Kashmanian et al,1991) can therefore be achieved. Although much research on dry anaerobic digestion of municipal solid wastes with or without sewage sludge has been reported in the literature, all were carried out using a one-stage mesophilic (35°C) and/or a thermophilic (55°C) digestion system.

Although modern composting practice calls for the *involvement* of mesophilic followed by thermophilic conditions (Golueke, 1991), no research has yet been attempted on a series or two-stage mesophilic-thermophilic digestion system, to the knowledge of the author. The word *involvement* implies that the mesophilic-thermophilic condition thus far used has depended entirely on heat energy internal to the composting mass for elevating the temperature from the mesophilic to the thermophilic range, rather than from the deliberate application of heat from an external or auxiliary source (Golueke, 1991).

The main purpose of this study is therefore to develop a two-stage dry anaerobic digestion process in which both the stability of a first-stage mesophilic digestion and the hygienic advantage of a second-stage thermophilic digestion may be achieved.

3. EXPERIMENTAL METHODS & MATERIALS

3.1 Experimental Design

Two different bench-scale DAD reactor configurations were set up to compare their performances and final compost quality. The first DAD reactor configuration involved a 28d mass retention time (MRT) mesophilic digestion process (herein referred to as a 28d meso). The second reactor configuration however, involved a 21d MRT mesophilic digestion followed by either a 7d or a 14d MRT thermophilic digestion process (herein referred to as a series 21d meso + 7d or 14d thermo).

The two-stage 21d meso + 7d thermo system was set up to compare with the one-stage 28d meso system. For the two-stage 21d meso + 14d thermo, the system was set up to compare with the 21d meso + 7d thermo process.

Two levels of digestion temperature (mesophilic at $35 \pm 1^{o}C$ and thermophilic at $55 \pm 1^{o}C$), four levels of mass retention time (7d, 14d, 21d, and 28d), and two different DAD reactor configurations constituted the main variables for this study.

Two different feedstocks, plain (FS) and coliform-inoculated feedstock (FSC) were used in the appropriate reactors where coliform analysis using the most probable technique (MPN) was conducted. Total solids (TS) for the feedstock was kept at 33% TS, based on earlier screening works by Poggi et al. (1990).

A total of 9 semi-continuous dry anaerobic digesters, 7 mesophilic ($35 \pm 1^{o}C$) and 2 thermophilic ($55 \pm 1^{o}C$) were started up and Table 1 summarizes their physical characteristics and operating conditions. Fig. 1 gives a schematic of the reactor-feed system set up for this DAD study. Reactors M6 (21d MRT), M7 (21d MRT) and M2 (28d MRT), M1 (21d MRT) and M3 (21d MRT) serve as control reactors. $M4_{28d}$, $M5_{21d}$, $T1_{7d}$ and $T2_{14d}$ were the experimental reactors.

3.2 Feedstock Preparation

The feedstock used in this research was similar in composition to the one used by Poggi (1992) to model a typical North American solid waste, which is higher in paper content than the European waste (Graindorge et al., 1989). The feedstock, on a dry weight basis, consisted of 44% newsprint, 44% putrescible food wastes, and 12% thickened waste sewage sludge (WSS) from the Town of Selkirk storage pond.

Food wastes, collected from the campus cafeteria, consisted mainly of vegetables, fruits, breads, and meats. Foods high in fats were manually removed at the lab prior to mashing. Shredded newsprint, approximately 5 mm x 50 mm was then mixed with the mashed food wastes and thickened WSS in a Hobart mixer until all the components were well blended.

The more or less homogeneous mixture was then spread out over metal trays and dried overnight in a 75 ± 1°C oven. Chunks of the dried feedstock were then milled for 1 to 2 hours in the Hobart mixer until the feedstock grain was less than 5 mm in diameter. For more consistency in the feedstock grain size, the crushed feedstock was then passed through a a 5 mm x 5 mm wire mesh.

TABLE 1

Physical Characteristics & Operating Conditions for DAD Reactors

REF	DIGESTER VOLUME (L)	MRT (d)	TEMP (°C)	FEED TYPE	VESSEL TYPE
M1	8.0	21	35	FS	Nalgene Palstic
M2	8.0	28	35	FS	Nalgene Plastic
M3	8.0	21	35	FSC	Nalgene Plastic
M4	8.0	28	35	FSC	Nalgene Plastic
M5	8.0	21	35	FSC	Nalgene Plastic
M6	4.0	21	35	FS	Glass Jar
M7	4.0	21	35	FS	Glass Jar
T1	8.0	7	55	B3 + B5	Plunger
T2	4.0	14	55	B1 + B6	Glass Jar

Notes:
FS = Plain Feedstock
FSC = Coliform-Inoculated Feedstock
MRT = Mass Retention Time

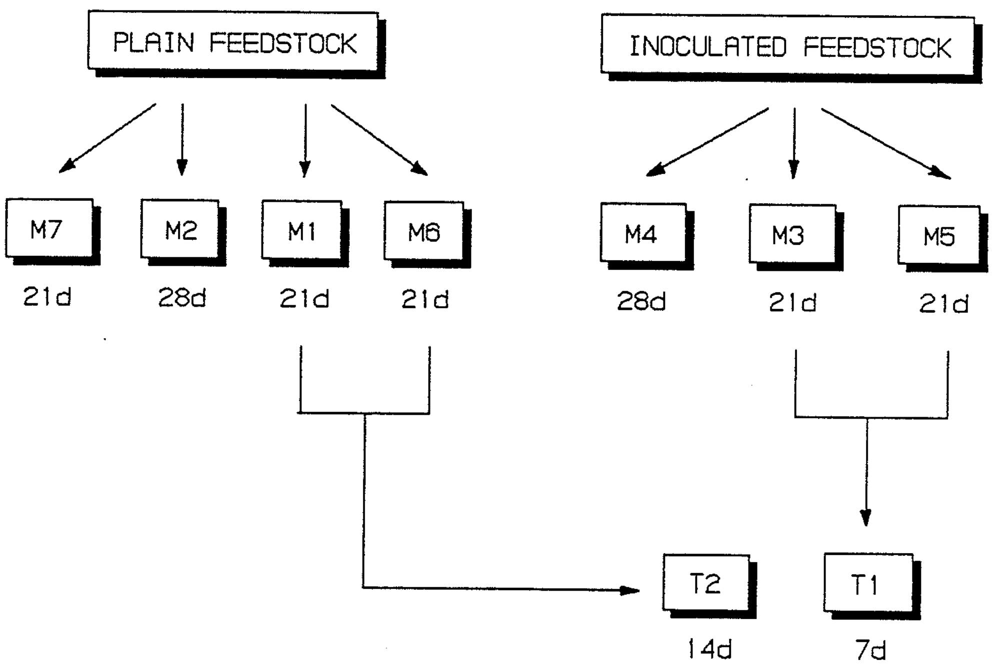

FIGURE 1 Schematic of Reactor-Feed System for DAD

The oversized feedstock i.e., those that remained on the wire mesh were then further size-reduced in a blender. The purpose of preparing the fine feedstock particle size was to increase the surface area of exposure of the organics to the microorganisms responsible for the digestion process (Tchobanoglous, 1977).

Large quantities of this dry feedstock were prepared prior to the start of the experiment and stored in a dry place. Prior to each draw and fill process, tap water was added to the dry feedstock in a feedstock:water ratio of 1:2 for reactors $M6_{21d}$, $M7_{21d}$, $M1_{21d}$, and $M2_{28d}$ to give a TS of 33.3% for the wet feedstock. For reactors $M3_{21d}$, $M4_{28d}$, and $M5_{21d}$, coliform inoculum slurry was added instead of tap water in a feedstock:inoculum ratio of 1:2 to increase the coliform count of the feedstock to a level higher than the average count inside the reactors for pathogen removal monitoring.

Sodium bicarbonate ($NaHCO_3$) buffer proportional to the mass loading rate was also added to the wet feedstock at 3 mg bic/g TS feed, to maintain the pH at 8.5. Concentrations of $NaHCO_3$ added for each reactor are provided in Appendix B.

3.3 Coliform Inoculum Preparation

The inoculum was started by aerating 25g of fresh wet compost from reactor $M4_{28d}$ and later $B2_{28d}$ in a 1.0 litre of Minimal Medium 1 culture broth (Phillips & Brock, 1984) at a pH of 7.0 ± 0.2 for 24 hours to enhance total coliform growth. For this research, coliform was chosen to be the pathogen indicator.

A 2.0 L erlenmeyer flask containing the medium and a magnetic stirrer was set up on a magnetic mixer while air was continuously bubbled into the medium to ensure proper aeration. The inoculum was harvested prior to the draw and fill process and mixed with the dry feedstock to give a total solids of 33.3%. Inoculum for the next draw and fill was prepared using the fresh compost from $M4_{28d}$ or $M2_{28d}$ after each draw and fill.

3.4 Reactor Set-Up

Reactors $M6_{21d}$, $M7_{21d}$, and $T2_{14d}$ consisted of 4.0 litre (L) glass jars while reactors M1 through M5 consisted of 8.0 L Nalgene Plastic Carboys from CANLAB. All mesophilic reactors, M1 through M7 were placed in a 35 ± 1°C walk-in chamber while the two thermophilic reactors, T1 and T2 were incubated in a 55 ± 1°C box-chamber.

Fig. 2 gives the schematic of a typical reactor set-up. All the reactors were connected by Tygon tubing to 10-L concentrated brine (NaCl) meters for biogas collection by liquid-displacement. When necessary, the brine meters were reset to resume biogas collection. For biogas composition analysis, 1.0 mL of the digester headspace gas was sampled through the rubber septum for analysis using the GOW-MAC Model 550 gas chromatograph.

Fig. 3 is a photograph showing the mesophilic reactors being incubated in a 35 ± 1°C walk-in chamber. Fig. 4 illustrates the plunger used for the thermophilic reactor $T1_{7d}$.

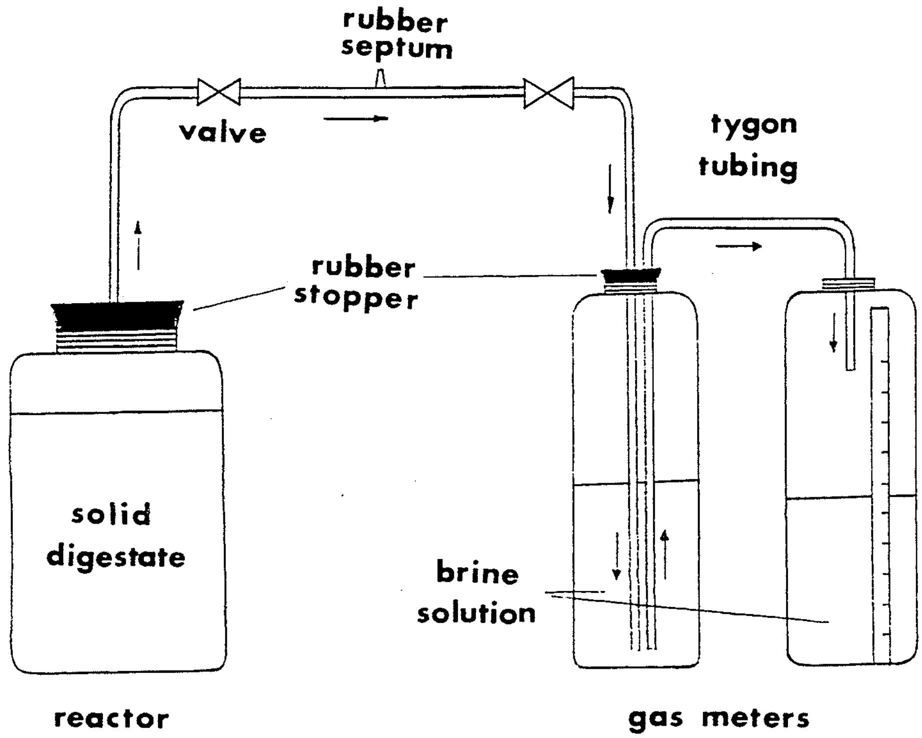

FIGURE 2 Schematic of a Typical DAD Reactor Set-up

FIGURE 3 Mesophilic Reactors in a 35 ± 1°C Walk-in Chamber

FIGURE 4 Thermophilic Plunger used for Reactor $T1_{7d}$

3.5 Digester Start-up

A total of 9 semi-continuous reactors, 7 mesophilic (35 ± 1°C) and 2 thermophilic (55 ± 1°C) were started up in a slurry form. Taring of the empty digester (including the rubber stopper and one clamp) was done before seeding it with 1.0 liter of anaerobic sludge from digesters at the City of Winnipeg North-End Water Pollution Control Center.

Dry feedstock (OMSW) and cow manure, obtained from the University's agriculture animal barn, were then added intermittently and the contents mixed thoroughly. A total of 0.45 litres and 0.30 litres of dry OMSW and cow manure, respectively were used. Nitrogen flushing was mandatory throughout the transfer process to minimize oxygen contamination of the digester headspace.

Nitrogen flushing was continued for another 10 minutes following mixing before the digester was sealed, weighed, and connected to a Tygon tubing attached to the 10-L gas collection brine meter.

Thermophilic reactors were started out in the exact same manner. However, instead of incubating the reactor at 55°C right away, the reactor was placed in a 48°C water bath. The temperature was increased by 1°C following every draw and fill, i.e., twice a week until the 55°C was reached. The reactor was then transferred into the 55 ± 1°C box chamber.

All the reactors were gradually brought to their specified TS of around 26% by initially feeding with a drier feedstock. When the consistency of the reactor contents were such that proper mixing could be achieved, the reactors were then fed the 33.3% TS feedstock. A period of approximately nine weeks was allowed for all the reactors to reach a pseudo steady-state condition before the data collected were used for the intended study. The assumption of steady-state was based on the rule of three times the mass retention time (MRT).

3.6 Draw and Fill Process

Draw and fill (D&F) for reactors M1 through M5, and T1 were carried out three times a week during the actual experimental run. For reactors $M6_{21d}$, $B7_{21d}$ and $T2_{14d}$ however, D&F were only carried out twice a week. An amount was drawn to maintain the specified target mass for each reactor. Following D&F, the reactor content was mixed by hand, under nitrogen flushing, before the reactor was resealed for incubation. When the reactor was reconnected to the gas collection brine meters, the reactor was shaken manually for about one minute to enhance distribution of the fresh OMSW among the microorganisms in the reactor.

3.7 Analysis

Analyses for pH, alkalinity, VFA, biogas production and composition, total and volatile solids, ammonia (NH3-N), total Kjeldahl nitrogen (TKN), coliform (MPN) and COC used to monitor the performance of the reactors were carried out according to the schedule presented in Table 2.

TABLE 2

Analysis Schedule for DAD Study

PARAMETER	ANALYSIS FREQUENCY
Biogas Production	2/day
Biogas Composition	weekly
Volatile Solids	2/week
Total Solids	2/week
Alkalinity	2/week
pH	every draw & fill
Ammonia (NH_3-N)	every 3 cycles
Total Kjeldahl Nitrogen (TKN)	every 3 cycles
Volatile Fatty Acid (VFA)	weekly
Most Probable Coliform Number (MPN)	2/week
Cumulative Oxygen Consumption (COC)	every 2 days

3.7.1 Biogas Production

Daily routine involved recording the overnight biogas production, manual shaking of the digesters for about a minute and when necessary, resetting of the gas collection brine meters.

3.7.2 Total and Volatile Solids

Total and Volatile solids were determined based on the procedures in Standard Methods (APHA, 1989). Ten grams of the solid digestate were dried overnight in a 103°C oven. The oven-dried samples were then left in a dessicator to cool down before being re-weighed to determine the total solids (TS). The dried solids were then ashed in a muffle furnace for 6 hours to determine the volatile solids (VS).

3.7.3 pH and Alkalinity

Sample preparation and analytical procedures for pH, alkalinity, and VFA were based on methods developed by Kasali et al. (1989) and modified by Poggi et al. (1989). Following D&F, 50 ml of deionized water was added to 10 g of the solid digestate and stirred vigorously to form a homogeneous slurry which was allowed to stand for 10 minutes. The slurry was stirred again just before taking the pH reading on a Fisher Accumet pH/Ion Meter Model 230.

The slurry was filtered through a wire mesh (1.8 mm x 1.8 mm) placed on a filter funnel. Alkalinity was measured volumetrically by titrating 20 mL of the filtrate against a 0.2 N H_2SO_4 according to Standard Methods (APHA, 1989). The filtrate was then boiled for

2¾ minutes on a hot plate to expel the CO_2, prior to total acidity determination. Titrimetric pH endpoints points for phenolpthalein, partial and total alkalinity were 8.3, 5.75, and 4.2, respectively.

3.7.4 Volatile Fatty Acid (VFA)

Following pH analysis, 1.5 ml of the filtrate (non-boiled) was centrifuged for 10 minutes in a high-speed IEC Centri-M Centrifuge prior to VFA analysis. 0.01N Oxalic acid and deionized water were then added to the clear supernatant in proportion to the specified dilution. VFA was then determined using the Hewlett Packard 5890 Gas Chromatograph (GC) fitted with a HP-FFAP capillary column having dimensions of 10 m x 5.3E-4 m x 1.0E-6 m. Output was recorded on a Waters 740 integrator. Flow rates for the different gases are illustrated in Table 3.

TABLE 3

Flow Rates for Gases flowing through the Hewlett Packard 5890 GC

GAS	FLOW RATE
Compressed Air (carrier gas)	13-14 ml/min
Nitrogen (make-up gas)	7-8 ml/min
Hydrogen to flame ionization detector (F.I.D)	30-31 ml/min
Air to F.I.D	450 ml/min

3.7.5 Coliform - MPN Technique

Coliform analysis using the Most Probable Number Technique (MPN) was based on methods developed by Phillips et al. (1984) and modified by Kuraszko (1991). Fresh compost from reactors $M7_{21d}$, $M4_{28d}$, $M5_{21d}$, and $T1_{7d}$ were analyzed for their stability in terms of total coliform count. Five grams of fresh compost was added to 495 ml of a phosphate buffer solution and blended to form a homogeneous slurry. Appropriate serial dilutions and incubation were carried out according to Standard Methods (APHA, 1989).

To use the MPN technique, 5 culture tubes, each containing 10 ml of the lauryl tryptose broth, was required for each dilution. Positive coliform count was confirmed only by a simultaneous yellow coloration of the purple lauryl tryptose broth and gas production in the inverted Durham tube. Total coliform count was then computed by multiplying the MPN index by the highest dilution factor with 5 positive tubes.

3.7.6 Biogas Composition

Biogas composition was analyzed using a thermal conductivity Gow Mac Model 550 gas chromatograph (GC). The carrier gas, Helium was allowed to flow through the stainless steel 1.8 m x 6 mm columns, packed with Poropak Q, 80/100 mesh to determine the concentrations of methane (CH_4) and carbon dioxide (CO_2). The GC was attached to a plotter and the results were automatically plotted on a chromatogram. Table 4 lists the required chromatograph settings for the biogas composition analysis.

TABLE 4

Chromatograph Settings for CH_4 and CO_2 Determinations

PARAMETER	SETTING
Bridge Current	150 mA
Column Temperature	55°C
Detector Temperature	110°C
Injector Port Temperature	95°C
Carrier Gas (Helium) Flowrate	10 ml/min

3.7.7 Cumulative Oxygen Consumption (COC)

Freezer-stored composite compost samples from November 4, 1991 to November 20, 1991 were used for this respirometric analysis. Sample preparation and analytical procedures were based on the method developed by Poggi and Yu (1992). Ten grams of compost were aerated in porcelain dishes for a period of 10 days. Daily routine involved re-wetting and over-turning of the compost to encourage the development of aerobic processes. This operation was carried out at room temperature, approximately 20°C.

Following the 10 days, the TS for each sample was determined and adjusted to about 50% TS. Five grams of the approximately 50% TS compost for each digester was then placed into serum bottles (duplicates), sealed with butyl rubber stoppers and capped to keep the stopper in place. One ml of the gas was immediately withdrawn from the headspace and analyzed for the initial oxygen concentrations in each bottle. The bottles were then incubated at 20 ± 1°C.

Oxygen content in the headspace of the serum bottles was determined using the thermal conductivity Gow Mac Model 550 gas chromatograph with Helium as the carrier gas. The carrier gas was allowed to flow through a stainless steel 1.8 m x 6 mm column, packed with a molecular sieve 5A with a 60/80 mesh to detect CH_4, O_2, and N_2. Chromatograph settings are reported in Table 3.

4. RESULTS AND DISCUSSION

Results of biogas productivity, biogas composition, TS and VS, pH, VFA, NH3, TKN, MPN and COC for the 5 week pseudo-steady-state study have been compiled in Appendices C and D. The results and discussion shall be handled in two sections, namely (1) reactor performance, (2) end product quality.

4.1 Reactor Performance

Only reactor performances for M1 through M6, T1, and T2 will be discussed here. Reactor $M7_{21d}$, which was only used in the early stages of the experiment for preliminary MPN analysis was not monitored further for this study.

Reactor performance for M1 through M6, T1, and T2 can best be described by identifying two different operating periods, A and B. Period A stretching from days 1 to 25 of the experimental run represented the period when all the reactors were performing well. Period B from days 25 onwards corresponded to the time when the performance of reactors $M3_{21d}$, $M4_{28d}$ and $M5_{21d}$ went down due to an overloading with organic matter (SOC) and volatile organic acids (VOA) as a result of the coliform inoculum.

At the end of the experimental run, the coliform inoculum was tested for both VFA and SOC. The VFA analysis (results not shown) indicated a very high concentration of the volatile organic acids. Results from the SOC indicated an additional organic loading of 233 mg SOC/gOM fed to digesters $M3_{21d}$, $M4_{28d}$ and $M5_{21d}$. Both VFA and SOC results seemed to imply reactor overloading because of the inoculum.

4.1.1 Biogas production, pH, and VFA

In period A, the mesophilic control reactors, $M6_{21d}$ and $M2_{28d}$ recorded on average, a biogas productivity of 10.5 L/kg TS.d (1.41 m^3/m^3.d) and 9.1 L/kg TS.d (1.26 m3/m3.d), respectively. At this time, T2, the 14d thermophilic reactor, was producing on average 3.0 L/kg TS.d (0.38 m^3/m^3.d). No biogas, however, was recorded for T1, the 7d thermophilic reactor. Biogas productivity for the present DAD study on a high-paper content (less degradable) OFMSW were low compared to other DAD studies reported in the literature.

Six and De Baere (1992) obtained a biogas productivity of 5-8 m^3/m^3.d for thermophilic anaerobic digestion of a highly degradable European OFMSW at 32% TS. Kayhanian and Tchobanoglous working with high-solids (25% TS feed) thermophilic anaerobic digestion of a highly degradable OFMSW reported a biogas productivity between 6.3-6.6 m^3/m^3.d active reactor biomass.

Figs. 5 through 9 display the dynamic performances in terms of pH, biogas production, and VFA for reactors $M6_{21d}$, $M4_{28d}$, $M5_{21d}$, $T1_{7d}$ and $T2_{14d}$, respectively. A VFA concentration of less than 1 mg HAc/g wet compost was observed in Fig. 5 for reactor $M6_{21d}$. The fairly constant pattern of the digester pH, VFA and biogas productivity displayed by $M6_{21d}$ therefore demonstrated the stability of the mesophilic DAD process.

Figs. 6 and 7 illustrates respectively, the gradual decline in reactor performance for $M4_{28d}$ and $M5_{21d}$. In $M4_{28d}$ and $M5_{21d}$, pH was seen to drop from an average of 8.5 to 5.5, despite buffering with sodium bicarbonate. The pH for both $T1_{7d}$ and $T2_{14d}$ were shown to remain fairly constant above the optimum 7.0, (Figs. 8 and 9). The feed schedule and quantity of sodium bicarbonate buffer added are listed in Appendix B.

Biogas productivity decrease appeared to be associated with a decrease in pH and an increase in VFA. This result is consistent with results reported by Gunnerson & Stuckey (1986), who have shown a drop in anaerobic digestion efficiency as a result of a drop in pH associated with an increase in VFA. Figs. 10 and 11 display the average biogas production during periods A and B, respectively. No biogas was collected for $T1_{7d}$.

It was speculated that the 7 day retention time could have resulted in the premature washout of the organisms that were responsible for biodegradation and hence, biogas production. Biogas production in reactors $M4_{28d}$, $M5_{21d}$ and $T2_{14d}$ were low because of the high VFA concentration in the reactors.

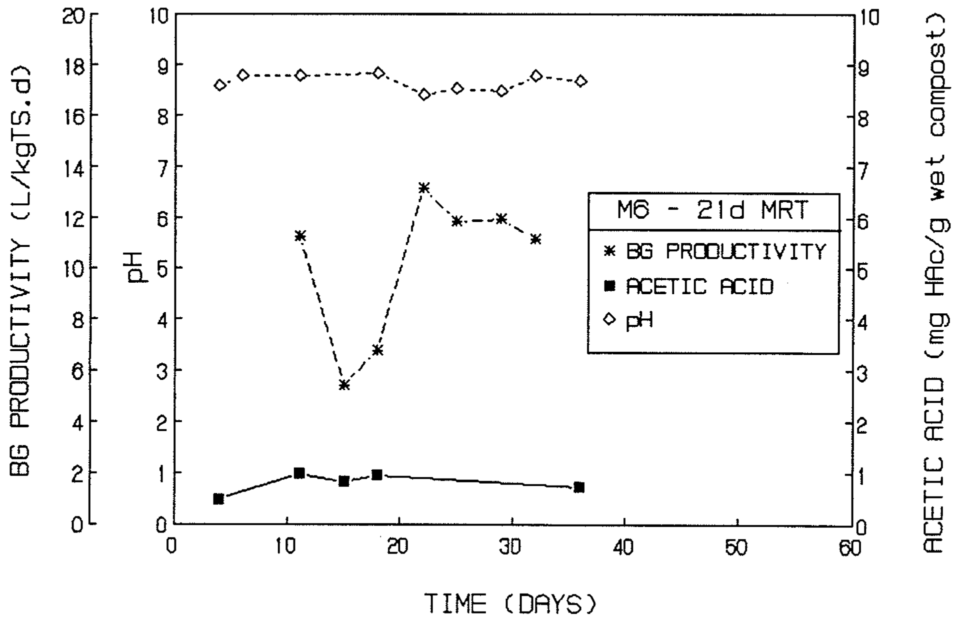

FIGURE 5 Performance of Mesophilic Reactor M6 Throughout the whole Pseudo-Steady-State Period

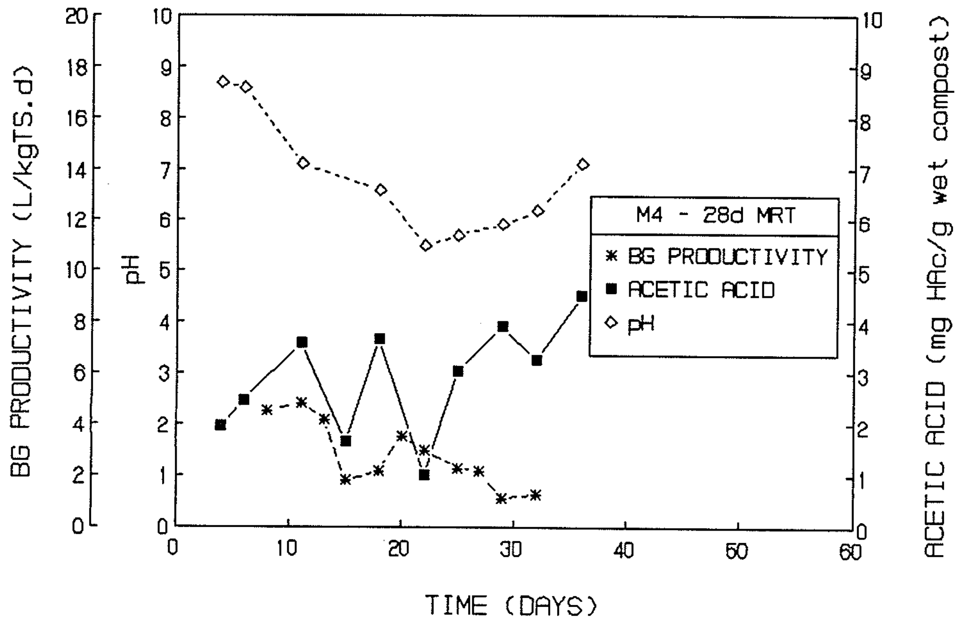

FIGURE 6 Performance of Mesophilic Reactor M4 Throughout the whole Pseudo-Steady-State Period

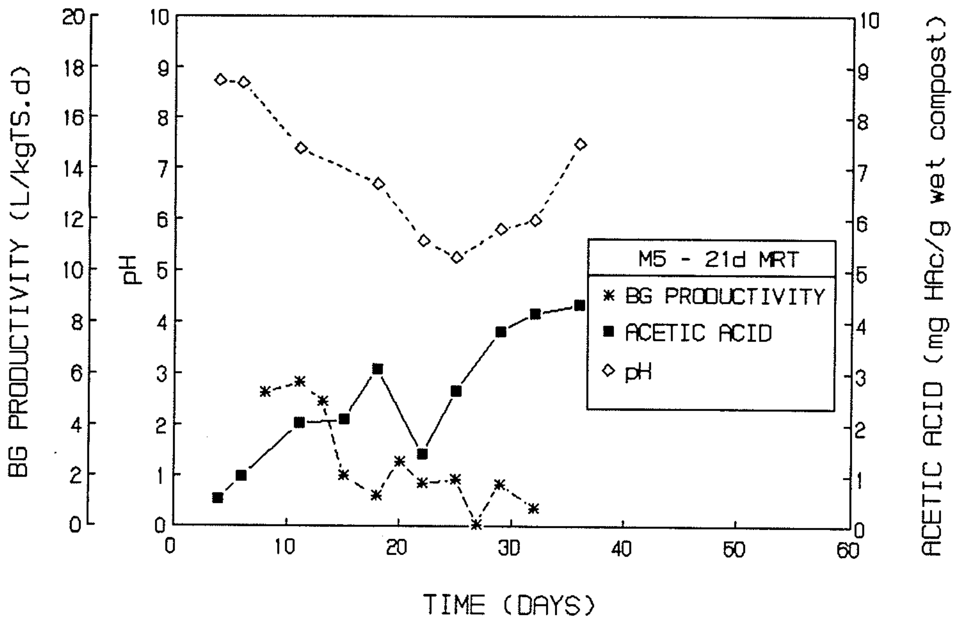

FIGURE 7 Performance of Mesophilic Reactor M5 Throughout the whole Pseudo-Steady-State Period

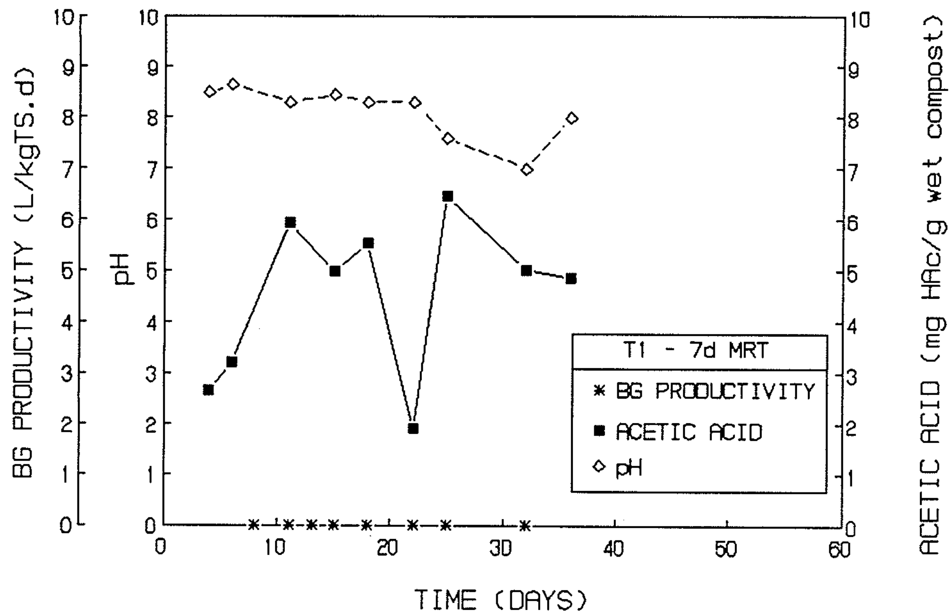

FIGURE 8 Performance of Thermophilic Reactor T1 Throughout the whole Pseudo-Steady-State Period

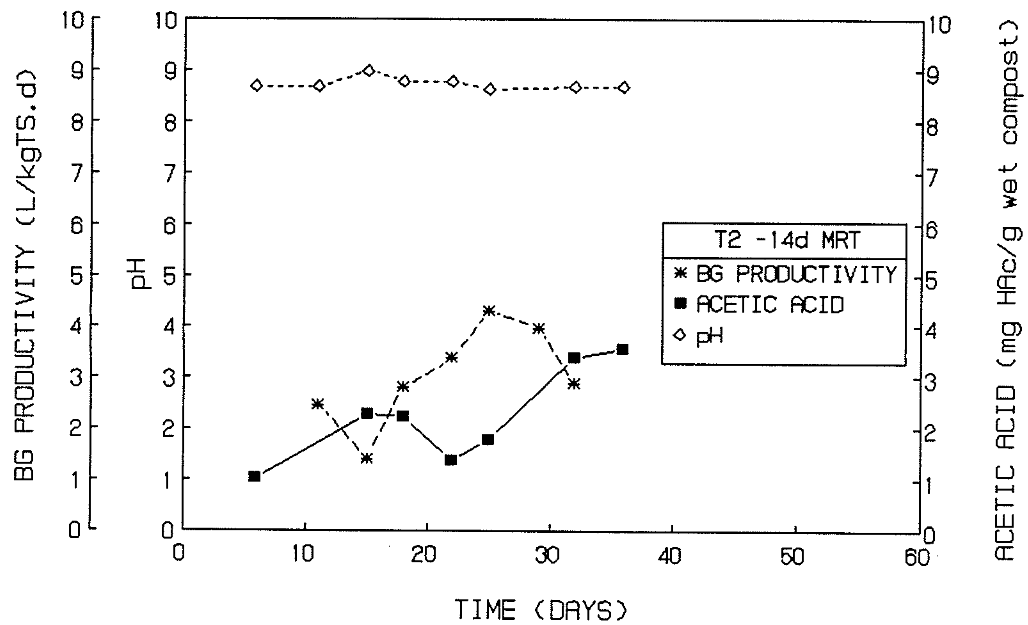

FIGURE 9 Performance of Thermophilic Reactor T2 Throughout the whole Pseudo-Steady-State Period

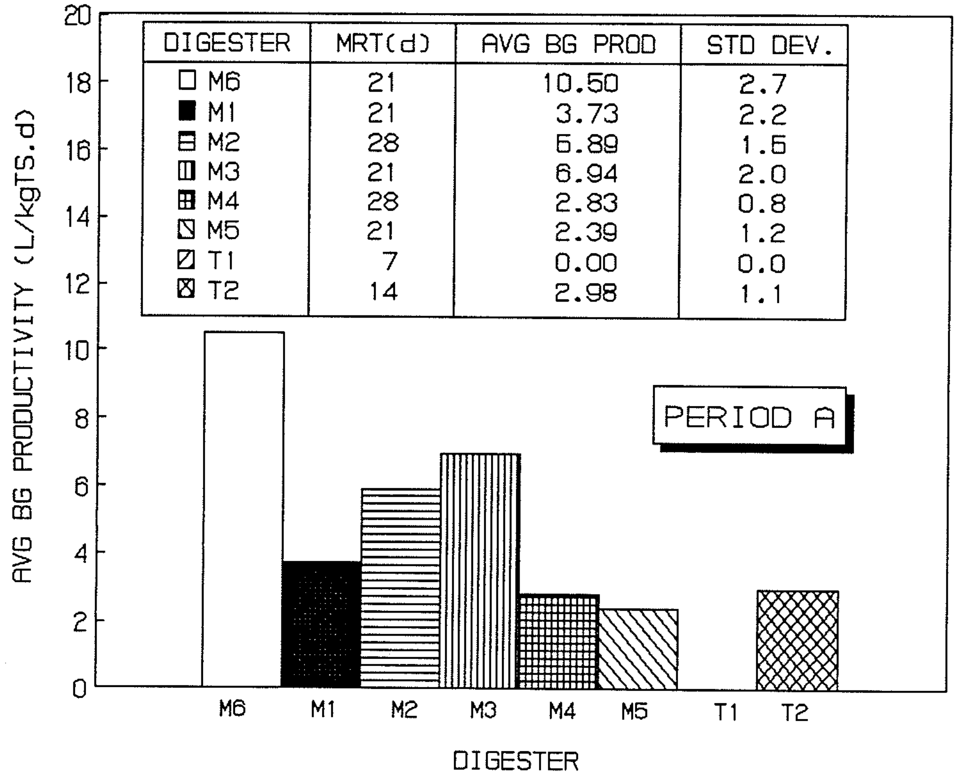

FIGURE 10 Average Biogas Productivity During Period A for all the reactors.

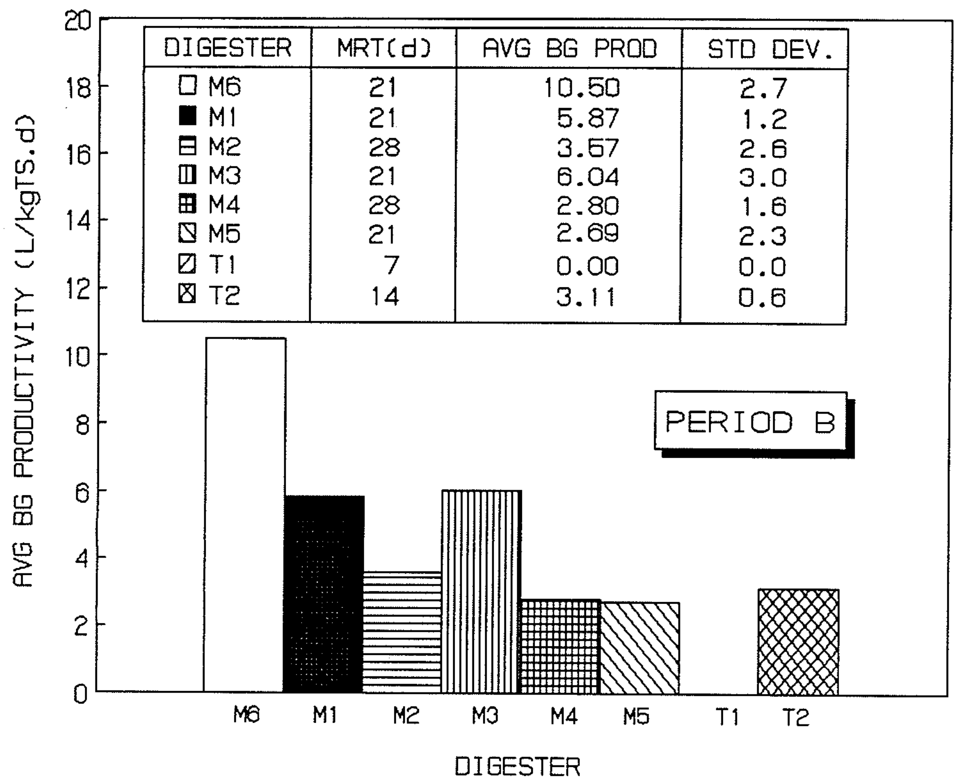

FIGURE 11 Average Biogas Productivity During Period B for all the reactors.

Acetic and propionic acid usually make up 85% of the total VFA in an anaerobic biological degradation of wastes (Sawyer & McCarty, 1978). VFA in the range of 50 to 250 mg/L, expressed as acetic acid, has been reported for stable anaerobic sludge digestion units. Assuming a sludge containing 5% TS, the VFA will be in the range of 1 to 5 mg HAc/gTS.

Maximum acetate content for this study determined to be 17.4, 16.7, 24.8 and 13.8 mg HAc/gTS for $M4_{28d}$, $M5_{21d}$, $T1_{7d}$ and $T2_{14d}$, respectively, appeared to be higher than results for a stable sludge digestion, with the exception of the control reactor, $M6_{21d}$ (3.8 mg HAc/gTS).

The high VFA concentration of the reactors maybe attributed to the coliform inoculum that was added. A VFA analysis (results not shown) conducted on the coliform inoculum at the end of the experimental run showed a very high concentration of volatile organic acids.

Poggi et al. (1990) working with a typical high-paper content North American substrate observed a decrease in VFA with a decrease in total solids and an increase in temperature. VFAs for a TS in the range between 25-40% TS were reported in the range of 0.5-3.5 mg HAc/gTS. Thermophilic conditions at 53°C reported a VFA of 3.1 mg HAc/gTS while the mesophilic conditions at 39°C registered 1.9 mg HAc/gTS.

A closer look at the pH and VFA for $M4_{28d}$ and $M5_{21d}$, in Figs. 12 and 13, indicated that the propionate concentration exceeded that of the acetate.

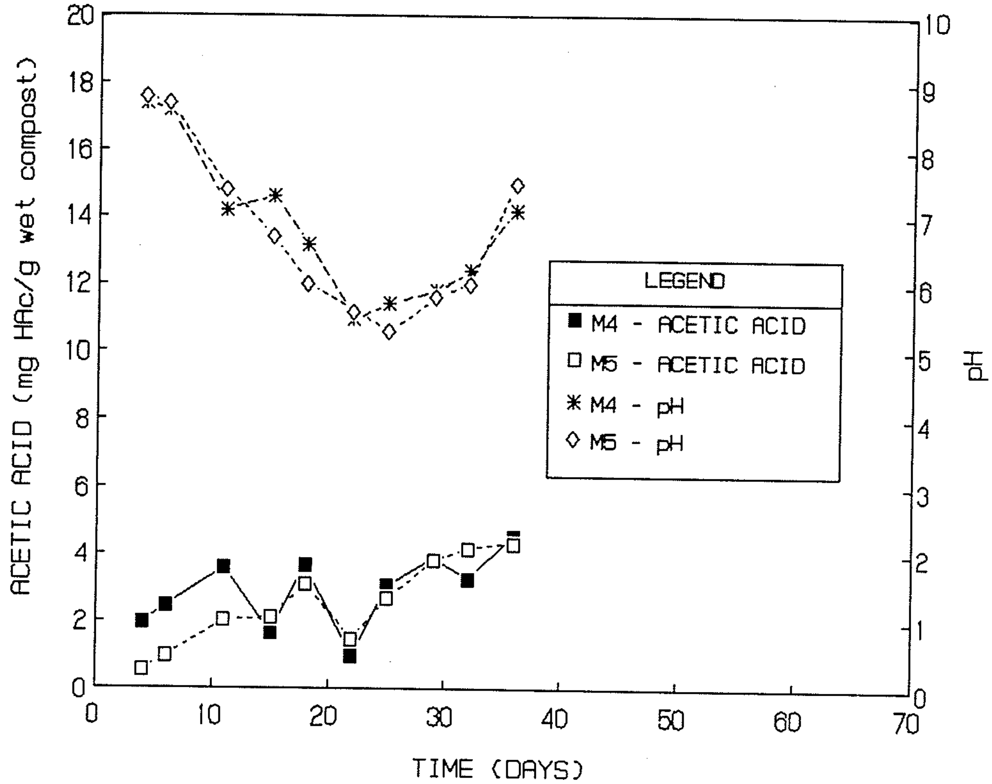

FIGURE 12 Acetate Concentrations for $M4_{28d}$ and $M5_{21d}$.

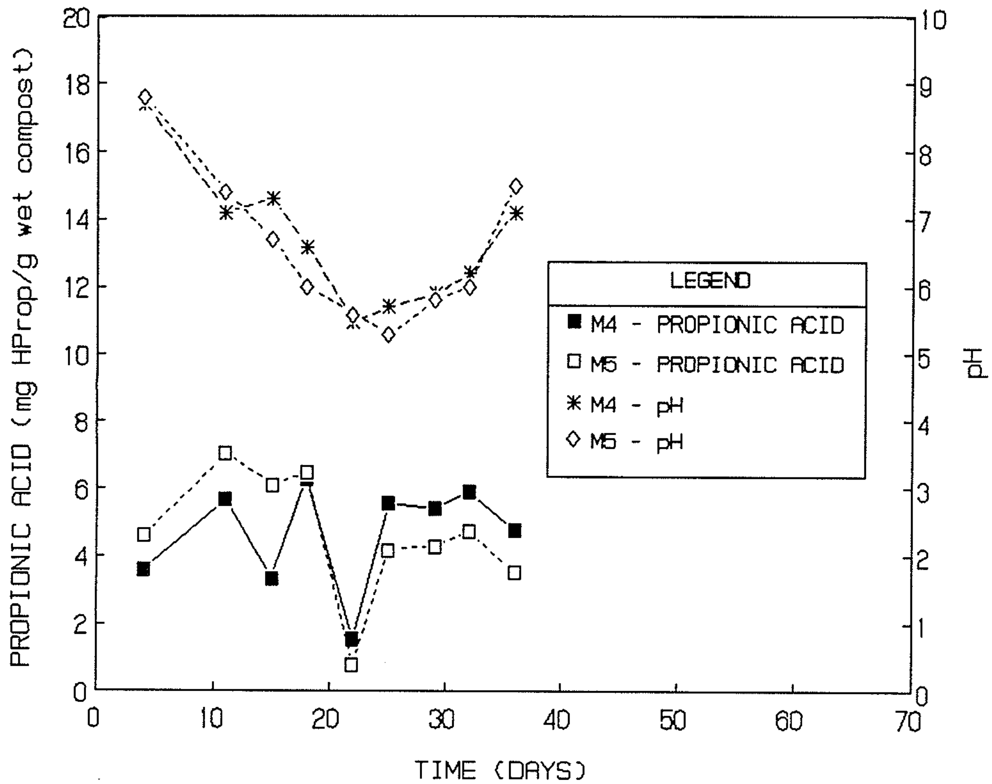

FIGURE 13 Propionate concentrations for $M4_{28d}$ and $M5_{21d}$.

Maximum propionate concentrations for $M4_{28d}$ and $M5_{21d}$ were 6.3 and 7.1 mg HProp/g wet mass, respectively, compared to only 2.01 mg HProp/g wet mass in control reactor, $M6_{21d}$. Results from the present 33% TS DAD study seemed to show that reactors with higher concentrations of propionate than acetate were associated with low process efficiency and a pH below 6.0.

Ianotti et al. (1984) found acetate to be the least toxic of the volatile acids, while McCarty et al. (1963) and Hobson et al. (1976) working with wastewaters agreed that propionate is a major cause for digester failure. Propionate was found to be inhibitory to H_2 assimilating organisms, including the methanogens (Iannoti et al., 1984). Hobson et al. (1976) demonstrated that propionate manifested inhibitory effects on anaerobic digestion only at relatively high concentrations of greater than 1,000 mg/L. According to McCarty et al (1963), although methanogenic activity were inhibited at total propionate concentrations greater than 3,000 mg/L, the effect could be overcome by acclimation.

Increase in VFA, generally associated with anaerobic reactor instability, is also indicative of environmental stress such as shock loadings, nutrient deficiency or infiltration of inhibitory substances, on the methanogens (Stronach et al., 1986). High VFA noted in $M4_{28d}$ and $M5_{21d}$ could have been the result of an overloading of the digesters with both organic matter (SOC) and volatile organic acids (VOA) from the inoculated feedstock. A soluble organic carbon (SOC) analysis on the coliform inoculum at the end of the experimental run reported a concentration of 296.8

mg SOC/gOM. The SOC for the plain feedstock was reported to be 64.0 mg SOC/gOM. The inoculum therefore introduced an additional 232.8 mg SOC/gOM into the feedstock.

VFA analyses (results not shown) conducted at the end of the experimental run reported a substantially high concentrations of VOA in the inoculum that was added to the feedstock of reactors $M4_{28d}$ and $M5_{21d}$. Results from the SOC and VFA analyses therefore implied a double overloading of the digesters $M4_{28d}$ and $M5_{21d}$ with organic matter and volatile acids by the coliform inoculum.

VFA accumulation and hence CH_4 inhibition occurred when the VFA intermediates produced by the saprophytic microbes were more than what the slow-growing methanogens could assimilate at any given time. According to Andrews (1969), CH_4 conversion rate inhibition at low pH was attributed to the penetration of un-ionized VFAs in significant quantities into the cell membrane, thereby decreasing the microbial metabolic rate. A pH-dependent equilibrium exists between the ionized and unionized form of VFAs:

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

A drop in pH will shift the equilibrium to the left, resulting in an increase in unionized VFA (UVA). An increase in the UVA above 10 mg/L will result in digester failure (Stronach et al. 1986). Sufficient alkalinity in an anaerobic system is thus important for pH control. Alkalinity, derived from the breakdown of organics, is present primarily in the form of bicarbonates, and are in equilibrium with the CO_2 in the biogas (Eckenfelder, 1970).

The pH-dependent relationship between alkalinity and CO_2 in the biogas can be illustrated as follows:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

Bicarbonate alkalinity in the range between 1000 and 5000 mg/L has been reported at pH between 6.6 and 7.4 for a normal CO_2 content between 30-40% by volume of the biogas. A portion of the total alkalinity in an anaerobic system may also appear as "volatile acid salts" because of the reaction between volatile acids with the bicarbonate present to give CO_2. Research has shown that about 83.3 percent of the VFA contributes to the alkalinity as "volatile acid salts" alkalinity.

A thorough understanding of the interrelationships between pH, alkalinity, VFA concentration and CO_2 content of the biogas are integral to the control of a successful anaerobic digestion system.

Toxicity in an anaerobic digestion system may result from high concentrations of ammonia. The methanogenesis phase in an anaerobic digestor is most vulnerable to the inhibitory effects of ammonia (Stronach et al. 1986). Ammonia (NH_3) which is released during anaerobic decomposition of organic substrates containing nitrogen (eg. protein), is a toxic to an anaerobic digestion system. The equilibrium between ammonia and the ammonium ion is pH sensitive and can be represented as follows:

$$NH_3 + H^+ \leftrightarrow NH_4^+$$

Free ammonia which is toxic to anaerobic systems is favored at high pH. The low pH in digesters $M3_{21d}$, $M4_{28d}$ and $M5_{21d}$ during period B seemed to suggest that the DAD digester failure were not associated with ammonia toxicity.

4.1.2 Biogas Composition

Typical gas production values which have been reported in the literature to vary between 0.75 to 1.12 m^3/kg VS destroyed for a healthy anaerobic sludge digester contained about 65 to 70% CH_4 by volume and 25 to 30% CO_2 (Metcalf & Eddy, 1991). Tchobanoglous et al. (1977), working with anaerobic co-digestion of MSW with WSS, obtained a biogas with 50 to 60% CH_4 (Tchobanoglous et al., 1977).

The two major pathways of methane production involve the biological decomposition of acetic acid and the microbial reduction of carbon dioxide by hydrogen (Eckenfelder, 1970). The $CH_4:CO_2$ ratio may be affected by the rate at which CO_2 is converted by microbial reduction with hydrogen to form methane. The higher the CH_4 content, the greater the rate of conversion and hence, the lower the CO_2 content in the biogas. Apart from this, the $CH_4:CO_2$ ratio may also be affected by the type of substrate that was used. A substrate that is highly degradable would have a higher $CH_4:CO_2$ ratio than a less degradable high-paper content waste.

Results from the biogas composition analysis are presented in Appendix C. Figs. 14 and 15 display the biogas composition results. The average CH_4 content for M1 through M6, T1 and T2 during period A were analyzed to be 60, 59, 51, 38, 42, 60, 7, and 55%, respectively. Both the 21d (M6 and M1) and 28d (M2) controls displayed CH_4 content of around 60%. The CH_4 content in $M4_{28d}$ and $M5_{21d}$ were only about 40%.

The higher CO_2 content in these two reactors may imply that the acetogenic bacteria were producing intermediates (eg. acetate, hydrogen) at a much faster rate than the methanogenic bacteria could convert into the end product, methane. Slow microbial reduction of CO_2 to CH_4 may also be implied.

T1, with a 7d MRT reported no CH_4 content in the reactor headspace, since no biogas was physically recorded for T1. Premature washout of the slow-growing methanogenic organisms due to the short retention time could be accounted for the result. This result concurs with published results that sufficient MRT should be allowed to prevent washout of the biomass required for digestion (Tchobanoglous, 1977). Everything else being equal, T2, with a 14d MRT showed a considerable increase in CH_4 content of up to 55%.

Six & De Baere (1992), working with a 32% TS mixed European OFMSW (highly degradable) at 55°C obtained 55% CH_4 at a pH of around 8.0. In the high-solids anaerobic digestion of a 25% TS OFMSW by Kayhanian and Tchobanoglous (1992), CH_4 content seemed to decrease from 53.8% to 49.5% with a decrease in MRT from 30-15d.

In a semi-dry (16-22% TS) thermophilic anaerobic digestion of fresh and pre-composted OFMSW, Mata-Alvarez et al. (1992) reported a methane content of 56%, 58% and 55%, respectively for fresh OFMSW at 11.7d, 7.4d and 5.7d HRT. CH_4 content of 62% ,53% and 57% were obtained at 11.7d, 7.8d and 6.1d, respectively for the pre-composted OFMSW.

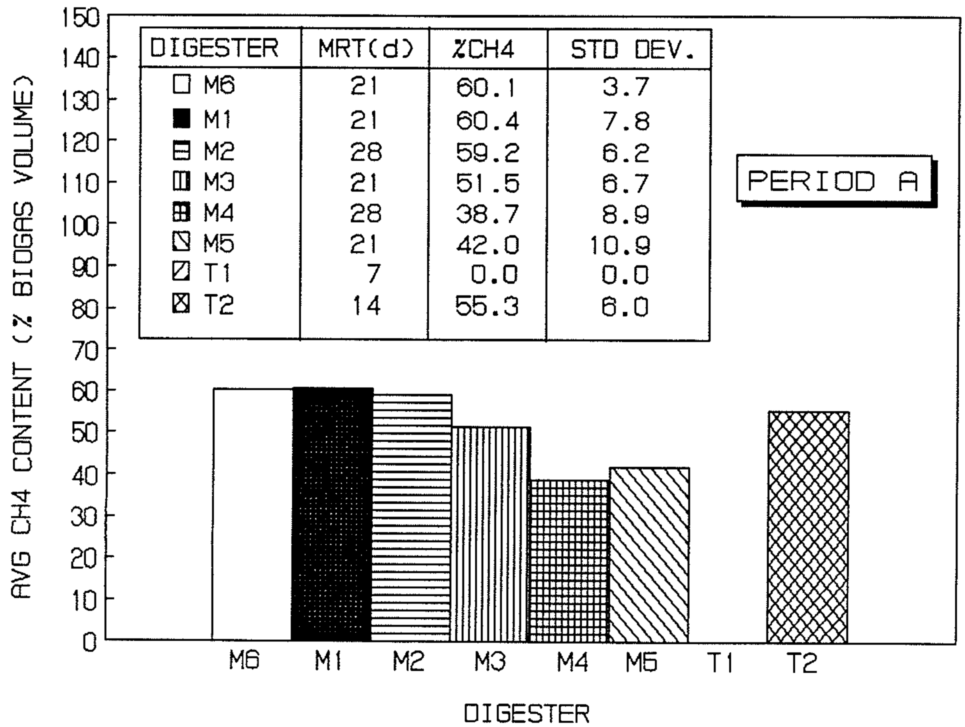

FIGURE 14 Average % CH_4 Content for During Period A for all the reactors.

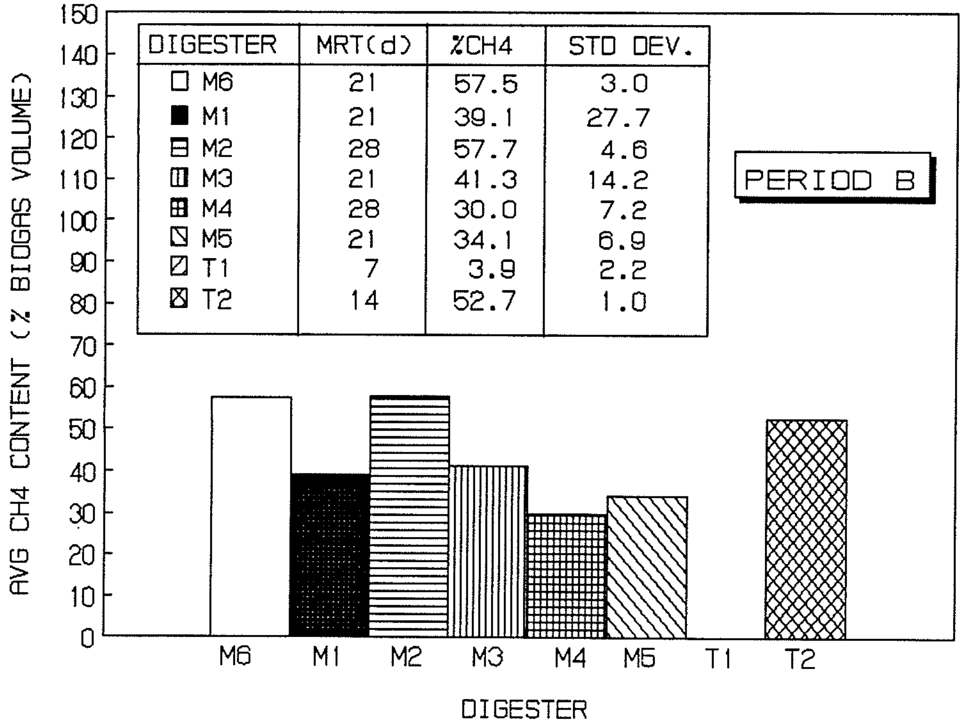

FIGURE 15 Average % CH_4 Content During Period B for all the reactors.

4.1.3 Digester Efficiencies

Digester efficiencies for all the reactors were calculated based on the following equation:

$$EFF(\%) = \frac{M_{b_i} + \sum (m_f \times VS_f) - \sum (m_d \times VS_d) - M_{B_f}}{\sum (m_f \times VS_f)} \times 100$$

where M_{bi} = Mass of reactor content before Draw & Fill (g)

M_{bf} = Mass of reactor content after Draw & Fill (g)

VS_f = Volatile Solids of feedstock (decimal)

VS_d = Volatile Solids of drawn compost (decimal)

m_f = mass of feed going into digester (g)

m_d = mass of compost drawn from digester (g)

EFF = Efficiency of digester (%)

Digester efficiencies during periods A and B for reactors $M3_{21d}$, $M4_{28d}$, $M5_{21d}$, $T1_{7d}$ and $T2_{14d}$, in terms of percent volatile solids removal, are illustrated in Figs. 16 and 17. Fig. 18 displays the efficiencies for the control reactors $M6_{21d}$, $M1_{21d}$ and $M2_{28d}$. The three control reactors were fed only with plain feedstock, while the rest of the mesophilic reactors were fed with the inoculated feedstock. $M3_{21d}$ and $M5_{21d}$, both with a shorter MRT of 21d appeared to be slightly less sensitive to digester upset than $M4_{28d}$ in Period A. Progressing from periods A to B, digester efficiencies for $M4_{28d}$ and $M5_{21d}$ decreased from 20% to 10% and 25% to 14%, respectively. The control reactor, $M6_{21d}$, showed the highest efficiency of 42% throughout the experimental run.

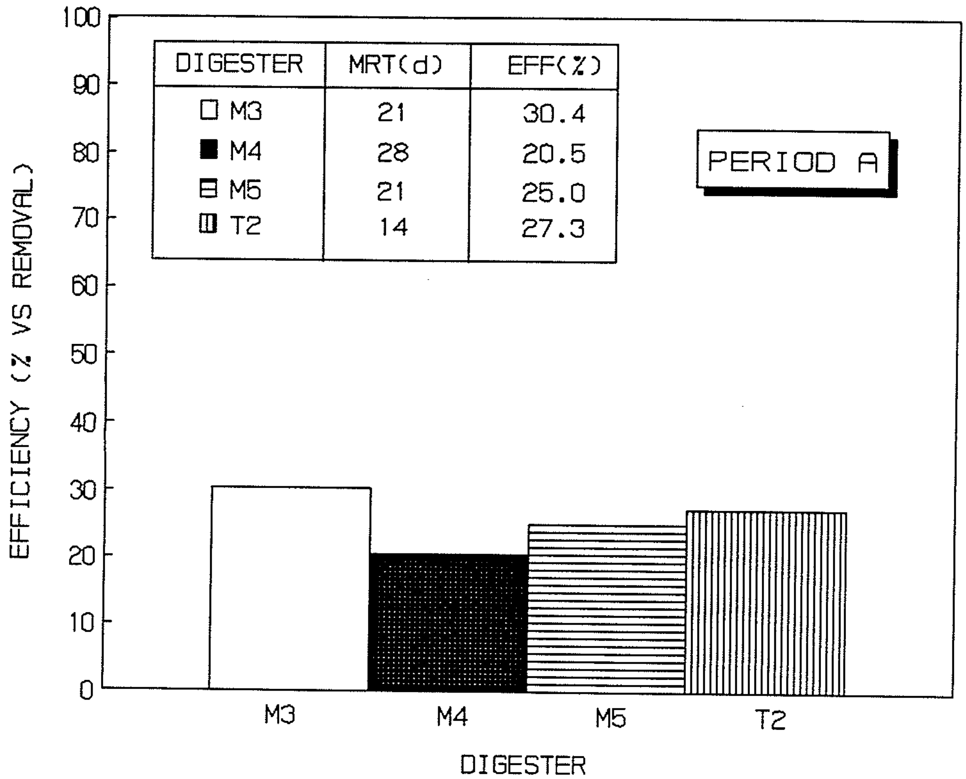

FIGURE 16 Digester Efficiency as % VS Removal for Period A

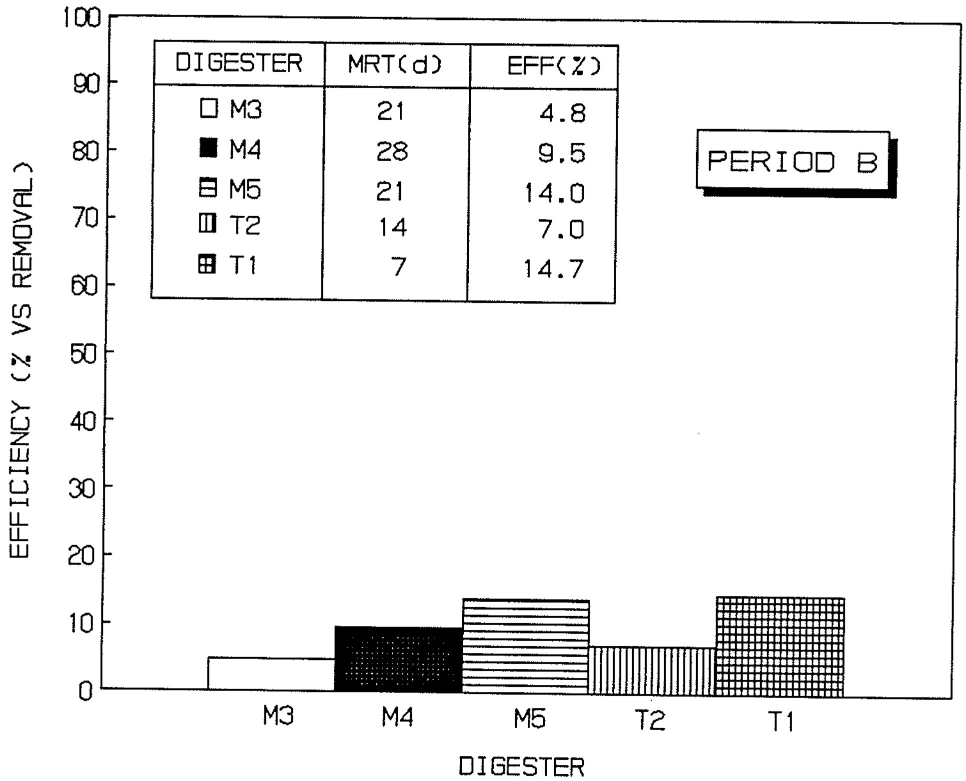

FIGURE 17 Digester Efficiency as % VS Removal for Period B

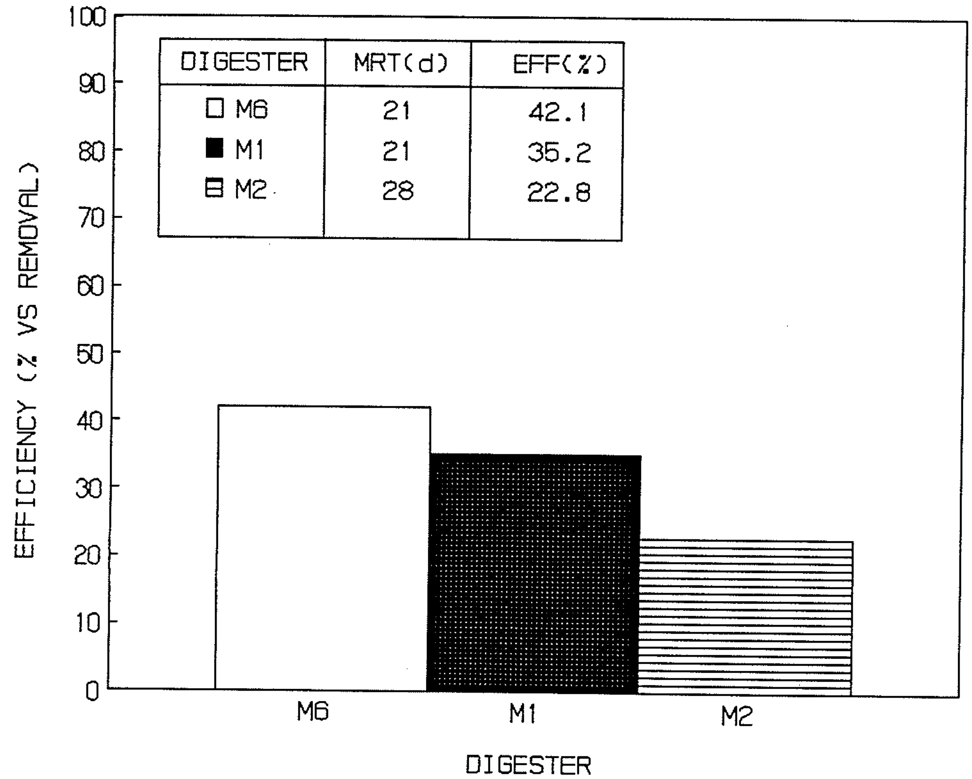

FIGURE 18 Efficiencies for Control Reactors (% VS Removal)

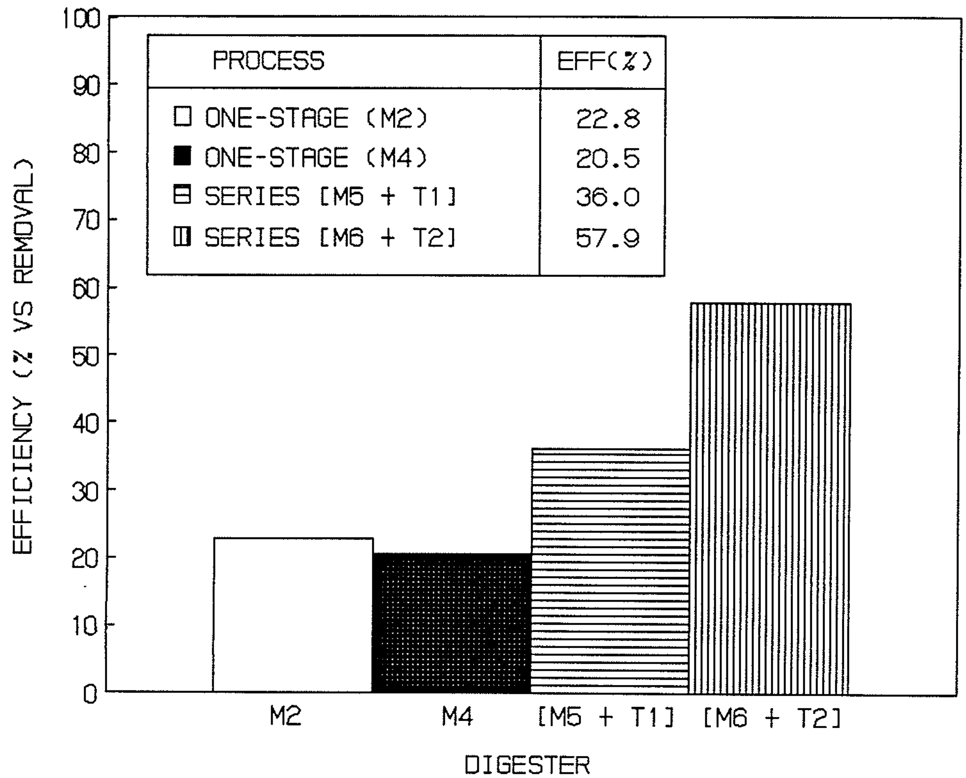

FIGURE 19 % VS Removal for One-Stage & Series DAD Process

The "14.7%" efficiency for $T1_{7d}$ were calculated based on weight loss during period B and should therefore be interpreted cautiously because no biogas was registered during the entire experimental run (see Figure 8). Mass balances for $T1_{7d}$ during Period A were carried out on a low precision balance of ± 100 grams and is therefore not reported. De Baere (private communication, OWS, 1992) suggested that some volatiles in $T1_{7d}$ may have been removed by a physical evaporation process at the 55°C temperature rather than by biochemical processes via the microorganisms.

$T2_{14d}$ with an efficiency of 27% in period A declined to 7% in period B. Biogas productivity decreased as VFA escalated (see Figure 9) with no pH drop. A plausible reason for the low efficiency detected in $T2_{14d}$ for Period B could be due to the fact that a large part of the organic matter has already been degraded in the first stage (21d mesophilic) of the two-stage digestion system.

Feed for $T2_{14d}$ came from $M6_{21d}$ and $M1_{21d}$, both of which reported efficiencies of 42 and 35%, respectively. Speculation is that only very little organic matter was left in the $M6_{21d}$ and $M1_{21d}$ composts to be further biodegraded in $T2_{14d}$. The speculation may be supported by the fact that $T2_{14d}$ reported the lowest COC values (260.6 mg O_2/gTS.35d) compared to reactors $M1_{21d}$, $M2_{28d}$, $M3_{21d}$, $M4_{28d}$, $M5_{21d}$ and $T1_{7d}$.

Based on the findings of this study, the one-stage 28d mesophilic DAD process displayed a volatile solids (VS) destruction of 20% for $M4_{28d}$ and 23% for $M2_{28d}$, while the series 21d (M6) mesophilic followed by a 14d (T2) thermophilic DAD process demonstrated an overall VS removal of 58%, as shown in Fig. 19.

A plausible reason for the low efficiency reported for $M2_{28d}$, may be due to two occasions when the rubber stopper slipped at the neck of the reactor jar and was blown off the reactors. As a result, the anaerobic reactor contents were exposed to air. It is possible therefore that some of the strict anaerobes on the exposed outer layers were killed, thereby reducing the potential to biodegrade as efficiently. Because of this, reactor $M2_{28d}$ was not used for comparison with the two-stage DAD process. As a result, only reactor $M4_{28d}$ was eligible to represent the one-stage DAD.

Another reason may be attributed to the physical characteristics of the digesters. Efficiency results seemed to imply that the 4-litre glass-jar reactors performed better than the 8-litre plastic containers. From the practical viewpoint, ease of manual shaking and mixing in the smaller glass-jar reactors and better fit between the glass jar necks and the rubber stoppers may be attributed to the reasonings behind the observed efficiencies.

4.2 End Product (Compost) Quality

Much research has been conducted to analyze the effects of temperature, moisture content, and pathogen control on the quality of the aerobically digested compost end product (Bertoldi, et al, 1991). For this DAD study, coliform count (MPN) and cumulative oxygen consumption (COC) were the two main responses used for the compost quality assessment.

4.2.1 Coliform Analysis (MPN)

Stronach et al. (1986) reported that the facultative population of a sewage digester was found to consist mainly of Escherichia coli. *Escherichia coli* or *E. coli*, a member of the *Enterobacteriaceae* family, is a facultative anaerobe which constitutes approximately 10% of the coliform bacterium in the human digestive system (Prescott, et al., 1990). Coliforms which are widely used indicator organisms in water and waste studies have been found to be quite reliable as a pathogen indicator for solid waste studies (Bertoldi et al., 1991).

Much of the initial microbiological studies on landfills for evaluating the potential health problems associated with refuse and landfill leachate were focused on fecal bacteria and pathogen counts (Cook, et al., 1967, Donnely, et al., 1984, Kinman, et al., 1986). De Baere et al. (1986) used fecal coli and streptococci as pathogen indicators.

Total coliform was used as the pathogen indicator organism for this DAD study. Preliminary coliform tests by Kuraszko (1991) for the DAD feedstock and the control reactor ($M7_{21d}$) compost, reported an average MPN of 10^1 and 10^7, respectively.

To monitor for coliform removal in the one-stage 28d meso and series 21d meso + 14d thermo digesters, it was decided to artificially increase the MPN in the feedstock with coliform. Coliform inoculum was thus added to the feedstock of $M4_{28d}$, $M3_{21d}$ and $M5_{21d}$. In the series process, composts from $M3_{21d}$ and $M5_{21d}$ were fed to $T1_{7d}$, while composts from $M6_{21d}$ and $M1_{21d}$ were fed to $T2_{14d}$.

Fig. 20 gives a coliform level profile in the plain (FS) and the preliminary control $M7_{21d}$, the inoculated feedstock (FSC) and the resultant coliform levels in $M4_{28d}$, $M5_{21d}$ and $T1_{7d}$ following the DAD process. MPN results for M4 (28d) showed a coliform reduction from a 2.0×10^{20} per gram FSC to 3.3×10^{7}. Reactor M5 (21d) with a shorter MRT reported a reduction to only 5.0×10^{9} while T1 (7d) had a final MPN of 1.1×10^{8}. Standard deviations illustrated in Fig. 20, however, showed no significant coliform reduction between M5 (21d) and T1 (7d). The MPN values for $M7_{21d}$, $M4_{28d}$, $M5_{21d}$ and $T1_{7d}$ all fell within the standard errors of deviation.

MPN results did not demonstrate any coliform removal below 10^{7}, irrespective of the MRT or operating temperature. Results seemed to imply that the DAD digesters had a tenacity to house a coliform population of the order of 10^{7}, which is independent of the coliforms in the feedstock. Thermal "kill" effect expected under the thermophilic conditions in T1 was not demonstrated because $T1_{7d}$ failed as a dry anaerobic digester.

De Wilde et al. (1990) working with anaerobic digesters operating at a loading rate of 17.2 kg COD/m^3 reactor.d, claimed complete destruction of fecal coliform and streptococci following three weeks of anaerobic fermentation at 55°C. Complete destruction under mesophilic conditions were also claimed for loadings not exceeding 17.2 kg COD/m^3 reactor.d.

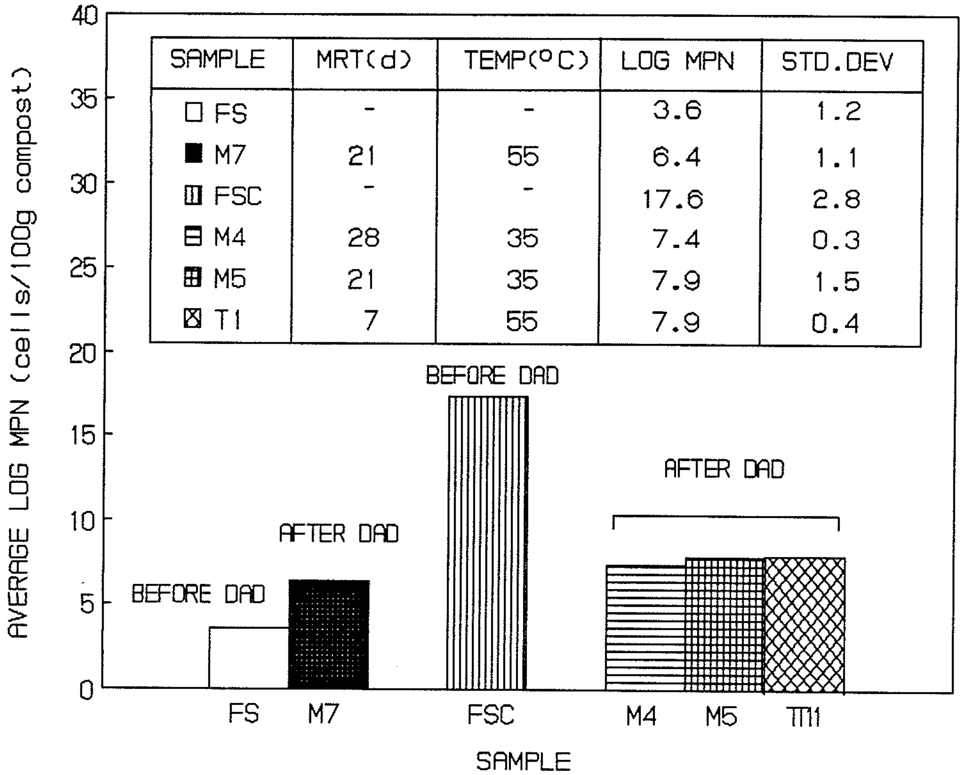

FIGURE 20 Coliform level profile before and after DAD

Intense competition and antagonism for nutrients (Zucconi et al, 1990) between the dense indigenous saprophytic population and the artificially introduced coliforms could be accounted for the reduction from 10^{20} to 10^{7}. Based on this concept and the MPN results, the 28d mesophilic reactor (M4), with its extended retention time, can be claimed to have permitted a greater generation of the indigenous organisms than the 21d reactor.

A plausible explanation for the coliform-sustaining behavior in the reactors could be due to the high average moisture content (74%) environment, i.e. 26% total solids basis in the reactor that is conducive for pathogen regrowth. To provide a non-conducive pathogen regrowth environment, De Bertoldi (1990) suggested a moisture content of less than 30% in the finished compost.

De Bertoldi et al. (1990) also showed that by subjecting aerobically digested compost at 65°C for two days, a 100 percent destruction of *Salmonella sp*. was possible. Moreover, under those conditions, it was possible to keep the concentrations of the two pathogen indicators, coliform and streptococcus, under 5×10^{2} and 3×10^{3}, respectively.

The MPN results arrived at in this study and the results from other independent aerobic studies gave reasons to believe that the 100% pathogen indicator removal efficiency claimed by some commercial process was actually effected during the post-digestion treatment stage. This post-treatment stage, usually included in commercial anaerobic composting processes may have involved compost drying and/or a 10 day or longer aerobic post-composting period.

4.2.2 Cumulative Oxygen Consumption (COC)

Oxygen consumption rate given in mg O_2/g volatile matter.h has been recognized as one of the most accurate indicators for the activity of the composting process (Schulze, 1960). Since the purpose of composting is to convert all the organic fraction of a waste into more stable compounds, the oxygen consumption rates of the finished compost should be expected to be considerably below those measured during the active phases of decomposition. Hence, the higher the oxygen consumption, the less stable the end product.

A low cost, laboratory scale respirometric analysis was developed to determine the quality of the ultimate compost by comparing the extent of microbial oxygen consumption in the approximately 50% TS mesophilic and thermophilic composts at their respective retention times. Figs. 21 through 26 display the 5-week cumulative oxygen consumption (COC) profiles for reactors, $M2_{28d}$, $M3_{21d}$, $M4_{28d}$, $M5_{21d}$, $T1_{7d}$ and $T2_{14d}$, respectively. The COC for the different MRT reactor composts relative to the control compost from $M2_{28d}$ are represented in the bar diagram as shown in Fig. 27.

Trends of the COC curve obtained in the present study concurred with those obtained by Haug, et al. (1991) and Graves et al. (1991) for organic substrate biodegradability in compost and soils, respectively. High oxygen uptake rates were observed for all the reactors at the beginning of the test (0 hours to 100 hours). Gradual decreases in COC observed in the reactors, and in particular, the 14d thermophilic reactor, T2, following 100 hours, indicated the gradual stabilization of the compost as a result of microbial consumption of the degradable organics in the presence of oxygen.

Table 5 gives a summary of the oxygen consumption rates at 100 hours. A decrease in oxygen consumption rates was observed in all the reactors. Table 6 gives the cumulative oxygen consumption for reactors $M2_{28d}$, $M3_{21d}$, $M4_{28d}$, $M5_{21d}$, $T1_{7d}$ and $T2_{14d}$ at 10 days and 35 days.

The relative COC were calculated based on Equation 1 below. Equation 2 was used to determine the coefficient of variation (CV) for the various composts.

$$* \quad REL.COC(\%) = \frac{COC_{compost}}{COC_{compost_{B2}}} \times 100\% \qquad \textbf{eq 1}$$

$$** \quad CV(\%) = \frac{STD.DEV.\ for\ COC_{compost_j}}{COC_{compost_j}} \times 100\% \qquad \textbf{eq 2}$$

The higher the COC, the less stable the compost, following DAD and 10 days of aeration. COC for M5 (21d) reported 11% less than that of M4 (28d). However, COC for $M3_{21d}$ reported about 4% more than that of M428d. COC for the $T1_{7d}$ and $T2_{14d}$ composts were significantly lower than those of the mesophilic reactors. It is apparent that the 55°C thermophilic conditions provided additional stability to the compost. De Baere et al. (1985) reported COC values between 150-160 mg O_2/g OM.10 d for composts subject to 6 weeks of aerobic windrow composting, while De wilde et al. (1990) reported COC values between 50-60 mg O_2/g OM.10 d for the 3-week DRANCO compost.

COC results from the present study demonstrated that the two-stage 21d meso + 14d thermo compost consumed 140.4 mg O_2/g TS.10d while the one-stage 28d meso compost consumed 142.3 mg O_2/g TS.10d, for an approximately 60% TS compost. Results for both the one- and two-stage DAD process in the present dry anaerobic composting study seemed to imply a better end product than the compost subject to 6 weeks of aerobic windrow composting (De Baere et al. 1985).

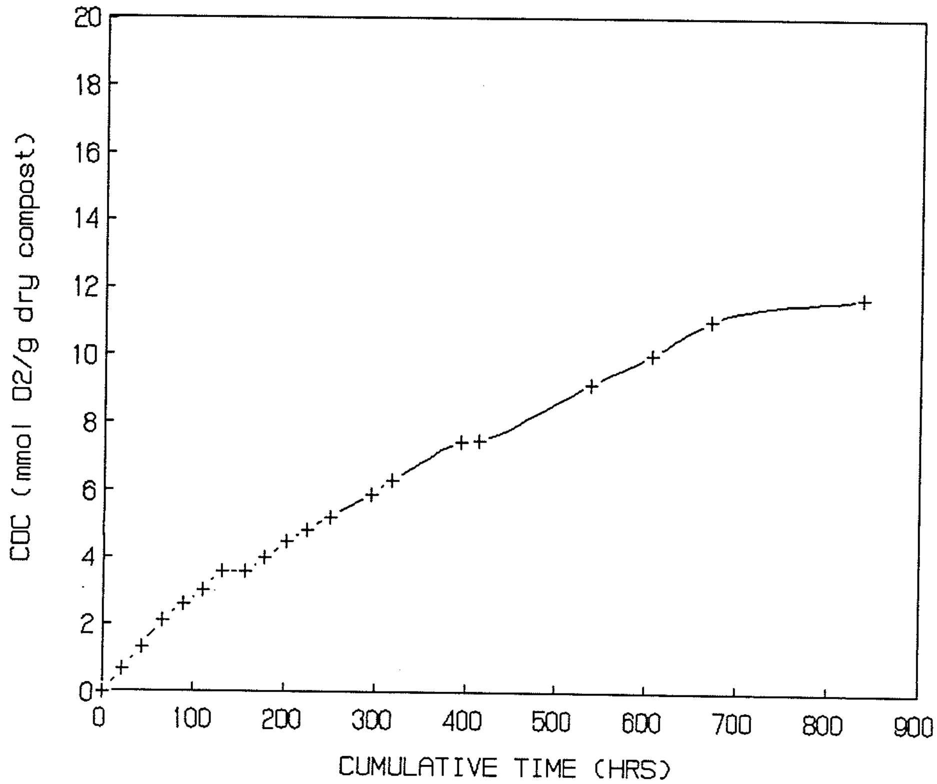

FIGURE 21 Cumulative Oxygen Consumption Profile for M2 (28d)

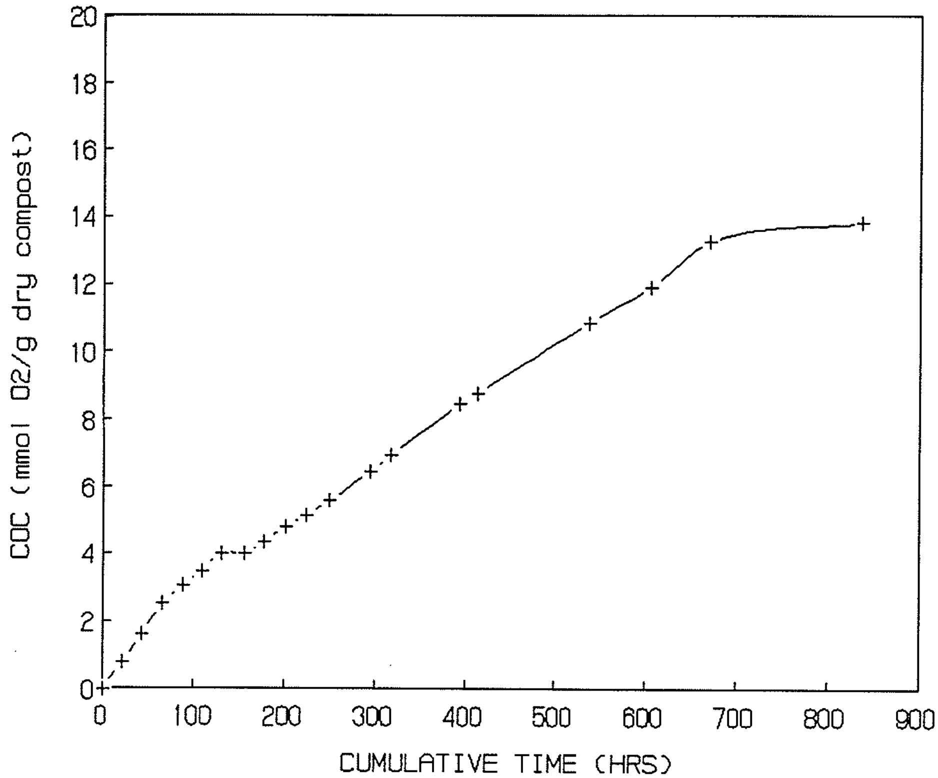

FIGURE 22 Cumulative Oxygen Consumption Profile for M3 (21d)

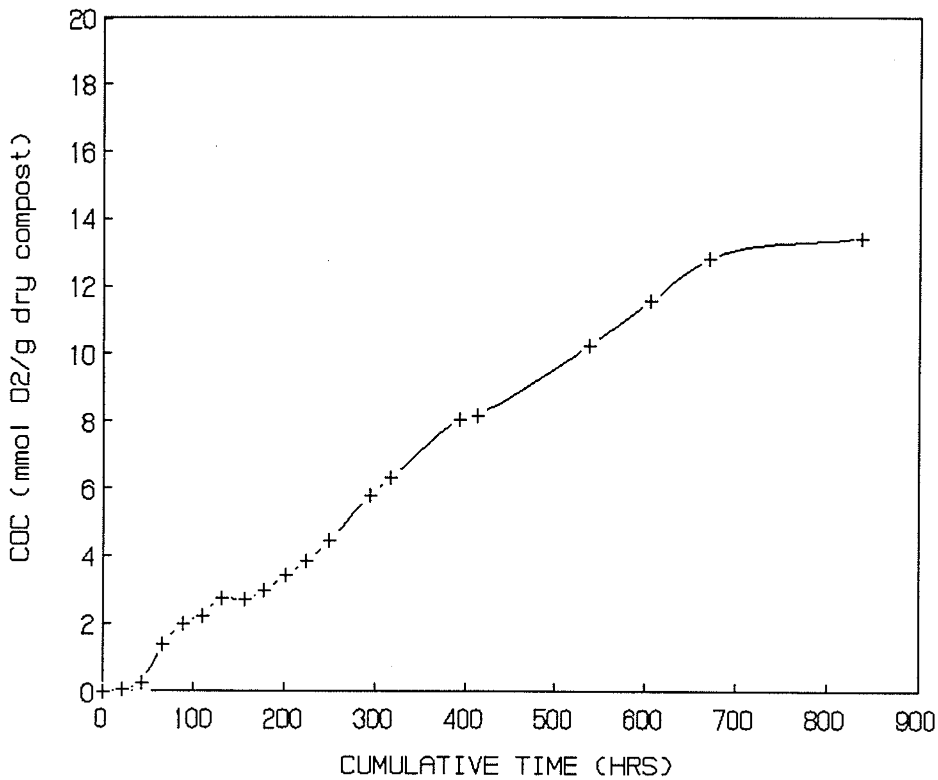

FIGURE 23 Cumulative Oxygen Consumption Profile for M4 (28d)

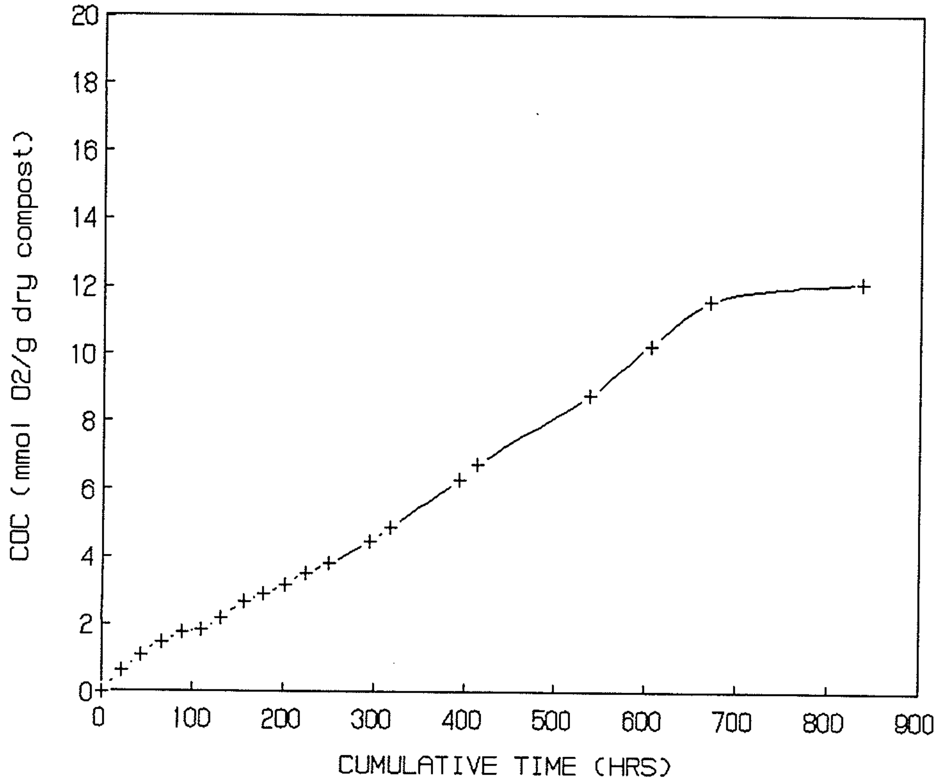

FIGURE 24 Cumulative Oxygen Consumption Profile for M5 (21d)

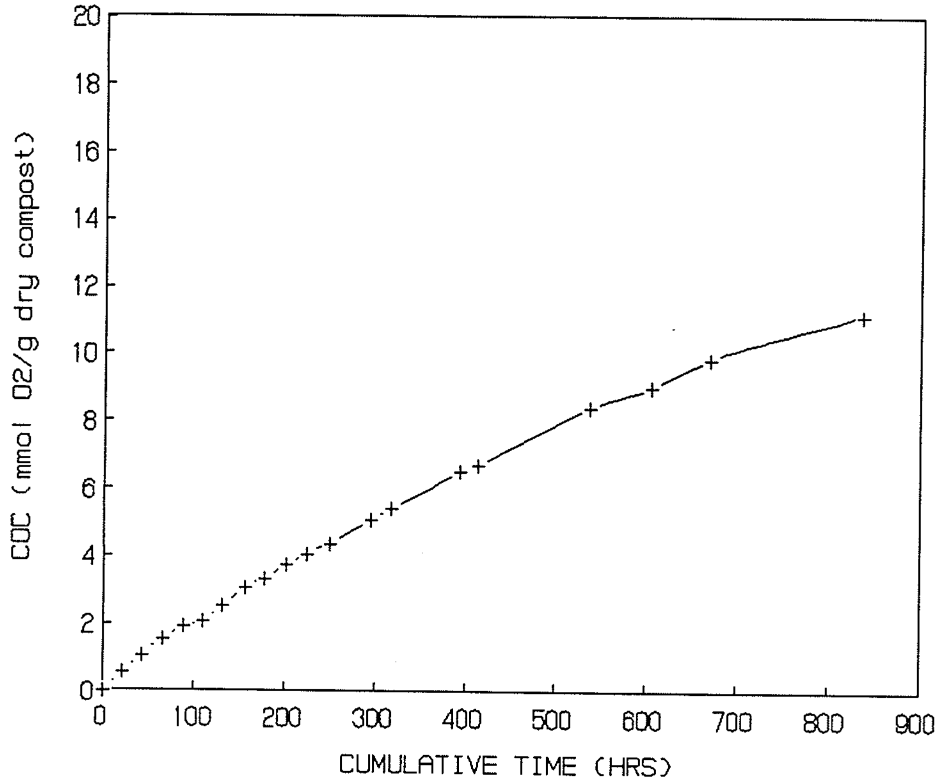

FIGURE 25 Cumulative Oxygen Consumption Profile for T1 (21d)

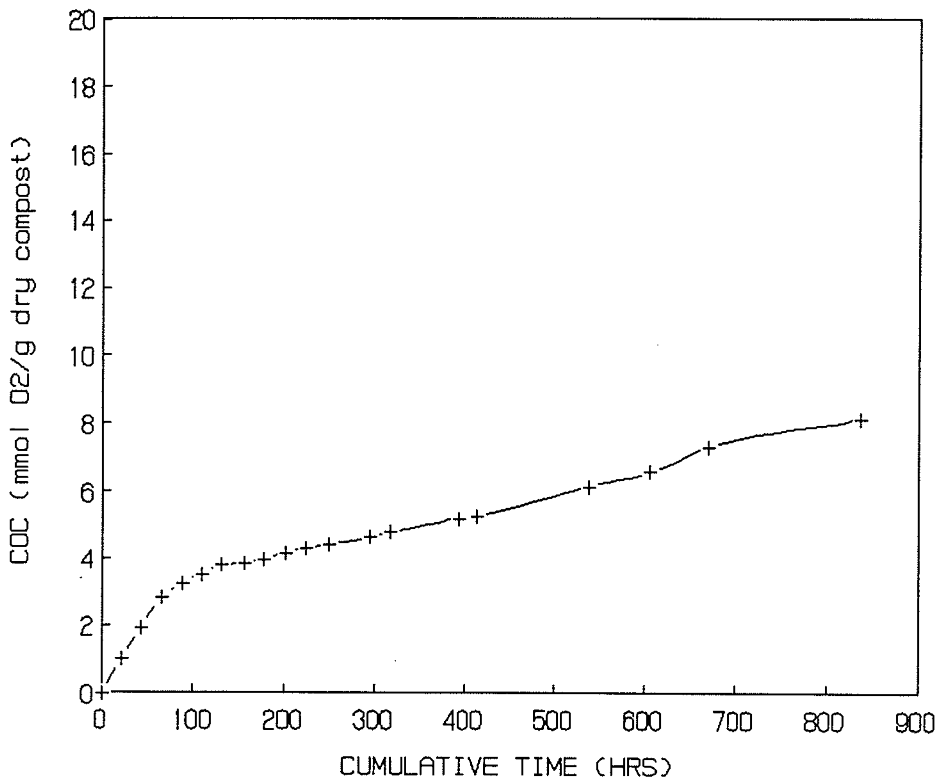

FIGURE 26 Cumulative Oxygen Consumption Profile for T2 (14d)

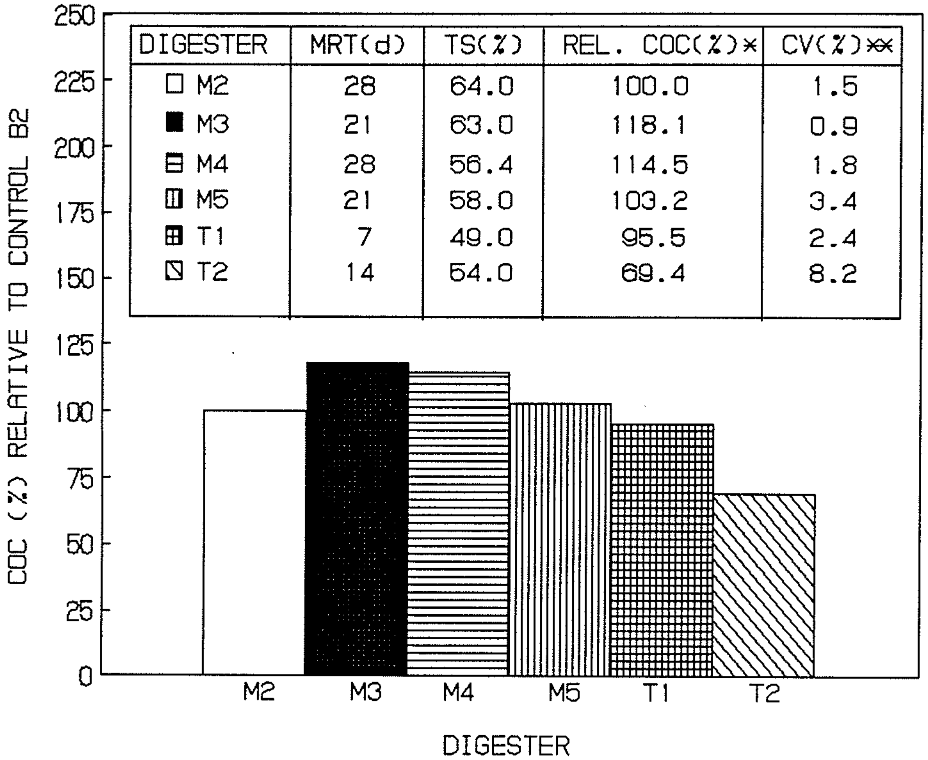

FIGURE 27 Cumulative Oxygen Consumption Relative to the Control Compost of $M2_{28d}$.

TABLE 5

Oxygen Consumption Rates for Mesophilic and Thermophilic DAD Compost following 10 days of post-aeration

Reference	MRT (d)	$\frac{mgO_2}{gTS.h}$ in the first 100 hours	Standard Deviations
M2	28	23.2	0.0
M3	21	26.6	0.1
M4	28	17.4	0.0
M5	21	14.2	0.0
T1	7	16.0	0.0
T2	14	26.8	0.0

TABLE 6

Cumulative Oxygen Consumption for Mesophilic(M) and Thermophilic (T) DAD Reactors Following 10 days of Post-Aeration

REF	MRT (d)	$\frac{mgO_2}{gTS.d}$ at 100h	STD DEV	$\frac{mgO_2}{gTS.d}$ at 10d	STD DEV	$\frac{mgO_2}{gTS.d}$ at 35 days	STD DEV
M2	28	96.6	0.0	167.6	0.1	375.4	0.2
M3	21	110.8	0.0	178.7	0.0	443.1	0.1
M4	28	72.4	0.1	142.3	0.0	430.0	0.2
M5	21	59.0	0.0	122.6	0.1	387.4	0.4
T1	7	66.6	0.1	140.4	0.1	358.4	0.3
T2	14	111.8	0.0	141.5	0.0	260.6	0.7

5. ENGINEERING SIGNIFICANCE

Comparisons between a one-stage and a two-stage dry anaerobic digestion system for this study were carried out between a one-stage 28d MRT mesophilic reactor and a two-stage 21d MRT mesophilic reactor followed by a 14d MRT thermophilic reactor. The 21d mesophilic reactor followed by a 7d thermophilic reactor could not be compared because $T1_{7d}$ failed as a DAD digester.

Based on the findings of this study, it may be more appropriate to compare between a one-stage 35d MRT mesophilic reactor and a two-stage 21d mesophilic reactor followed by a 14d thermophilic reactor.

The inoculation of feedstock with the coliform enriched inoculum should not be implemented in future studies because of the high additional VOA and SOC concentrations in the inoculum. If the inoculum was to be used, caution must be taken to not use the liquid portion of the inoculum which contains high VOA and SOC.

The common practice today for commercial processes dealing with compost production is to subject the anaerobic composts to a period of aerobic "polishing" inorder to obtain a favorable COC value. Aerobic "polishing" should therefore be considered as an important option to improve the stability of the DAD composts, in terms of cumulative oxygen consumption.

6. CONCLUSIONS

Based on the results of the present one-stage 28d mesophilic and two-stage 21d mesophilic followed by a 7 or 14d thermophilic dry anaerobic digestion study on the co-composting of a synthetic OFMSW and WSS, the following conclusions have been made:

1. Results from volatile solids removal efficiencies, biogas productivity and cumulative oxygen consumption seemed to favor the series DAD process.

2. During Period A, a healthy 21d mesophilic reactor M6 produced 10.5 L BG/kgTS.d while the 28d (M2) produced only 9.1 L/kgTS.d. The low biogas productivity in M2 maybe attributed to the several occasions of stopper slippage from the jar necks. As a result, $M2_{28d}$ was not used to represent the one-stage DAD process. The 14d thermophilic reactor, T2 produced on average, 3.0 L BG/kgTS.d. No biogas productivity was recorded for T1, the 7d thermophilic reactor.

3. Digester efficiencies (Period A) of 42%, 21%, 25%, "14%" and 27% in terms of percent VS removal, were determined for $M6_{21d}$, $M4_{28d}$, $M5_{21d}$, $T1_{7d}$ and $T2_{14d}$, respectively. The "14%" efficiency for T1 should be interpreted cautiously because no biogas was recorded during the experimental run. Overall, the series DAD: reactors $M6_{21d}$ + $T2_{14d}$ had a VS removal of 58% while the one-stage DAD, $M4_{28d}$ had a VS removal of 21%.

4. Methane content for $M1_{21d}$, $M2_{28d}$, $M3_{21d}$, $M4_{28d}$, $M5_{21d}$, $M6_{21d}$, and $T2_{14d}$ were reported to be 60, 59, 52, 39, 42, 60, and 55%, respectively. Methane content for reactors $M1_{21d}$, $M2_{28d}$, $M6_{21d}$, and $T2_{14d}$ were comparable to the 60-70% CH_4 range reported for a successful anaerobic digestion system. The methane content in reactors $M4_{28d}$ and $M5_{21d}$, fed with the inoculated feedstock were low compared to the control reactors, fed with plain feedstock.

5. MPN analyses did not demonstrate coliform removal below 10^7 in any of the reactors, irrespective of their MRT or operating temperatures. M4 (28d) reduced coliform from the artificially inoculated feedstock of 2.0×10^{20} MPN down to 3.3×10^7 MPN, while M5 (21d) only reduced it down to 5.0×10^9. When the 21d compost was transferred into T1 for further anaerobic treatment, no further reduction was observed. Thermal kill, expected in the thermophilic reactor, T1 was not conclusively demonstrated because T1 failed as a dry anaerobic digester.

6. The one-stage 28d mesophilic M4 consumed a total of 430 mg O_2/g TS.35d. By itself, the 21d mesophilic reactor, M1, consumed a total of 387 mg O_2/g TS.35d, which is lower than M4. However, when the 21d compost underwent further treatment in the 14d thermophilic reactor, T2, the COC was significantly reduced to only 261 mg O_2/g TS.35d. The second thermophilic stage in the series DAD can therefore be regarded as an

elevated temperature curing or "polishing" step. A plot for COC versus %VS removal (result not shown) did not demonstrate any relationship between COC and %VS removal.

7. Overall results demonstrated the two-stage 21d mesophilic followed by a 14d thermophilic dry anaerobic digestion process to be technically feasible, for digestors operating at 33% TS.

REFERENCES

Andrews, J.F. (1969), *Journal of Sanitary Engineering Division*, ASCE 95, SAI 95-0000 (in Stronach et al. 1986, 71-72).

APHA, (1989), *Standard Methods of Examination of Water and* Wastewaters, 17th Edition, APHA-WPCF-AWWA, U.S.A.

Bonhomme, M. (1988), *Energy From Biomass and Wastes XI*, Klass, D., ed., Institute of Gas Technology.

Brinton, W. Jr. (1985), "Nitrogen Response of Maize to Fresh and Composted Manure", *Biological Agriculture and Horticulture*, Vol. 3, pp 55-64.

Buivid, M.G., Wise, D.L., Blanchet, M.J., Remedios, E.C., Jenkins, B.M., Boyd, W.F. and Pacey, J.C. (1981), "Fuel Gas Enhancement by Controlled Landfilling of Municipal Solid Waste", *Resources & Conservation*, 6, 3-20.

Cayrol, F., Claquin, C. and Peillex, J.P. "Anaerobic Digestion of Municipal Solid Waste by the Valorga Process", *I.S.W.A* Sept.

Cecchi, F., Marcomini, A., Pavan, P., Fazzini, G. and Mata-Alvarez, J. (1991), "Anaerobic Digestion of MSW", *The Biocycle Guide to the Art & Science of Composting*, The JG Press Inc., Emmaus, Pennsylvania.

Cecchi, F., Pavan, P., Alvarez, J.M., Bassetti, A. and Cozzolino, C. (1991), "Anaerobic Digestion of Municipal Solid Waste: Thermophilic vs. Mesophilic Perofrmance at High Solids", *Waste Management & Research*, Vol.9, No. 4, August.

Cecchi, F., Traverso, P.G., Mata-Alvarez, J., Clancy, J., Zaror, C. (1988), "State of the Art of R&D in the Anaerobic Digestion Process of Municipal Solid Waste in Europe", *Biomass, Vol. 16,* pp 257-284.

Cecchi, F., Traverso, P.G., Perin, G., and Vallini, G. (1988), "Comparison of Co-digestion Performance of Two Differently Collected Organic Fractions of Municipal Solid Wastes with Sewage Sludges", *Environmental Technology Letters, Vol. 9, pp. 391-400.*

Chanyasak, V., Katayama, A., Hirai, M.F., Mori, S. and Kubota, H. (1983), "Effects of Compost Maturity onGrowth of komatsuna (*Brasica rapa* var. *peridis*) in Neubauer's pot.II. Growth inhibitory factors amd assessment of degree of maturity by org.-C/org.-N ratio of water extract", *Soil Sci. Plant Nutr.* 29:251-259.

Chynoweth, D.P., Bosch, G., Earle, J.F.K., and Legrand, R., and Liu, Kexin (1990), "A Novel Process for Anaerobic Composting of Municipal Solid Waste", *Applied Biochemistry and Biotechnology, Vol. 28/29.*

Chynoweth, D.P. and Legrand, R. (1988), "Anaerobic Digestion as an Integral Part of Municipal Waste Management", *Proceedings from International Conference on Landfill Gas and Anaerobic Digestion of Solid Waste*, Chester, England. Oct.

Converse, J.C., Evans, G.W., Verhoven, C.R., Gibbon, W., and Gibbon, M. (1977), "Performance of a Large Size Anaerobic Digester for Poultry Manure", *ASAE Paper No. 77-0451*, ASAE, St. Joseph, MI 49085.

Cook, H.A. et al. (1967), "Microorganisms in household refuse and seepage water from sanitary landills", *Proc. W. VA. Acad. Sci.*

Cooney, C.L., and Wise, D.L. (1975), "Thermophilic Anaerobic Digestion of Solid Waste for Fuel Gas Production", *Biotechnol. Bioeng.* 17 1199-1133.

De Baere, L., Van Meenen, P., Verstraete, W. (1986), "Anaerobic Fermentation of Refuse". *Proceeding form Materials and Energy from Refuse.*

De Baere, L., Verdonck, O., and Verstraete, W. (1985), "High Rate Dry Anaerobic Composting Process for the Organic Fraction of Solid Wastes", *Biotechnology and Bioengineering Symp. No. 15.*

De Baere, L. and Verstraetae, W. (1984), "High Rate Anaerobic Composting with Recovery of Biogas", *Biocycle*, 25, 30-34.

De Bertoldi, M., Zucconi, F., civilini, M. (1991), "Temperature, Pathogen Control and Product Quality", *The Biocycle Guide to the Art & Science of Composting,* The JG Press Inc., Emmaus, Pennsylvania, 195-199.

De Vleéschauwer, D., Verdonck, O. and VanAssche, P. (1981), "Phytotoxicity of Refuse Compost", *Biocycle* 22:44-46.

De Wilde, B. and De Baere, L. (1990), "Dry Anaerobic Conversion of MSW in a Demonstration Plant", *Presented at the IGT Energy From Biomass and Wastes XIV Conference, Jan 29 - Feb 2.*

Donnely, F.A., and Scarpino, P.V. (1984), "Isolation, Characterization and Identification of Microorganisms from Laboratory and Full Scale Landfills", *EPA Proj. Summary, EPA-600/S2-84-119.*

Eckenfelder, W.W. Jr. (1970), "Manual of Treatment Processes", *Water Resource Management Series*, Vol. 1, Environmental Science Services Corporation, Stamford, Connecticut.

Eliassen, R., (1969), *Solid Waste Management: A Comprehensive Assessment of Solid Waste Problems, Practices, and Needs,* Office of Science and Technology, Executive Office of the President, Washington, D.C.

Garber, W.F. (1954), Pilot-Scale Studies of Thermophilic Digestion at Los Angeles, *Sewage and Ind. Wastes*, 26, 1202.

Garber, W.F., O'Hara, G.T., Colbaugh, J.E., and Raksit, S.K. (1975), Thermophilic Digestion at the Hyperion Treatment Plant, *J. Water Poll. Cont. Fed.*, 47 (5) 950-61.

Garber, W.F. (1977), Certain Aspects of Anaerobic Digestion of Wastewater Solids in the Thermophilic Range at the Hyperion Treatment Plant, *Prog. Wat. Tech.*, 8, 401-6.

Golueke, C.G. (1991), "Principles of Composting: Understanding the Process", In: The Biocycle Guide to the Art & Science of Composting, The JG Press Inc., Emmaus, Pennsylvania, 14-27.(a)

Golueke, C.G. (1991), "When is compost 'safe'?", In: *The Biocycle Guide to the Art & Science of Composting,* The JG Press Inc., Emmaus, Pennsylvania, 220-229.(b)

Graindorge, P., Cayrol, F., and Pavia, A. (1989), "Methane Fermentation of Urban Waste with a High Paper Content", *I.G.T Conference*, France.

Graves, D.A., Lang, C.A. and Leavitt, M.E. (1991), "Respirometric Analysis of the Biodegradation of Organic Contaminants in Soil and Water", *Applied Biochemistry and Biotechnology*, Vol. 28/29

Gunnerson, C.G. and Stuckey, D.C. (1986), "Integrated Resource Recovery Anaerobic Digestion: Principles and Practices for Biogas Systems", *World Bank Technical Paper No. 49*, UNDP Project Management Report No. 5.

Hartz, K.E., Klink, R.E., Ham, R.K. (1982), "Temperature Effects: Methane Generation from Landfill Samples", *J. Environ. Eng. Div. ASCE*, 108 629-638.

Hashimoto, A.G., Varel, V.H., and Chen, Y.R. (1981), "Ultimate Methane Yield from Beef Cattle Manure: Effect of Temperature, Ration Constituents, Antibiotics and manure Age", *Agric. Wastes*, 3 (4) 241-56.

Haug, R.T. and Ellsworth, W.F. (1991), "Measuring Compost Substrate Degradability", In: *The Biocycle Guide to the Art & Science of Composting*, The JG Press, Inc., Emmaus, Pennsylvania.

Heinrichs, D.M. (1990), "Dry Anaerobic Digestion of Municipal Solid Waste", M.Sc. Thesis, University of Manitoba, Canada.

Hill, D.T. (1982), "Optimum Operational Design Criteria for Anaerobic Digestion of Dairy Manure", *Transactions of the ASAE*, 26(2), 1029 32

Hills, D.J. (1980), "Biogas from a High Solids Combination of Dairy Manure and Barley Straw", *Transactions of the ASAE, Vol. 23, No.6*, 1500-1504. American Society of Agricultural Engineers, St. Jposeph, Michigan (1980a).

Hills, D.J. (1980), "Methane Gas Production from Dairy Manure at High Solids Concentrations", *Transactions of the ASAE, Vol. 23, No.1*, 122-126. American Society of Agricultural Engineers, St. Joseph, Michigan (1980a).

Hobson, P.N., and Shaw, B.J. (1976), *Water Res 10:849*.

Ianotti, E.L., Fischer, J.R. (1984), "Effects of Ammonia, Volatile Acids, pH and sodium on growth of bace\teria isolated from a swine manure digester" in: Developments in industrial microbiology: *Proc 40th Gen Meeting Soc Ind Microbiol*, Sarasota, Florida, Victor Graphics, Baltimore.

Inbar, Y., chen, Y., Hadar, Y. and Hoitink, H.A.J. (1991), "Approaches to Determining Compost Maturity", *The Biocycle Guide to the Art & Science of Composting*, The JG Press Inc., Emmaus, Pennsylvania.

Jewell, W.J. (1979), "Future Trend in Digester Design", In D.A. Stafford, B.I. Wheatly and D.E. Hughes (ed.), *Proceeding of the First Symposium on Anaerobic Digestion*, Cardiff. Wales, Applied Science Publishers Ltd., London, pp. 17-21.

Jewell, W.J., Chandler, J.A., Dell'Orto, S., Fanfoni, K.J., Fast, S., Jackson, D. and Kabrick, R.M. (1981), "Dry Fermentation of Agricultural Residues", Solar Energy Research Institute, USA.

Kasali, G.B., Senior, E., Watson-Craik, I.A. (1989), "Preliminary Investigation of the Influence of pH on the Solid State Refuse Methanogenic Fermentation", *Journal of Applied Bateriology*, 65 231-239.

Kasali, G.B. and Senior, E., (1989), "Effects of Temperature and Moisture on the Anaerobic Digestion of Refuse", *J. Chem. Tech. Biotechnol.* 44 31-41.

Kashmanian, R.M., Gregory, H.C. and Dressing, S.A. (1991), "Where Will All the Compost Go?", *The Biocycle Guide to the Art & Science of Composting*, Emmaus, Pennsylvania, 148-157.

Kayhanian, M., Lindenauer, K., Hardy, S., and Tchobanoglous, G. (1991), "High-Solids Anaerobic Digestion/Aerobic Composting Process", *The Biocycle Guide to the Art & Science of Composting*, The JG Press, Inc., Emmaus, Pennsylvania, 80-89.

Kayhanian, M. & Tchobanoglous, G. (1992), "Pilot Investigation of an Innovative Two-Stage Anaerobic Digestion and Aerobic Composting Process fro the Recovery of Energy and Compost from the Organic Fraction of MSW", *Proceedings, International Symposium on Anaerobic Digestion of Solid Wastes*, Venice, Italy, 14-17 April.

Kimchie, S., Tarre, S., Lumbroso, E. and Green, M. (1988), "Developments in Anaerobic Digestion of Organic Wastes in Israel", *Biological Wastes* 26 275-284.

Kinman, R.N. et al. (1986), "Gas Characterization, Microbiological Analysis, and Disposal of Refuse in GRI Landfill Simulators", EPA Project Summary EPA/600/S2-86/041.

Kuraszko, M., (1992), "Modified MPN Techniques Protocol", Department of Civil Engineering, University of Manitoba, Canada.

Lawrence, A.W. and McCarty, P.L. (1969), "Kinetics of Methane Fermentation in Anaerobic Treatment", *Journal WPCF, Vol. 41, No. 2*, Part 2.

Lawrence, A.W. and McCarty, P.L. (1970), "A Unified Basis for Biological Treatment Design and Operation", *J. Sanit. Eng. Div., Proc. Am. Soc. Civ. Eng.* 96 757-778.

Le Roux, N.W. and Wakerley, D.S. (1978), "The Microbial Production of Methane from Putrescible Fractions of Sorted Household Waste", *Conservation & Recycling*, 2, 163-169.

Logsdon, G. (1990), "Anaerobic Composting Gains Greater Support", *Biocycle, Vol. 31, No. 10*, pp. 42-48.

Marchaim, U. and Creden, J. (1980), "Research and Development in the Utilization of Agricultural Wastes in Israel for Energy, Feedstock, Fodder and Industrial Products", *Fuel Gas Production from Biomass, Vol. 1*, ed. D. Wise CRC Press, Boca Raton, FL. 95-120.

Mata-Alvarez, J., Cecchi, F., Pavan, P. and Bassetti, A. (1992), "Semi-Dry Thermophilic Anaerobic Digestion of Fresh and Pre-composted Organic Fraction of MSW. Digester Performance", *Proceedings, International Symposium on Anaerobic Digestion of Solid Wastes*, Venice, Italy, 14-17 April.

Mata-Alvarez, J. and Martinez-Viturtia, A. (1986), "Laboratory Simulation of Municipal Solid Waste Fermentation with Leachate Recycle", *J. Chem. Tech. Biotechnol.* 36, 547-556.

Maynard, A.A. (1989), "Agricultural Composts as Amendments Reduce Nitrate Leaching from Soil", *Frontiers of Plant Science*, Vol. 42, No. 1, Fall, pp. 2-4.

McCarty, P.L., Brosseau M, H. (1963), "Effects of high concentration of individual volatile fatty acids on anaerobic treatment, In: *Proc 18th Ind Waste Conf*, Purdue Univ., Lafayette, Indiana, Ann Arbor Science, Ann Arbor, Michigan.

McKinley, V.L., Vestal, J.R. and Eralp, A.E. (1989), "Microbial Activity in Composting", *The Biocycle Guide to Composting Municipal Wastes*, The JG Press, Inc., Emmaus, Pennsylvania.

Metcalf and Eddy, Inc. (1991), *Wastewater Engineering: Treatment, Disposal, and Reuse*, McGraw-Hill, Inc., U.S.A.

Molnar, L. and Bartha, I. (1989), "Factors Influencing Solid-State Anaerobic Digestion", *Biological Wastes*, 28 15-24.

Mosey, F.E., Swanwick, J.D., and Hughes, D.A. (1971), "Factors Affecting the Availability of Heavy Metals to Inhibit the Anaerobic Digestion of Sludge", *Wat. Poll. Control* (G.B.), 75.

Parkin, G.F., and Owen, W.F. (1986), "Fundamentals of Anaerobic Digestion of Wastewater Sludges", *Journal of Env. Eng. ASAE*. 112 No.5. Oct. 867-914.

Peavy, H.S., Rowe, D.R. and Tchobanoglous, G. (1985), *Environmental Engineering*, McGraw-Hill Publishing Company, U.S.A.

Pfeffer, J.T. (1973), "Processing Organic Solids by Anaerobic Fermentation", *Proceedings of the International Biogas Conference, Biomass Energy Institute*, Winnipeg, Canada.

Pfeffer, J.T. (1979), "Anaerobic Digestion Processes", Presented at the *First Symposium on Anaerobic Digestion*, Cardiff, Wales. Sept.

Poggi-Varaldo, H.M. (1992), PhD Thesis in Preparation, University of Manitoba. Canada.

Poggi-Varaldo, H.M. et al., (1991), *Journal of Chemical Technology, Biotechnology*.

Poggi-Varaldo, H.M., Heinrichs, D.M., and Tingley, J. (1989), *Laboratory Technique Manual for Dry Digestion Studies*, University of Manitoba, Canada.

Poggi-Varaldo, H.M., Heinrichs, D.M., and Oleszkiewicz, J.A. (1990), "Dry Anaerobic Co-composting of Waste Sludge and Municipal Solid Waste", Proceedings, CSCE 1990 Annual Conference, Hamilton, Ontario.

Poggi-Varaldo, H.M. & Oleszkiewicz, J.A. (1992),"Anaerobic Co-Composting of Municipal Solid Waste and Waste Sludge at High Total Solids Levels", *Environmental Technology, Vol. 13*, 409-421.

Poggi-Varaldo, H.M. & Yu, A., (1992), "COC Analysis Protocol", Department of Civil Engineering, University of Manitoba, Canada.

Prescott, L.M., Harley, J.P., Klein, D.A. (1990), *Microbiology*, Wm. C. Brown Publishers, U.S.A.

Price, R.T. and Cheremisinoff, P.N. (1981), *Biogas:Production and Utilization*, Ann-Arbor Science Publishers Inc., Mich. USA.

Richard, T. (1991), "Clean Compost Production", *The Biocycle Guide to the Art & Science of Composting*, The JG Press Inc., Emmaus, Pennsylvania.

Sawyer, C.N. and McCarty, P.L. (1978), *Chemistry for Environmental Engineering*. McGraw-Hill Publishing Company, U.S.A., Third Edition.

Schellenbach, S. (1980), "Imperial valley Biogas Project, Operations and Methane Production from Cattle Manure", Oct 1978 - Nov 1979, In Symposium Papers: Energy from Biomass and Wastes, IV, IGT, Chicago, Ill., USA.

Schulze, K.L. (1958), "Sludge Digestion and Methane Fermentation, Part 1, Increase Solids Concentration", *Sewage and Industrial Wastes, Vol. 30, No. 1*, pp 28-33.

Schulze, K.L. (1960), "Rate of Oxygen Consumption and Respiratory Quotients During the Aerobic Decomposition of a Synthetic Garbage", *Compost Science, No. 1*.

Shelef, G., Kimchie, S., and Grynberg H. (1980), "High-rate Thermophilic Anaerobic Digestion of Agricultural Wastes", *Biotech. and Bioeng. Symp. No. 10*, 341-51.

Six, W., and De Baere, L. (1988), "Dry Anaerobic Composting of Various Organic Wastes", *Fifth International Symposium on Anaerobic Digestion*, Bologna, Italy.

Six, W., and De Baere, L. (1992), "Dry Anaerobic Conversion of Municipal Solid Waste by Means of the DRANCO Process at Brecht, Belgium", *Proceedings, International Symposium on Anaerobic Digestion of Solid Wastes*, Venice, Italy, 14-17 April.

Speers, T., (1990), "Developments that are Sustainable", *Bio-Joule*, September Issue.

Stronach, S.M., Rudd, T., and Lester, J.N. (1986), *Anaerobic Digestion Processes in Industrial Wastewater Treatment*, Springer-Verlag Berlin Heidelberg, Germany.

Tchobanoglous, G., Theisen, h., Eliassen, R., (1977), *Solid Wastes: Engineering Principles and Management Issues*, McGraw-Hill Publishing Company, U.S.A.

Ten Brummeler, E., Koster, I.W. and Zeevalkink,J.A. (1988), "Dry Digestion of the Organic Fraction of Municipal Solid Waste in a Batch Process", *International Symp. Anaer. Dig.*, Bologne, Italia.

Theis, T.L. and Hayes, T.D. (1979), "Chemistry of Heavy Metals in Anaerobic Digestion", *Chemistry of Wastewater Technology*, Chapter 23, Ann Arbor Science, Ann Arbor, Mich. USA, 403-19.

Wujcik, W.J. and Jewell, W.J. (1980), "Dry Anaerobic Fermentation", *Biotechnology and Bioengineering Symposium No.10* pp.43-65.

Zucconi, F. and de Bertoldi, M. (1989), "Specifications for solid waste compost", *The Biocycle Guide to Composting Municipal Wastes*, The JG Press, Inc., Emmaus, Pennsylvania.

Zucconi, F. and de Bertoldi, M. (1991), "Specifications for solid waste compost", *The Biocycle Guide to the Art & Science of Composting*, The JG Press, Inc., Emmaus, Pennsylvania.

Zucconi, F., Pera, A., Forte, M. and de Bertoldi, M. (1981), "Evaluating toxicity of immature compost", *Biocycle* 22:54-57.

APPENDIX A

DAD DIGESTER CHARACTERISTICS

DAD DIGESTER MASS DATA
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DIGESTER	MRT (d)	Vreactor (L)	Mtarget (g)	TARE (g)	FEED TYPE
2-1	21	4.0	2000.00	1830.90	FS
B1	21	8.0	4200.00	1368.40	FS
B2	28	8.0	4200.00	1387.00	FS
B3	21	8.0	4200.00	1379.00	FSC
B4	28	8.0	4200.00	1378.00	FSC
B5	21	8.0	4200.00	1378.00	FSC
T1	7	8.0	1500.00	7700.00	B3+B5
T2	14	4.0	2000.00	1857.50	B1+2-1

APPENDIX B

DAD DIGESTER MASS DATA

MASS DATA
=========

DATE : WEDNESDAY/06/11/91 (Day 6)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED TYPE	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	-	-	-	-	-	-	-
B1	4200.0	1368.4	21	5551.2	5168.4	382.8	5563.2	FS	400.0	1.2
B2	4200.0	1387.0	28	5395.6	5287.0	108.6	5581.4	FS	300.0	0.9
B3	4200.0	1379.0	21	5577.8	5179.0	398.8	5573.8	FSC	400.0	1.2
B4	4200.0	1378.0	28	5393.7	5278.0	115.7	5573.6	FSC	300.0	0.9
B5	4200.0	1378.0	21	5572.4	5178.0	394.4	5572.2	FSC	400.0	1.2
T1	1500.0	7700.0	7	10100.0	8771.4	1329.0	8900.0	C-B3+B5	428.6	1.3
T2	2000.0	1857.5	14	-	-	-	-	-	-	-

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet FS
(giving approximately 0.75 mg NA/g Wet FS)

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
=========

DATE : FRIDAY/08/11/91 (Day 8)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED TYPE	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	4118.8	3545.2	573.6	3826.9	FS	285.7	0.86
B1	4200.0	1368.4	21	5521.6	4968.4	553.2	5566.6	FS	600.0	1.80
B2	4200.0	1387.0	28	5556.1	5137.0	419.1	5578.7	FS	450.0	1.35
B3	4200.0	1379.0	21	5536.5	4979.0	557.5	5578.8	FSC	600.0	1.80
B4	4200.0	1378.0	28	5552.0	5128.0	424.0	5569.9	FSC	450.0	1.35
B5	4200.0	1378.0	21	5543.4	4978.0	565.4	5573.5	FSC	600.0	1.80
T1	1500.0	7700.0	7	8900.0	8557.1	400.0	9300.0	C-B3+B5	642.9	1.93
T2	2000.0	1857.5	14	4168.0	3428.9	739.1	3852.5	C-B1+2-1	428.6	1.29

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet FS
(giving approximately 0.75 mg NA/g Wet FS)

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
C-B1+2-1 = Compost from B1 and 2-1
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
=========

DATE : MONDAY/11/11/91 (Day 11)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED TYPE	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	3794.0	3449.9	344.1	3821.5	FS	381.0	1.14
B1	4200.0	1368.4	21	5485.4	5168.4	317.0	5561.4	FS	400.0	1.20
B2	4200.0	1387.0	28	5480.5	5287.0	193.4	5581.7	FS	300.0	0.90
B3	4200.0	1379.0	21	5508.0	5179.0	329.0	5570.3	FSC	400.0	1.20
B4	4200.0	1378.0	28	5528.0	5278.0	250.0	5570.3	FSC	300.0	0.90
B5	4200.0	1378.0	21	5516.3	5178.0	338.3	5479.0	FSC	400.0	1.20
T1	1500.0	7700.0	7	9000.0	8771.4	325.8	9000.0	C-B3+B5	428.6	1.29
T2	2000.0	1857.5	14	3822.7	3286.1	536.6	3840.4	C-B1+2-1	571.4	1.71

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet FS
(giving approximately 0.75 mg NA/g Wet FS)

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
C-B1+2-1 = Compost from B1 and 2-1
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA

DATE : WEDNESDAY/13/11/91 (Day 13)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	-	-	-	-	-	-	-
B1	4200.0	1368.4	21	5517.6	5168.4	349.2	5560.2	FS	400.0	1.2
B2	4200.0	1387.0	28	5555.7	5287.0	268.7	5584.1	FS	300.0	0.9
B3	4200.0	1379.0	21	5537.6	5179.0	358.6	5569.4	FSC	400.0	1.2
B4	4200.0	1378.0	28	5551.5	5278.0	273.5	5576.4	FSC	300.0	0.9
B5	4200.0	1378.0	21	5457.3	5178.0	279.3	5573.0	FSC	400.0	1.2
T1	1500.0	7700.0	7	9300.0	8771.4	528.6	9300.0	C-B3+B5	428.6	1.3
T2	2000.0	1857.5	14	-	-	-	-	-	-	-

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet feedstock (giving approximately 0.75 mg NA/g Wet feedstock

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
=========

DATE : FRIDAY/15/11/91 (Day 15)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED TYPE	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	3780.1	3545.2	234.9	3819.7	FS	285.7	0.86
B1	4200.0	1368.4	21	5514.5	4968.4	546.1	5564.1	FS	600.0	1.80
B2	4200.0	1387.0	28	5554.2	5137.0	417.2	5578.6	FS	450.0	1.35
B3	4200.0	1379.0	21	5530.1	4979.0	551.1	5567.4	FSC	600.0	1.80
B4	4200.0	1378.0	28	5588.0	5128.0	460.0	5567.5	FSC	450.0	1.35
B5	4200.0	1378.0	21	5550.8	4978.0	572.8	5565.8	FSC	600.0	1.80
T1	1500.0	7700.0	7	9200.0	8557.1	507.0	-	C-B3+B5	642.9	1.93
T2	2000.0	1857.5	14	3829.5	3428.9	400.6	3848.1	C-B1+2-1	428.6	1.29

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet FS
(giving approximately 0.75 mg NA/g Wet FS)

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
C-B1+2-1 = Compost from B1 and 2-1
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
=========

DATE : MONDAY/18/11/91 (Day 18)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED TYPE	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	3779.7	3449.9	329.8	3817.3	FS	381.0	1.14
B1	4200.0	1368.4	21	5486.3	5168.4	317.9	5553.7	FS	400.0	1.20
B2	4200.0	1387.0	28	5583.0	5287.0	296.0	5566.3	FS	300.0	0.90
B3	4200.0	1379.0	21	5508.5	5179.0	329.5	5567.7	FSC	400.0	1.20
B4	4200.0	1378.0	28	5538.6	5278.0	260.6	5559.3	FSC	300.0	0.90
B5	4200.0	1378.0	21	5529.3	5178.0	351.3	5559.8	FSC	400.0	1.20
T1	1500.0	7700.0	7	9320.0	8771.4	548.6	9192.0	C-B3+B5	428.6	1.29
T2	2000.0	1857.5	14	3839.7	3286.1	553.6	3840.6	C-B1+2-1	571.4	1.71

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet FS
(giving approximately 0.75 mg NA/g Wet FS)

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
C-B1+2-1 = Compost from B1 and 2-1
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
=========

DATE : WEDNESDAY/20/11/91 (Day 20)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	-	-	-	-	-	-	-
B1	4200.0	1368.4	21	5495.3	5168.4	326.9	5563.0	FS	400.0	1.2
B2	4200.0	1387.0	28	5477.2	5287.0	190.2	5580.2	FS	300.0	0.9
B3	4200.0	1379.0	21	5532.0	5179.0	353.0	5573.2	FSC	400.0	1.2
B4	4200.0	1378.0	28	5543.7	5278.0	265.7	5574.6	FSC	300.0	0.9
B5	4200.0	1378.0	21	5538.5	5178.0	360.5	5572.8	FSC	400.0	1.2
T1	1500.0	7700.0	7	9100.0	8771.4	328.6	9100.0	C-B3+B5	428.6	1.3
T2	2000.0	1857.5	14	-	-	-	-	-	-	-

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet feedstock
(giving approximately 0.75 mg NA/g Wet feedstock

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
=========

DATE : FRIDAY/22/11/91 (Day 22)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED TYPE	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	3769.9	3545.2	224.7	3824.1	FS	285.7	0.86
B1	4200.0	1368.4	21	5512.6	4968.4	544.2	5563.8	FS	600.0	1.80
B2	4200.0	1387.0	28	5552.6	5137.0	415.6	5580.0	FS	450.0	1.35
B3	4200.0	1379.0	21	5547.2	4979.0	568.2	5574.1	FSC	600.0	1.80
B4	4200.0	1378.0	28	5562.8	5128.0	434.8	5573.2	FSC	450.0	1.35
B5	4200.0	1378.0	21	5559.2	4978.0	581.2	5569.7	FSC	600.0	1.80
T1	1500.0	7700.0	7	9150.0	8557.1	507.0	9187.0	C-B3+B5	642.9	1.93
T2	2000.0	1857.5	14	3826.7	3428.9	397.8	3858.0	C-B1+2-1	428.6	1.29

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet FS
(giving approximately 0.75 mg NA/g Wet FS)

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
C-B1+2-1 = Compost from B1 and 2-1
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
=========

DATE : MONDAY/25/11/91 (Day 25)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED TYPE	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	3786.3	3449.9	336.4	3823.1	FS	381.0	1.14
B1	4200.0	1368.4	21	5498.9	5168.4	330.5	5554.8	FS	400.0	1.20
B2	4200.0	1387.0	28	5538.2	5287.0	251.2	5576.6	FS	300.0	0.90
B3	4200.0	1379.0	21	5542.7	5179.0	363.7	5557.4	FSC	400.0	1.20
B4	4200.0	1378.0	28	5558.8	5278.0	280.8	5567.5	FSC	300.0	0.90
B5	4200.0	1378.0	21	5553.0	5178.0	375.0	5561.6	FSC	400.0	1.20
T1	1500.0	7700.0	7	9023.0	8771.4	251.6	9264.0	C-B3+B5	428.6	1.29
T2	2000.0	1857.5	14	3831.7	3286.1	545.6	3839.6	C-B1+2-1	571.4	1.71

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet FS
(giving approximately 0.75 mg NA/g Wet FS)

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
C-B1+2-1 = Compost from B1 and 2-1
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
=========

DATE : WEDNESDAY/27/11/91 (Day 27)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	-	-	-	-	-	-	-
B1	4200.0	1368.4	21	5497.7	5168.4	329.3	5558.5	FS	400.0	1.2
B2	4200.0	1387.0	28	5535.9	5287.0	248.9	5583.2	FS	300.0	0.9
B3	4200.0	1379.0	21	5933.7	5179.0	754.7	5572.6	FSC	400.0	1.2
B4	4200.0	1378.0	28	5555.2	5278.0	277.2	5576.3	FSC	300.0	0.9
B5	4200.0	1378.0	21	5548.8	5178.0	370.8	5575.0	FSC	400.0	1.2
T1	1500.0	7700.0	7	9328.0	8771.4	556.6	9200.0	C-B3+B5	428.6	1.3
T2	2000.0	1857.5	14	-	-	-	-	-	-	-

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet feedstock
(giving approximately 0.75 mg NA/g Wet feedstock

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
=========

DATE : FRIDAY/29/11/91 (Day 29)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED TYPE	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	3771.8	3545.2	226.6	3822.7	FS	285.7	0.86
B1	4200.0	1368.4	21	5520.6	4968.4	552.2	5557.3	FS	600.0	6.86
B2	4200.0	1387.0	28	5554.6	5137.0	417.6	5578.6	FS	450.0	6.86
B3	4200.0	1379.0	21	5555.3	4979.0	576.3	5573.4	FSC	600.0	2.80
B4	4200.0	1378.0	28	5569.5	5128.0	441.5	5574.6	FSC	450.0	2.35
B5	4200.0	1378.0	21	5564.6	4978.0	586.6	5568.7	FSC	600.0	2.80
T1	1500.0	7700.0	7	9100.0	8557.1	507.0	9300.0	C-B3+B5	642.9	1.93
T2	2000.0	1857.5	14	3819.4	3428.9	390.5	3842.5	C-B1+2-1	428.6	1.29

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet FS
(giving approximately 0.75 mg NA/g Wet FS)

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
C-B1+2-1 = Compost from B1 and 2-1
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

MASS DATA
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DATE : MONDAY/02/12/91 (Day 32)

DIGESTER	M(target) (g)	Tare (g)	MRT (d)	Mb (g)	Minus (g)	md (g)	Ma (g)	FEED TYPE	mf (g)	NaHCO3 (g)
2-1	2000.0	1830.9	21	3799.5	3449.9	349.6	3825.7	FS	381.0	1.14
B1	4200.0	1368.4	21	5505.3	5168.4	336.9	5562.1	FS	400.0	1.20
B2	4200.0	1387.0	28	5541.7	5287.0	254.7	5581.0	FS	300.0	0.90
B3	4200.0	1379.0	21	5546.0	5179.0	367.0	5585.2	FSC	400.0	11.20
B4	4200.0	1378.0	28	5565.8	5278.0	287.8	5569.8	FSC	300.0	10.90
B5	4200.0	1378.0	21	5557.0	5178.0	379.0	5583.0	FSC	400.0	11.20
T1	1500.0	7700.0	7	9369.0	8771.4	597.6	9244.0	C-B3+B5	428.6	1.29
T2	2000.0	1857.5	14	3809.1	3286.1	523.0	3894.8	C-B1+2-1	571.4	1.71

NOTES: Sodium Bicarbonate is dosed at 3 mg bic/g wet FS (giving approximately 0.75 mg NA/g Wet FS)

Mb = Gross mass before draw & fill
Ma = Gross mass after draw & fill
mf = mass to be fed
md = mass to be drawn
FS = Plain feedstock
FSC = Coliform-inoculated feedstock
C-B3+B5 = Compost from B3 and B5
C-B1+2-1 = Compost from B1 and 2-1
Minus = [M(target) + Tare - mf] to determine md
M(target)= Fixed target mass of reactor content

APPENDIX C

DAD DIGESTER OPERATIONAL DATA

APPENDIX C-1

BIOGAS PRODUCTIVITY

BIOGAS PRODUCTIVITY

DATE : 06/11/91 - 08/11/91

DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	-	-	-	-	-	-	-	-
B1	2.00	4168.00	0.26	14.50	308.00	12.85	6.43	5.98
B2	2.00	4088.85	0.25	1.80	308.00	1.60	0.80	0.77
B3	2.00	4178.15	0.27	23.23	308.00	20.59	10.30	9.23
B4	2.00	4094.85	0.27	11.20	308.00	9.93	4.96	4.55
B5	2.00	4179.90	0.28	13.70	308.00	12.14	6.07	5.28
T1	2.00	1800.00	0.26	0.00	298.00	0.00	0.00	0.00
T2	-	-	-	-	-	-	-	-

BIOGAS PRODUCTIVITY

DATE : 08/11/91 - 11/11/91

DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	3.00	2125.50	0.26	21.10	308.00	18.70	6.23	11.31
B1	3.00	4135.10	0.26	18.90	308.00	16.75	5.58	5.29
B2	3.00	4131.30	0.26	13.00	308.00	11.52	3.84	3.64
B3	3.00	4143.25	0.26	35.97	308.00	31.88	10.63	10.04
B4	3.00	4162.00	0.26	18.10	308.00	16.04	5.35	4.85
B5	3.00	4151.85	0.28	22.10	308.00	19.59	6.53	5.67
T1	3.00	1250.00	0.27	0.00	298.00	0.00	0.00	0.00
T2	3.00	2137.85	0.25	4.40	298.00	4.03	1.34	2.47

BIOGAS PRODUCTIVITY
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DATE : 11/11/91 - 13/11/91
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DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	-	-	-	-	-	-	-	-
B1	2.00	4133.10	0.26	13.00	308.00	11.52	5.76	5.46
B2	2.00	4131.10	0.26	8.70	308.00	7.71	3.86	3.66
B3	2.00	4143.80	0.26	22.98	308.00	20.37	10.18	9.62
B4	2.00	4161.75	0.25	10.00	308.00	8.86	4.43	4.18
B5	2.00	4108.80	0.28	12.80	308.00	11.35	5.67	4.97
T1	2.00	1450.00	0.27	0.00	298.00	0.00	0.00	0.00
T2	-	-	-	-	-	-	-	-

BIOGAS PRODUCTIVITY

DATE : 13/11/91 - 15/11/91

DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	2.00	1949.20	0.27	6.50	308.00	5.76	2.88	5.42
B1	2.00	4147.65	0.26	6.50	308.00	5.76	2.88	2.72
B2	2.00	4167.95	0.26	18.45	308.00	16.35	8.18	7.66
B3	2.00	4154.85	0.25	10.99	308.00	9.74	4.87	4.66
B4	2.00	4191.75	0.26	4.50	308.00	3.99	1.99	1.84
B5	2.00	4126.05	0.28	5.20	308.00	4.61	2.30	2.01
T1	2.00	1550.00	0.28	0.00	298.00	0.00	0.00	0.00
T2	2.00	1972.00	0.25	1.50	298.00	1.37	0.69	1.40

BIOGAS PRODUCTIVITY

DATE : 15/11/91 - 18/11/91

DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	3.00	1949.00	0.27	12.20	308.00	10.81	3.60	6.78
B1	3.00	4132.00	0.26	0.60	308.00	0.53	0.18	0.17
B2	3.00	4181.60	0.26	22.75	308.00	20.16	6.72	6.28
B3	3.00	4140.30	0.25	15.79	308.00	14.00	4.67	4.48
B4	3.00	4185.30	0.26	8.00	308.00	7.09	2.36	2.19
B5	3.00	4162.05	0.28	4.70	308.00	4.17	1.39	1.20
T1	3.00	1560.00	0.28	0.00	298.00	0.00	0.00	0.00
T2	3.00	1977.10	0.25	4.50	298.00	4.12	1.37	2.80

BIOGAS PRODUCTIVITY

DATE : 18/11/91 - 20/11/91

DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	-	-	-	-	-	-	-	-
B1	2.00	4122.40	0.26	5.90	308.00	5.23	2.61	2.48
B2	2.00	4143.10	0.26	13.54	308.00	12.00	6.00	5.65
B3	2.00	4141.25	0.25	19.08	308.00	16.91	8.46	8.11
B4	2.00	4163.15	0.26	8.60	308.00	7.62	3.81	3.55
B5	2.00	4155.90	0.28	6.60	308.00	5.85	2.93	2.54
T1	2.00	1510.00	0.28	0.00	298.00	0.00	0.00	0.00
T2	-	-	-	-	-	-	-	-

BIOGAS PRODUCTIVITY

DATE : 20/11/91 - 22/11/91

DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	2.00	1943.90	0.28	16.23	308.00	14.38	7.19	13.18
B1	2.00	4135.55	0.26	16.70	308.00	14.80	7.40	6.86
B2	2.00	4127.90	0.30	21.18	308.00	18.77	9.39	7.67
B3	2.00	4160.60	0.28	23.28	308.00	20.63	10.32	8.93
B4	2.00	4175.25	0.28	7.90	308.00	7.00	3.50	2.95
B5	2.00	4170.85	0.29	4.70	308.00	4.17	2.08	1.71
T1	2.00	1425.00	0.28	0.00	298.00	0.00	0.00	0.00
T2	2.00	1975.70	0.25	3.60	298.00	3.30	1.65	3.38

BIOGAS PRODUCTIVITY
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DATE : 22/11/91 - 25/11/91
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DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	3.00	1947.20	0.28	22.00	308.00	19.50	6.50	11.89
B1	3.00	4128.70	0.26	17.10	308.00	15.16	5.05	4.69
B2	3.00	4120.70	0.30	18.28	308.00	16.20	5.40	4.42
B3	3.00	4158.35	0.28	22.78	308.00	20.19	6.73	5.83
B4	3.00	4173.25	0.28	9.10	308.00	8.07	2.69	2.27
B5	3.00	4167.75	0.29	7.80	308.00	6.91	2.30	1.89
T1	3.00	1361.50	0.28	0.00	298.00	0.00	0.00	0.00
T2	3.00	1971.70	0.25	6.90	298.00	6.32	2.11	4.33

BIOGAS PRODUCTIVITY
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DATE : 25/11/91 - 27/11/91
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DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	-	-	-	-	-	-	-	-
B1	2.00	4129.90	0.26	19.50	308.00	17.28	8.64	8.02
B2	2.00	4150.05	0.30	23.68	308.00	20.99	10.49	8.53
B3	2.00	4359.20	0.28	12.50	308.00	11.08	5.54	4.58
B4	2.00	4179.00	0.28	5.90	308.00	5.23	2.61	2.20
B5	2.00	4172.90	0.29	0.20	308.00	0.18	0.09	0.07
T1	2.00	1475.50	0.28	0.00	298.00	0.00	0.00	0.00
T2	-	-	-	-	-	-	-	-

BIOGAS PRODUCTIVITY

DATE : 27/11/91 - 29/11/91

DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	2.00	1948.15	0.25	13.30	308.00	11.79	5.89	11.98
B1	2.00	4140.75	0.25	13.00	308.00	11.52	5.76	5.53
B2	2.00	4158.25	0.27	6.18	308.00	5.48	2.74	2.48
B3	2.00	4365.50	0.28	7.90	308.00	7.00	3.50	2.90
B4	2.00	4184.35	0.28	3.10	308.00	2.75	1.37	1.17
B5	2.00	4178.70	0.30	4.70	308.00	4.17	2.08	1.67
T1	2.00	1514.00	0.28	0.00	298.00	0.00	0.00	0.00
T2	2.00	1965.55	0.25	4.30	298.00	3.94	1.97	3.97

BIOGAS PRODUCTIVITY

DATE : 29/11/91 - 02/12/91

DIGESTER	# OF DAY	Avg Mass (g)	Avg TS (dec)	VBG(EXPT) (L)	TEMP (K)	VBG(NTP) (L)	VBG/d (L/d)	BGPROD (L/d/kgTS)
2-1	3.00	1954.75	0.25	18.40	308.00	16.31	5.44	11.22
B1	3.00	4133.10	0.26	16.50	308.00	14.63	4.88	4.51
B2	3.00	4151.80	0.26	9.00	308.00	7.98	2.66	2.44
B3	3.00	4360.85	0.28	14.40	308.00	12.76	4.25	3.44
B4	3.00	4182.50	0.29	5.00	308.00	4.43	1.48	1.23
B5	3.00	4174.90	0.30	3.20	308.00	2.84	0.95	0.74
T1	3.00	1648.50	0.28	0.00	298.00	0.00	0.00	0.00
T2	3.00	1960.40	0.25	4.70	298.00	4.31	1.44	2.89

APPENDIX C-2

BIOGAS COMPOSITION

BIOGAS COMPOSITION

DATE OF ANALYSIS = 18/NOV/1991

DIGESTER	CH4 RDG	CO2 RDG	% CH4	% CO2
2-1	73.00	33.00	65	32
B1	78.00	35.00	71	34
B2	74.00	41.00	67	40
B3	69.00	35.00	61	34
B4	59.00	49.00	49	49
B5	62.00	50.00	53	50
T1	12.00	5.50	8	5
T2	71.00	33.00	63	32

STANDARD CALIBRATION

CH4

RDG	RDG^2	%
40.00	1600.00	30.00
59.00	3481.00	50.00
77.00	5929.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		0.72
R Squared		1.00
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.595726	0.004107
Std Err of Coef.	0.034500	0.000513

CO2

RDG	RDG^2	%
30.00	900.00	30.00
52.00	2704.00	50.00
67.00	4489.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		2.59
R Squared		0.99
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.890661	0.002096
Std Err of Coef.	0.141776	0.002399

BIOGAS COMPOSITION

DATE OF ANALYSIS = 24/NOV/1991

DIGESTER	CH4 RDG	CO2 RDG	% CH4	% CO2
2-1	73.00	39.00	58	35
B1	70.00	37.00	54	33
B2	75.00	41.00	60	37
B3	60.00	41.00	45	37
B4	41.00	44.00	28	40
B5	40.00	46.00	27	42
T1	9.00	6.00	5	5
T2	70.00	43.00	54	39

STANDARD CALIBRATION

CH4

RDG	RDG^2	%
41.00	1681.00	30.00
70.00	4900.00	50.00
82.00	6724.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		5.71
R Squared		0.96
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.533272	0.003503
Std Err of Coef.	0.276848	0.003762

CO2

RDG	RDG^2	%
35.00	1225.00	30.00
53.00	2809.00	50.00
72.00	5184.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		1.22
R Squared		1.00
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.783952	0.002679
Std Err of Coef.	0.059791	0.000953

BIOGAS COMPOSITION

DATE OF ANALYSIS = 01/DEC/1991

DIGESTER	CH4 RDG	CO2 RDG	% CH4	% CO2
2-1	73.00	33.00	53	27
B1	78.00	35.00	58	29
B2	74.00	41.00	54	35
B3	69.00	35.00	49	29
B4	59.00	49.00	40	43
B5	62.00	50.00	43	44
T1	12.00	5.50	6	4
T2	71.00	33.00	51	27

STANDARD CALIBRATION

CH4

RDG	RDG^2	%
44.00	1936.00	30.00
75.00	5625.00	50.00
86.00	7396.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		6.65
R Squared		0.94
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.475651	0.003478
Std Err of Coef.	0.312781	0.004030

CO2

RDG	RDG^2	%
37.00	1369.00	30.00
54.00	2916.00	50.00
73.00	5329.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		1.86
R Squared		1.00
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.711653	0.003480
Std Err of Coef.	0.091088	0.001434

BIOGAS COMPOSITION

DATE OF ANALYSIS = 04/DEC/1991

DIGESTER	CH4 RDG	CO2 RDG	% CH4	% CO2
2-1	77.00	40.00	60	33
B1	0.00	0.00	0	0
B2	81.00	41.00	64	34
B3	70.00	33.00	53	26
B4	38.00	40.00	25	33
B5	48.00	49.00	33	42
T1	8.00	5.00	5	3
T2	70.00	47.00	53	40

STANDARD CALIBRATION

CH4

RDG	RDG^2	%
43.00	1849.00	30.00
68.00	4624.00	50.00
86.00	7396.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		1.59
R Squared		1.00
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.549945	0.002993
Std Err of Coef.	0.069309	0.000915

CO2

RDG	RDG^2	%
37.00	1369.00	30.00
56.00	3136.00	50.00
72.00	5184.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		0.24
R Squared		1.00
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.634094	0.004681
Std Err of Coef.	0.012556	0.000199

BIOGAS COMPOSITION

DATE OF ANALYSIS = 08/DEC/1991

DIGESTER	CH4 RDG	CO2 RDG	% CH4	% CO2
2-1	76.00	45.00	59	38
B1	76.00	45.00	59	38
B2	72.00	43.00	55	36
B3	36.00	48.00	21	42
B4	40.00	49.00	24	43
B5	42.00	47.00	26	41
T1	2.00	4.00	1	3
T2	71.00	46.00	54	40

STANDARD CALIBRATION

CH4

RDG	RDG^2	%
44.00	1936.00	30.00
73.00	5329.00	50.00
82.00	6724.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		7.35
R Squared		0.93
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.426875	0.004620
Std Err of Coef.	0.371018	0.004989

CO2

RDG	RDG^2	%
38.00	1444.00	30.00
54.00	2916.00	50.00
73.00	5329.00	70.00

Regression Output:

Constant		0.00
Std Err of Y Est		2.44
R Squared		0.99
No. of Observations		3.00
Degrees of Freedom		2.00
X Coefficient(s)	0.675059	0.004007
Std Err of Coef.	0.119856	0.001889

APPENDIX C-3

TOTAL & VOLATILE SOLIDS

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
02/12/91	2-1	10.95	15.37	12.09	11.11	25.79	22.17
	B1	10.36	14.48	11.52	10.56	28.16	23.30
	B2	10.45	15.02	11.67	10.64	26.70	22.54
	B3	10.53	14.73	11.75	10.71	29.05	24.76
	B4	10.49	15.06	11.80	10.66	28.67	24.95
	B5	10.01	13.99	11.22	10.18	30.40	26.13
	T1	10.62	15.18	11.91	10.81	28.29	24.12
	T2	10.35	14.79	11.48	10.54	25.45	21.17
	FEED	10.14	14.34	11.47	10.34	31.67	26.90

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
06/12/91	2-1	29.13	33.32	30.15	29.28	24.34	20.76
	B1	28.17	33.36	29.55	28.43	26.59	21.58
	B2	27.21	31.58	28.41	27.37	27.46	23.80
	B3	27.56	31.78	28.90	27.79	31.75	26.30
	B4	26.96	31.61	28.37	27.20	30.32	25.16
	B5	29.47	34.64	31.03	29.75	30.17	24.76
	T1	27.30	33.03	28.92	27.58	28.27	23.39
	T2	30.20	35.97	31.90	30.46	29.46	24.96
	FEED	28.52	33.49	30.14	28.76	32.60	27.77

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
04/11/91	2-1	28.03	33.70	29.52	28.21	26.28	23.10
	B1	10.41	14.90	11.59	10.53	26.28	23.61
	B2	10.38	14.31	11.38	10.48	25.45	22.90
	B3	10.91	15.55	12.10	11.08	25.65	21.98
	B4	10.69	14.53	11.72	10.51	26.82	31.51
	B5	10.22	14.28	11.29	10.36	26.35	22.91
	T1	10.30	14.57	11.47	10.45	27.40	23.89
	T2	0.00	0.00	0.00	0.00	0.00	0.00
	FEED	9.93	12.37	10.79	10.01	35.25	31.97

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
06/11/91	2-1	0.00	0.00	0.00	0.00	0.00	0.00
	B1	10.75	13.68	11.51	10.84	25.94	22.87
	B2	10.60	13.86	11.43	10.69	25.46	22.70
	B3	10.01	16.03	11.59	10.24	26.25	22.43
	B4	10.45	13.25	11.22	10.53	27.50	24.64
	B5	10.42	13.32	11.21	10.81	27.24	13.79
	T1	11.22	13.95	11.91	11.31	25.27	21.98
	T2	0.00	0.00	0.00	0.00	0.00	0.00
	FEED	9.99	12.65	10.89	10.07	33.83	30.83

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
08/11/91	2-1	28.25	35.06	30.07	28.46	26.73	23.64
	B1	10.88	13.65	11.59	10.95	25.63	23.10
	B2	11.63	14.63	12.39	11.74	25.33	21.67
	B3	10.69	16.18	12.18	10.88	27.14	23.68
	B4	11.10	14.24	11.91	11.20	25.80	22.61
	B5	11.31	13.97	12.05	11.41	27.82	24.06
	T1	9.98	13.95	11.04	10.12	26.70	23.17
	T2	10.31	16.17	11.79	10.62	25.26	19.97
	FEED	9.83	12.47	10.75	9.92	34.85	31.44

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
11/11/91	2-1	11.71	15.93	12.77	11.84	25.12	22.04
	B1	10.00	14.33	11.10	10.15	25.40	21.94
	B2	9.92	13.34	10.80	10.03	25.73	22.51
	B3	27.57	32.58	28.77	27.73	23.95	20.76
	B4	10.13	14.46	11.22	10.28	25.17	21.71
	B5	10.09	13.99	11.17	10.24	27.69	23.85
	T1	10.60	15.04	11.78	10.79	26.58	22.30
	T2	28.13	33.52	29.51	28.41	25.60	20.41
	FEED	0.00	0.00	0.00	0.00	0.00	0.00

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
13/11/91	2-1	0.00	0.00	0.00	0.00	0.00	0.00
	B1	11.21	15.49	12.31	11.34	25.70	22.66
	B2	10.49	14.53	11.52	10.62	25.50	22.28
	B3	10.34	14.47	11.43	10.51	26.39	22.28
	B4	11.31	16.41	12.66	11.49	26.47	22.94
	B5	10.50	14.56	11.63	10.68	27.83	23.40
	T1	10.96	15.54	12.26	11.15	28.38	24.24
	T2	0.00	0.00	0.00	0.00	0.00	0.00
	FEED	10.50	15.00	12.05	10.68	34.44	30.44

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
15/11/91	2-1	10.13	10.64	10.28	10.14	29.41	27.45
	B1	10.46	10.96	10.59	10.47	26.00	24.00
	B2	10.94	11.44	11.10	10.97	32.00	26.00
	B3	10.08	10.58	10.22	10.10	28.00	24.00
	B4	10.52	11.03	10.67	10.54	29.41	25.49
	B5	10.48	10.99	10.63	10.51	29.41	23.53
	T1	11.30	11.80	11.44	11.32	28.00	24.00
	T2	10.53	11.03	10.65	10.55	24.00	20.00
	FEED	0.00	0.00	0.00	0.00	0.00	0.00

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
22/11/91	2-1	27.57	35.28	29.63	27.82	26.72	23.48
	B1	11.31	16.28	12.61	11.48	26.16	22.74
	B2	10.13	16.18	11.78	10.34	27.27	23.80
	B3	9.92	14.93	11.30	10.11	27.54	23.75
	B4	10.08	16.03	11.71	10.32	27.39	23.36
	B5	27.00	33.79	28.98	27.28	29.16	25.04
	T1	28.13	35.82	30.23	28.45	27.31	23.15
	T2	27.30	34.56	29.14	27.62	25.34	20.94
	FEED	30.20	36.60	32.39	30.45	34.22	30.31

TOTAL & VOLATILE SOLIDS

DATE	DIGESTER	T (g)	T + S (g)	T + D (g)	T + A (g)	TS (%)	VS (%)
29/11/91	2-1	10.52	15.61	11.73	10.68	23.77	20.63
	B1	10.01	15.10	11.24	10.18	24.17	20.83
	B2	10.61	15.56	11.89	10.79	25.86	22.22
	B3	11.41	15.49	12.54	11.57	27.70	23.77
	B4	11.71	15.75	12.88	11.87	28.96	25.00
	B5	10.36	16.05	12.10	10.61	30.58	26.19
	T1	11.20	16.35	12.66	11.42	28.35	24.08
	T2	10.53	15.89	11.88	10.75	25.19	21.08
	FEED	10.96	15.91	12.56	11.17	32.32	28.08

APPENDIX C-4

VFA & pH

VFA ANALYSIS
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DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SMPL WT. (g)	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE
4/11/91	2.1	89.65	289.30	N-T	110.65	N-T	N-T	8.55	10.00	0.055	1.00	0.49	1.59	N-T	0.61	N-T
4/11/91	B.1	172.25	351.95	N-T	106.80	N-T	N-T	8.70	10.00	0.055	1.00	0.95	1.94	N-T	0.59	N-T
4/11/91	B.2	89.45	190.00	N-T	N-T	N-T	N-T	8.70	10.00	0.055	1.00	0.49	1.04	N-T	N-T	N-T
4/11/91	B.3	99.75	778.25	N-T	N-T	N-T	N-T	8.80	10.00	0.055	1.00	0.55	4.28	N-T	N-T	N-T
4/11/91	B.4	354.40	654.15	N-T	N-T	N-T	N-T	8.70	10.00	0.055	1.00	1.95	3.60	N-T	N-T	N-T
4/11/91	B.5	98.15	835.15	N-T	N-T	N-T	N-D	8.75	10.00	0.055	1.00	0.54	4.59	N-T	N-T	N-T
4/11/91	T.1	483.60	415.50	N-T	N-T	N-T	N-T	8.50	10.00	0.055	1.00	2.66	2.29	N-T	N-T	N-T
4/11/91	FEED	59.50	N-T	N-T	N-T	N-T	N-T	5.60	10.00	0.055	1.00	0.33	N-T	N-T	N-T	N-T
4/11/91	FSC	916.95	N-T	N-T	N-T	N-T	N-T	5.70	10.00	0.055	1.00	5.04	N-T	N-T	N-T	N-T

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-T = NO TRACE

VFA ANALYSIS

DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SMPL WT. (g)	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE	NV.mg/g IN SMLE
6/11/91	B.1	79.35	N-T	N-D	N-D	N-T	N-D	8.80	9.00	0.055	2.00	0.97	N-T	N-D	N-D	N-T	N-D
6/11/91	B.2	148.85	N-T	N-D	N-D	N-T	N-D	8.90	10.00	0.055	2.00	1.64	N-T	N-D	N-D	N-T	N-D
6/11/91	B.3	N-D	N-T	N-T	N-T	N-T	N-T	8.80	10.00	0.055	2.00	N-D	N-T	N-T	N-T	N-T	N-T
6/11/91	B.4	224.25	N-T	N-D	N-D	N-D	N-D	8.60	10.01	0.055	2.00	2.46	N-T	N-D	N-D	N-D	N-D
6/11/91	B.5	91.20	N-T	N-D	N-D	N-T	N-D	8.70	10.01	0.055	2.00	1.00	N-T	N-D	N-D	N-T	N-D
6/11/91	T.1	290.45	N-T	N-D	N-D	N-D	N-T	8.65	10.01	0.055	2.00	3.19	N-T	N-D	N-D	N-D	N-T
6/11/91	T.2	95.80	N-T	N-T	N-T	N-T	N-T	-	10.00	0.055	2.00	1.05	N-T	N-T	N-T	N-T	N-T

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-T = NO TRACE

VFA ANALYSIS
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DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SMPL WT. (g)	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE	NV.mg/g IN SMLE
11/11/91	2.1	88.65	144.10	N-D	N-D	N-T	N-D	8.80	10.00	0.055	2.00	0.98	1.59	N-D	N-D	N-T	N-D
11/11/91	B.2	N-D	58.50	N-T	N-D	N-T	N-T	8.50	10.00	0.055	2.00	N-D	0.64	N-T	N-D	N-T	N-T
11/11/91	B.3	N-D	219.60	N-D	N-D	N-T	N-D	8.70	10.00	0.055	2.00	N-D	2.42	N-D	N-D	N-T	N-D
11/11/91	B.4	326.80	516.25	N-D	260.65	64.30	61.85	7.10	10.00	0.055	2.00	3.59	5.68	N-D	2.87	0.71	0.68
11/11/91	B.5	184.15	642.15	N-D	245.55	N-D	91.35	7.40	10.00	0.055	2.00	2.03	7.06	N-D	2.70	N-D	1.00
11/11/91	T.1	540.00	475.60	50.10	144.15	81.85	N-D	8.30	10.00	0.055	2.00	5.94	5.23	0.55	1.59	0.90	N-D
11/11/91	T.2	N-D	155.40	N-T	N-T	N-T	N-T	8.70	10.00	0.055	2.00	N-D	1.71	N-T	N-T	N-T	N-T
11/11/91	FEED	N-D	N-T	N-T	N-T	N-T	N-T	5.20	10.00	0.055	2.00	N-D	N-T	N-T	N-T	N-T	N-T
11/11/91	FE.INN.	305.20	N-T	N-T	N-T	N-T	N-T	5.30	10.00	0.055	2.00	3.36	N-T	N-T	N-T	N-T	N-T

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-T = NO TRACE

VFA ANALYSIS
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DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SMPL WT. (g)	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE	NV.mg/g IN SMLE
15/11/91	2.1	75.05	83.15	N-T	106.65	N-T	N-D	8.95	9.90	0.055	2.00	0.83	0.92	N-T	1.19	N-T	N-D
15/11/91	B.1	102.85	183.90	N-D	N-D	N-T	N-D	8.55	9.95	0.055	2.00	1.14	2.03	N-D	N-D	N-T	N-D
15/11/91	B.2	117.70	291.00	N-T	N-D	N-D	N-D	8.30	10.00	0.055	2.00	1.29	3.20	N-T	N-D	N-D	N-D
15/11/91	B.3	72.00	248.35	N-T	N-D	N-T	N-D	8.65	9.83	0.055	2.00	0.81	2.78	N-T	N-D	N-T	N-D
15/11/91	B.4	150.85	304.30	N-D	99.30	N-D	N-D	7.30	9.97	0.055	2.00	1.66	3.36	N-D	1.10	N-D	N-D
15/11/91	B.5	191.45	554.90	N-D	203.20	N-D	11.58	6.70	9.99	0.055	2.00	2.11	6.11	N-D	2.24	N-D	0.13
15/11/91	T.1	452.80	394.80	N-D	58.55	N-D	N-D	8.45	9.96	0.055	2.00	5.00	4.36	N-D	0.65	N-D	N-D
15/11/91	T.2	207.25	266.30	N-D	N-T	N-D	N-T	9.00	10.00	0.055	2.00	2.28	2.93	N-D	N-T	N-D	N-T
15/11/91	FEED	N-S	N-S	N-S	N-S	N-S	N-S		10.00	0.055	2.00	N-S	N-S	N-S	N-S	N-S	N-S
15/11/91	FE.INN.	N-D	N-T	N-T	N-T	N-T	N-T	5.95	4.17	0.055	2.00	N-D	N-T	N-T	N-T	N-T	N-T

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-S = SAMPLE NOT AVAILABLE

VFA ANALYSIS
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DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SMPL WT. (g)	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE	NV.mg/g IN SMLE
18/11/91	2.1	88.40	149.20	N-D	54.90	N-T	N-D	8.85	10.03	0.055	2.00	0.97	1.64	N-D	0.60	N-T	N-D
18/11/91	B.1	N-D	190.20	N-T	N-D	N-T	N-T	8.85	10.02	0.055	2.00	N-D	2.09	N-T	N-D	N-T	N-T
18/11/91	B.2	177.50	505.95	N-D	104.65	N-D	N-D	7.95	10.00	0.055	2.00	1.95	5.57	N-D	1.15	N-D	N-D
18/11/91	B.3	139.45	615.00	N-D	53.90	57.10	60.45	8.20	10.02	0.055	2.00	1.53	6.75	N-D	0.59	0.63	0.66
18/11/91	B.4	332.70	572.55	N-D	238.10	75.70	72.25	6.60	10.00	0.055	2.00	3.66	6.30	N-D	2.62	0.83	0.79
18/11/91	B.5	283.30	586.75	N-D	416.05	N-D	98.00	6.05	10.02	0.055	2.00	3.11	6.44	N-D	4.57	N-D	1.08
18/11/91	T.1	504.35	499.65	N-D	N-D	79.10	N-D	8.30	10.00	0.055	2.00	5.55	5.50	N-D	N-D	0.87	N-D
18/11/91	T.2	203.75	382.10	N-D	N-T	N-D	N-T	8.80	10.02	0.055	2.00	2.24	4.19	N-D	N-T	N-D	N-T
18/11/91	FEED	N-D	N-T	N-T	N-T	N-T	N-T	5.15	10.00	0.055	2.00	N-D	N-T	N-T	N-T	N-T	N-T
18/11/91	FE.INN.	220.05	N-T	N-T	N-T	N-T	N-T	5.40	10.00	0.055	2.00	2.42	N-T	N-T	N-T	N-T	N-T

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-T = NO TRACE

VFA ANALYSIS

DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SAMPLE WGHT	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE	NV.mg/g IN SMLE
22/11/91	2.1	N-D	N-D	N-T	N-D	N-T	N-D	8.40	10.00	0.055	2.00	N-D	N-D	N-T	N-D	N-T	N-D
22/11/91	B.1	69.00	236.55	N-T	N-D	N-T	N-D	7.25	10.00	0.055	2.00	0.76	2.60	N-T	N-D	N-T	N-D
22/11/91	B.2	87.00	183.30	N-T	59.10	N-T	N-D	6.50	10.00	0.055	2.00	0.96	2.02	N-T	0.65	N-T	N-D
22/11/91	B.3	127.45	218.20	N-D	120.80	N-D	N-D	6.30	10.00	0.055	2.00	1.40	2.40	N-D	1.33	N-D	N-D
22/11/91	B.4	91.20	138.45	N-T	206.70	N-T	N-D	5.50	10.00	0.055	2.00	1.00	1.52	N-T	2.27	N-T	N-D
22/11/91	B.5	130.70	71.10	N-T	213.60	N-T	N-D	5.60	10.00	0.055	2.00	1.44	0.78	N-T	2.35	N-T	N-D
22/11/91	T.1	347.80	398.50	N-D	N-D	N-D	N-D	8.30	10.00	0.055	1.00	1.91	2.19	N-D	N-D	N-D	N-D
22/11/91	T.2	124.40	205.40	N-D	N-T	N-T	N-T	8.79	10.00	0.055	2.00	1.37	2.26	N-D	N-T	N-T	N-T
22/11/91	FEED	N-D	N-T	N-T	N-T	N-T	N-T		10.00	0.055	2.00	N-D	N-T	N-T	N-T	N-T	N-T
22/11/91	FE.INN.	N-S	N-S	N-S	N-S	N-S	N-S		10.00	0.055	2.00	N-S	N-S	N-S	N-S	N-S	N-S
22/11/91	2.1 SC	N-D	100.50	N-D	109.00	N-T	N-D	8.40	10.00	0.055	2.00	N-D	1.11	N-D	1.20	N-T	N-D

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-T = NO TRACE

VFA ANALYSIS

DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SAMPLE WGHT	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE	NV.mg/g IN SMLE
25/11/91	2.1	N-D	102.75	N-T	N-D	N-T	N-D	8.55	10.00	0.055	2.00	N-D	1.13	N-T	N-D	N-T	N-D
25/11/91	B.1	68.50	273.85	N-D	101.20	N-T	N-D	8.50	10.00	0.055	2.00	0.75	3.01	N-D	1.11	N-T	N-D
25/11/91	B.2	94.30	435.80	N-D	142.05	N-D	N-D	7.55	10.00	0.055	2.00	1.04	4.79	N-D	1.56	N-D	N-D
25/11/91	B.3	186.35	599.45	N-D	277.20	N-D	69.25	6.65	10.00	0.055	2.00	2.05	6.59	N-D	3.05	N-D	0.76
25/11/91	B.4	278.05	505.65	N-D	513.95	N-D	91.40	5.70	10.00	0.055	2.00	3.06	5.56	N-D	5.65	N-D	1.01
25/11/91	B.5	242.25	378.15	N-D	698.10	N-D	101.0	5.25	10.00	0.055	2.00	2.66	4.16	N-D	7.68	N-D	1.11
25/11/91	T.1	587.25	563.20	55.30	257.95	50.15	75.25	7.60	10.00	0.055	2.00	6.46	6.20	0.61	2.84	0.55	0.83
25/11/91	T.2	163.15	410.40	N-D	N-D	N-D	N-T	8.65	10.00	0.055	2.00	1.79	4.51	N-D	N-D	N-D	N-T
25/11/91	FEED	N-D	N-T	N-T	N-T	N-T	N-T	4.90	10.00	0.055	2.00	N-D	N-T	N-T	N-T	N-T	N-T
25/11/91	FE.INN.	348.40	N-D	N-T	N-D	N-T	N-T	5.55	10.00	0.055	2.00	3.83	N-D	N-T	N-D	N-T	N-T

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-T = NO TRACE

VFA ANALYSIS
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DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SAMPLE WGHT	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE	NV.mg/g IN SMLE
29/11/91	2.1	N-D	N-T	N-T	N-T	N-T	N-T	8.50	10.08	0.055	2.00	N-D	N-T	N-T	N-T	N-T	N-T
29/11/91	B.1	N-D	88.65	N-T	N-T	N-T	N-T	8.50	10.07	0.055	2.00	N-D	0.97	N-T	N-T	N-T	N-T
29/11/91	B.2	N-T	126.55	N-T	N-T	N-T	2.10	8.40	10.59	0.055	2.00	N-T	1.31	N-T	N-T	N-T	0.02
29/11/91	B.3	310.70	558.95	N-D	N-D	N-D	62.95	7.20	10.04	0.055	2.00	3.40	6.12	N-D	N-D	N-D	0.69
29/11/91	B.4	358.15	494.80	N-D	449.40	N-D	112.5	5.90	10.10	0.055	2.00	3.90	5.39	N-D	4.89	N-D	1.23
29/11/91	B.5	347.85	389.85	N-D	481.10	N-D	147.9	5.80	10.01	0.055	2.00	3.82	4.28	N-D	5.29	N-D	1.62
29/11/91	T.1	N-S	N-S	N-S	N-S	N-S	N-S		10.16	0.055	2.00	N-S	N-S	N-S	N-S	N-S	N-S
29/11/91	T.2	N-S	N-S	N-S	N-S	N-S	N-S		10.12	0.055	2.00	N-S	N-S	N-S	N-S	N-S	N-S
29/11/91	FEED	100.00	N-D	N-T	N-T	N-T	N-T	6.30	10.00	0.055	2.00	1.10	N-D	N-T	N-T	N-T	N-T
29/11/91	FE.INN.	61.35	N-D	N-T	N-T	N-T	N-T	6.60	10.04	0.055	2.00	0.67	N-D	N-T	N-T	N-T	N-T

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-T = NO TRACE

VFA ANALYSIS
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DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SAMPLE WGHT	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE	NV.mg/g IN SMLE
2/12/91	2.1	N-D	N-D	N-T	N-T	N-T	N-T	8.80	10.10	0.055	2.00	N-D	N-D	N-T	N-T	N-T	N-T
2/12/91	B.1	55.35	64.00	N-T	N-T	N-T	N-T	8.90	10.20	0.055	2.00	0.60	0.69	N-T	N-T	N-T	N-T
2/12/91	B.2	N-D	335.65	N-T	N-T	N-T	N-T	8.70	10.22	0.055	2.00	0.00	3.61	N-T	N-T	N-T	N-T
2/12/91	B.3	163.75	549.50	N-D	N-D	N-D	63.35	8.10	10.13	0.055	2.00	1.78	5.97	N-D	N-D	N-D	0.69
2/12/91	B.4	297.05	537.30	N-D	493.05	N-D	118.8	6.20	10.00	0.055	2.00	3.27	5.91	N-D	5.42	N-D	1.31
2/12/91	B.5	377.80	428.30	N-D	495.85	N-D	163.6	6.00	10.00	0.055	2.00	4.16	4.71	N-D	5.45	N-D	1.80
2/12/91	T.1	463.45	535.40	N-D	316.00	N-D	96.80	7.00	10.13	0.055	2.00	5.03	5.81	N-D	3.43	N-D	1.05
2/12/91	T.2	308.85	278.20	N-D	N-D	N-D	N-T	8.70	10.07	0.055	2.00	3.37	3.04	N-D	N-D	N-D	N-T
2/12/91	FEED	243.00	N-D	N-T	N-D	N-T	N-T	6.00	10.02	0.055	2.00	2.67	N-D	N-T	N-D	N-T	N-T
2/12/91	FE.INN.	N-S	N-S	N-S	N-S	N-S	N-S		10.00	0.055	2.00	N-S	N-S	N-S	N-S	N-S	N-S

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-T = NO TRACE

VFA ANALYSIS
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DATE OF SAMPLE	SAMPLE #	ACETIC mg/l	PROP. mg/l	IBUT. mg/l	NBUT. mg/l	IVAL mg/l	NVAL. mg/l	PH	SAMPLE WGHT	EXTRACT (L)	DILL. FACT.	AC.mg/g IN SMLE	PR.mg/g IN SMLE	IB.mg/g IN SMLE	NB.mg/g IN SMLE	IV.mg/g IN SMLE	NV.mg/g IN SMLE
6/12/91	2.1	67.70	183.40	N-T	N-T	N-T	N-T	8.70	10.03	0.055	2.00	0.74	2.01	N-T	N-T	N-T	N-T
6/12/91	B.1	52.15	N-D	N-T	N-T	N-T	N-T	8.90	10.10	0.055	2.00	0.57	0.00	N-T	N-T	N-T	N-T
6/12/91	B.2	52.10	182.30	N-T	N-T	N-T	N-T	8.80	10.17	0.055	2.00	0.56	1.97	N-T	N-T	N-T	N-T
6/12/91	B.3	230.65	485.60	N-D	N-D	N-D	N-D	8.70	10.05	0.055	2.00	2.52	5.32	N-D	N-D	N-D	N-D
6/12/91	B.4	417.65	440.05	N-D	447.10	N-D	111.1	7.10	10.17	0.055	2.00	4.52	4.76	N-D	4.84	N-D	1.20
6/12/91	B.5	399.85	321.80	N-D	306.30	N-D	107.2	7.50	10.10	0.055	2.00	4.35	3.50	N-D	3.34	N-D	1.17
6/12/91	T.1	446.75	51.80	140.0	N-D	78.15	N-T	8.00	10.07	0.055	2.00	4.88	0.57	1.53	N-D	0.85	N-T
6/12/91	T.2	337.95	267.25	N-D	N-D	N-D	N-T	8.70	10.39	0.055	2.00	3.58	2.83	N-D	N-D	N-D	N-T
6/12/91	FEED	236.70	N-D	N-T	N-T	N-T	N-T	5.90	10.46	0.055	2.00	2.49	N-D	N-T	N-T	N-T	N-T
6/12/91	FE.INN.	130.30	N-D	N-T	N-T	N-T	N-T	8.50	10.34	0.055	2.00	1.39	N-D	N-T	N-T	N-T	N-T

NOTE N-D = NOT DETECTABLE, LESS THAN 10 mg/g.
N-T = NO TRACE

APPENDIX C-5

NH3-N & TKN

TKN AND NH3-N ANALYSIS
DAD SAMPLES
DATE OF SAMPLE :C.S. 4/6/8 NOV.1991

DIG	Sample Wieght TKN	HCl for Sample TKN	HCl for Blank TKN	Conc. of HCl	M.W. of HCl	TKN g/Kg. (wet)	Sample Wieght NH3-N	HCl for Sample NH3-N	HCl for Blank NH3-N	Conc. of HCl NH3-N	NH3-N g/Kg. (wet)
2-1	2.30	6.70	0.12	0.10	14.01	4.01	3.10	22.14	0.52	0.01	0.98
B1	1.09	4.17	0.12	0.10	14.01	5.22	3.07	30.58	0.52	0.01	1.37
B2	1.10	3.99	0.12	0.10	14.01	4.92	3.37	31.08	0.52	0.01	1.27
B3	1.10	3.66	0.12	0.10	14.01	4.50	3.45	31.43	0.52	0.01	1.26
B4	1.43	4.91	0.12	0.10	14.01	4.71	3.75	34.56	0.52	0.01	1.27
B5	1.09	3.98	0.12	0.10	14.01	4.98	3.16	31.45	0.52	0.01	1.37
T1	1.42	4.96	0.12	0.10	14.01	4.76	3.53	44.46	0.52	0.01	1.74
T2	1.67	5.94	0.12	0.10	14.01	4.87	3.28	42.76	0.52	0.01	1.80
FEED	1.27	4.56	0.12	0.10	14.01	4.90	3.63	3.53	0.52	0.01	0.12
FEED IN.	1.58	5.51	0.12	0.10	14.01	4.79	3.42	4.69	0.52	0.01	0.17

TKN AND NH3-N ANALYSIS
DAD SAMPLES
DATE OF SAMPLE :C.S. 11/13 NOV.1991

DIG	Sample Wieght TKN	HCl for Sample TKN	HCl for Blank TKN	Conc. of HCl	M.W. of HCl	TKN g/Kg. (wet)	Sample Wieght NH3-N	HCl for Sample NH3-N	HCl for Blank NH3-N	NH3-N g/Kg. (wet)
2-1	6.44	18.85	0.10	0.10	14.01	4.08	5.73	4.73	0.03	1.15
B1	4.23	13.42	0.10	0.10	14.01	4.41	5.16	4.98	0.03	1.34
B2	4.64	15.04	0.10	0.10	14.01	4.51	6.63	6.49	0.03	1.36
B3	5.34	15.41	0.10	0.10	14.01	4.02	5.77	5.49	0.03	1.33
B4	4.26	14.51	0.10	0.10	14.01	4.74	4.17	4.54	0.03	1.52
B5	4.31	14.73	0.10	0.10	14.01	4.76	4.50	4.66	0.03	1.44
T1	4.15	14.15	0.10	0.10	14.01	4.74	4.33	7.77	0.03	2.51
T2	4.16	13.62	0.10	0.10	14.01	4.55	4.42	5.78	0.03	1.82
FEED	4.33	12.42	0.10	0.10	14.01	3.98	5.77	0.63	0.03	0.14
FEED IN.	4.00	11.61	0.10	0.10	14.01	4.03	4.97	0.65	0.03	0.17

TKN AND NH3-N ANALYSIS
DAD SAMPLES
DATE OF SAMPLE :C.S. 18/20/22 NOV.91

DIG	Sample Wieght TKN	HCl for Sample TKN	HCl for Blank TKN	Conc. of HCl	M.W. of HCl	TKN g/Kg. (wet)	Sample Wieght NH3-N	HCl for Sample NH3-N	HCl for Blank NH3-N	NH3-N g/Kg. (wet)
2-1	3.15	9.78	0.25	0.10	14.01	4.23	2.99	2.20	0.02	1.02
B1	3.32	10.86	0.25	0.10	14.01	4.48	3.25	2.92	0.02	1.25
B2	3.11	10.35	0.25	0.10	14.01	4.55	3.13	3.04	0.02	1.35
B3	3.42	11.26	0.25	0.10	14.01	4.51	3.02	3.41	0.02	1.57
B4	3.21	11.53	0.25	0.10	14.01	4.93	3.32	4.02	0.02	1.68
B5	3.34	11.76	0.25	0.10	14.01	4.83	3.12	3.33	0.02	1.49
T1	3.12	10.98	0.25	0.10	14.01	4.82	3.25	5.07	0.02	2.18
T2	3.06	8.06	0.25	0.10	14.01	3.58	2.99	3.44	0.02	1.60
FEED	3.41	10.33	0.25	0.10	14.01	4.15	3.16	0.39	0.02	0.16
FEED IN.	3.22	10.56	0.25	0.10	14.01	4.49	3.13	0.70	0.02	0.30

TKN AND NH3-N ANALYSIS
DAD SAMPLES
DATE OF SAMPLE :C.S. 25/27/29 NOV.91

DIG	Sample Wieght TKN	HCl for Sample TKN	HCl for Blank TKN	Conc. of HCl	M.W. of HCl	TKN g/Kg. (wet)	Sample Wieght NH3-N	HCl for Sample NH3-N	HCl for Blank NH3-N	NH3-N g/Kg. (wet)
2-1	3.15	10.08	0.04	0.10	14.01	4.47	3.40	3.11	0.02	1.27
B1	3.35	10.68	0.04	0.10	14.01	4.45	3.41	3.36	0.02	1.37
B2	2.93	9.93	0.04	0.10	14.01	4.72	3.48	3.00	0.02	1.20
B3	3.00	9.67	0.04	0.10	14.01	4.49	3.14	3.82	0.02	1.69
B4	3.10	10.65	0.04	0.10	14.01	4.80	3.10	3.28	0.02	1.48
B5	3.00	9.43	0.04	0.10	14.01	4.38	3.08	2.85	0.02	1.29
T1	3.22	10.50	0.04	0.10	14.01	4.55	3.11	4.79	0.02	2.15
T2	3.79	11.28	0.04	0.10	14.01	4.16	3.23	4.28	0.02	1.85
FEED	3.30	16.34	0.04	0.10	14.01	6.92	3.48	0.41	0.02	0.16
FEED IN.	3.29	23.33	0.04	0.10	14.01	9.93	3.52	0.74	0.02	0.28

TKN AND NH3-N ANALYSIS
DAD SAMPLES
DATE OF SAMPLE :C.S. 2/4/6 DEC.91

DIG	Sample Wieght TKN	HCl for Sample TKN	HCl for Blank TKN	Conc. of HCl	M.W. of HCl	TKN g/Kg. (wet)	Sample Wieght NH3-N	HCl for Sample NH3-N	HCl for Blank NH3-N	NH3-N g/Kg. (wet)
2-1	3.72	12.29	0.06	0.10	14.01	4.61	3.05	1.99	0.02	0.91
B1	3.18	9.61	0.06	0.10	14.01	4.21	3.17	2.33	0.02	1.02
B2	3.43	7.85	0.06	0.10	14.01	3.18	3.09	2.68	0.02	1.21
B3	3.35	10.24	0.06	0.10	14.01	4.26	3.00	3.52	0.02	1.64
B4	3.35	10.98	0.06	0.10	14.01	4.57	3.14	3.22	0.02	1.43
B5	3.14	10.28	0.06	0.10	14.01	4.56	3.28	3.07	0.02	1.30
T1	3.33	12.18	0.06	0.10	14.01	5.09	3.73	5.79	0.02	2.17
T2	3.34	11.04	0.06	0.10	14.01	4.60	3.60	4.57	0.02	1.77
FEED	3.07	9.31	0.06	0.10	14.01	4.22	3.01	0.26	0.02	0.12
FEED IN.	3.40	9.60	0.06	0.10	14.01	3.92	3.23	0.26	0.02	0.11

APPENDIX C-6

COLIFORM (MPN) DATA

COLIFORM (MPN) ANALYSIS

SAMPLE : PLAIN FEEDSTOCK (FS)

DATE	MPN	LOG MPN	AVG LOG MPN	STD DEV.
JUNE-06-91	7.00E+03	3.85	3.63	1.15
JUNE-13-91	5.00E+04	4.70		
JUNE-20-91	5.00E+04	4.70		
JUNE-24-91	1.60E+06	6.20		
JUNE-27-91	2.00E+03	3.30		
JULY-04-91	2.00E+03	3.30		
JULY-08-91	1.30E+04	4.11		
JULY-11-91	8.00E+03	3.90		
JULY-15-91	2.00E+02	2.30		
JULY-22-91	4.00E+02	2.60		
JULY-29-91	2.00E+02	2.30		
AUG.-01-91	2.00E+02	2.30		

COLIFORM (MPN) ANALYSIS

SAMPLE : M7 COMPOST

DATE	MPN	LOG MPN	AVG LOG MPN	STD DEV.
JUNE-17-91	3.00E+07	7.48	6.40	1.09
JUNE-20-91	4.10E+07	7.61		
JUNE-24-91	4.73E+07	7.68		
JUNE-27-91	7.00E+05	5.85		
JULY-04-91	2.25E+05	5.35		
JULY-08-91	2.57E+06	6.41		
JULY-11-91	7.14E+06	6.85		
JULY-15-91	2.00E+04	4.30		
JULY-18-91	4.00E+04	4.60		
JULY-22-91	6.32E+05	5.80		
JULY-25-91	1.17E+07	7.07		
JULY-29-91	8.00E+06	6.90		
AUG.-01-91	2.30E+07	7.36		

COLIFORM (MPN) ANALYSIS

SAMPLE : INOCULATED FEEDSTOCK (FSC)

DATE	MPN	LOG MPN	AVG LOG MPN	STD DEV.
NOV.-18-91	1.60E+17	17.20	17.36	2.76
NOV.-21-91	1.60E+13	13.20		
DEC.-02-91	8.00E+20	20.90		
DEC.-08-91	1.30E+18	18.11		

COLIFORM (MPN) ANALYSIS

SAMPLE : M4 COMPOST

DATE	MPN	LOG MPN	AVG LOG MPN	STD DEV.
NOV.-18-91	1.30E+07	7.11	7.40	0.30
NOV.-21-91	2.30E+07	7.36		
DEC.-02-91	1.70E+07	7.23		
DEC.-08-91	8.00E+07	7.90		

COLIFORM (MPN) ANALYSIS
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SAMPLE : M5 COMPOST
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DATE	MPN	LOG MPN	AVG LOG MPN	STD DEV.
NOV.-18-91	2.00E+10	10.30	7.86	1.48
NOV.-21-91	2.00E+06	6.30		
DEC.-02-91	2.40E+07	7.38		
DEC.-08-91	3.00E+07	7.48		

COLIFORM (MPN) ANALYSIS
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SAMPLE : T1 COMPOST
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DATE	MPN	LOG MPN	AVG LOG MPN	STD DEV.
NOV.-18-91	2.00E+08	8.30	7.90	0.38
NOV.-21-91	2.40E+07	7.38		
DEC.-02-91	1.60E+08	8.20		
DEC.-08-91	5.00E+07	7.70		

APPENDIX C-7

CUMULATIVE OXYGEN CONSUMPTION (COC) DATA

BATCH 1 - COC ANALYSIS: CYCLE 1
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DATE OF ANALYSIS = MON/03/FEB/1992
ROOM TEMPERATURE = 20 DEG C 20.000
ROOM PRESSURE   = 757 mm Hg = 757/760 ATM
GC ATTENUATION   = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	51.900	0.996	0.001	0.083	293.000	0.041	41.156
0.600	0.126	30.900	0.996	0.001	0.083	293.000	0.025	24.694
0.300	0.063	15.500	0.996	0.000	0.083	293.000	0.012	12.347
0.000	0.000	0.000	0.996	0.000	0.083	293.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2
17:50	0.000	B1 101-1	50.200	1.000	0.040	159.000	6.343	0.040	0.000	0.000
	0.000	B1 101-2	51.000	1.000	0.041	159.000	6.444	0.041	0.000	0.000
	0.000	B2 102-1	50.000	1.000	0.040	159.000	6.318	0.040	0.000	0.000
	0.000	B2 102-2	50.500	1.000	0.040	159.000	6.381	0.040	0.000	0.000
	0.000	B3 103-1	50.200	1.000	0.040	159.000	6.343	0.040	0.000	0.000
	0.000	B3 103-2	50.000	1.000	0.040	159.000	6.318	0.040	0.000	0.000
	0.000	B4 104-1	49.500	1.000	0.039	159.000	6.255	0.039	0.000	0.000
	0.000	B4 104-2	50.200	1.000	0.040	159.000	6.343	0.040	0.000	0.000
	0.000	B5 105-1	50.000	1.000	0.040	159.000	6.318	0.040	0.000	0.000
	0.000	B5 105-2	50.500	1.000	0.040	159.000	6.381	0.040	0.000	0.000
	0.000	T1 106-1	49.500	1.000	0.039	159.000	6.255	0.039	0.000	0.000
	0.000	T1 106-2	50.500	1.000	0.040	159.000	6.381	0.040	0.000	0.000
	0.000	T2 107-1	50.000	1.000	0.040	159.000	6.318	0.040	0.000	0.000
	0.000	T2 107-2	50.000	1.000	0.040	159.000	6.318	0.040	0.000	0.000

BATCH 1 - COC ANALYSIS: CYCLE 1
==============================

DATE OF ANALYSIS = TUE/04/FEB/1992
ROOM TEMPERATURE = 20 DEG C 22.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	51.400	0.996	0.001	0.083	295.000	0.041	40.877
0.600	0.126	30.500	0.996	0.001	0.083	295.000	0.025	24.526
0.300	0.063	15.600	0.996	0.000	0.083	295.000	0.012	12.263
0.000	0.000	0.000	0.996	0.000	0.083	295.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
16:32	22.700	B1 101-1	29.500	1.000	0.023	159.000	3.728	0.023	2.576	2.576	3.200	0.805
	22.700	B1 101-2	29.500	1.000	0.023	159.000	3.728	0.023	2.676	2.676	3.200	0.836
	22.700	B2 102-1	33.000	1.000	0.026	159.000	4.170	0.026	2.108	2.108	3.150	0.669
	22.700	B2 102-2	33.500	1.000	0.027	159.000	4.233	0.027	2.108	2.108	3.150	0.669
	22.700	B3 103-1	31.800	1.000	0.025	159.000	4.018	0.025	2.285	2.285	2.822	0.810
	22.700	B3 103-2	32.000	1.000	0.025	159.000	4.044	0.025	2.235	2.235	2.822	0.792
	22.700	B4 104-1	48.500	1.000	0.039	159.000	6.129	0.039	0.087	0.087	2.900	0.030
	22.700	B4 104-2	47.500	1.000	0.038	159.000	6.002	0.038	0.301	0.301	2.900	0.104
	22.700	B5 105-1	35.000	1.000	0.028	159.000	4.423	0.028	1.856	1.856	2.900	0.640
	22.700	B5 105-2	35.500	1.000	0.028	159.000	4.486	0.028	1.855	1.855	2.900	0.640
	22.700	T1 106-1	39.000	1.000	0.031	159.000	4.928	0.031	1.287	1.287	2.450	0.525
	22.700	T1 106-2	39.000	1.000	0.031	159.000	4.928	0.031	1.413	1.413	2.450	0.577
	22.700	T2 107-1	26.900	1.000	0.021	159.000	3.399	0.021	2.879	2.879	2.700	1.066
	22.700	T2 107-2	28.000	1.000	0.022	159.000	3.538	0.022	2.740	2.740	2.700	1.015

BATCH 1 - COC ANALYSIS: CYCLE 1
==============================

DATE OF ANALYSIS = WED/05/FEB/1992
ROOM TEMPERATURE = 22 DEG C 22.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	51.950	0.996	0.001	0.083	295.000	0.041	40.877
0.600	0.126	30.800	0.996	0.001	0.083	295.000	0.025	24.526
0.300	0.063	15.500	0.996	0.000	0.083	295.000	0.012	12.263
0.000	0.000	0.000	0.996	0.000	0.083	295.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
12:40	42.833	B1 101-1	10.800	1.000	0.009	159.000	1.365	0.009	2.340	4.915	3.200	1.536
	42.833	B1 101-2	11.500	1.000	0.009	159.000	1.453	0.009	2.251	4.927	3.200	1.540
	42.833	B2 102-1	16.000	1.000	0.013	159.000	2.022	0.013	2.122	4.230	3.150	1.343
	42.833	B2 102-2	16.500	1.000	0.013	159.000	2.085	0.013	2.122	4.230	3.150	1.343
	42.833	B3 103-1	13.500	1.000	0.011	159.000	1.706	0.011	2.287	4.572	2.822	1.620
	42.833	B3 103-2	13.500	1.000	0.011	159.000	1.706	0.011	2.312	4.547	2.822	1.611
	42.833	B4 104-1	42.900	1.000	0.034	159.000	5.421	0.034	0.669	0.756	2.900	0.261
	42.833	B4 104-2	43.000	1.000	0.034	159.000	5.434	0.034	0.531	0.832	2.900	0.287
	42.833	B5 105-1	24.000	1.000	0.019	159.000	3.033	0.019	1.362	3.218	2.900	1.110
	42.833	B5 105-2	24.500	1.000	0.019	159.000	3.096	0.019	1.362	3.217	2.900	1.109
	42.833	T1 106-1	28.500	1.000	0.023	159.000	3.601	0.023	1.296	2.583	2.450	1.054
	42.833	T1 106-2	28.500	1.000	0.023	159.000	3.601	0.023	1.296	2.709	2.450	1.106
	42.833	T2 107-1	8.900	1.000	0.007	159.000	1.125	0.007	2.253	5.132	2.700	1.901
	42.833	T2 107-2	8.400	1.000	0.007	159.000	1.061	0.007	2.454	5.195	2.700	1.924

BATCH 1 - COC ANALYSIS: CYCLE 2
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DATE OF ANALYSIS = WED/05/FEB/1992 (FOLLOWING REFLUSH)
ROOM TEMPERATURE = 22 DEG C 22.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	51.950	0.996	0.001	0.083	295.000	0.041	40.877
0.600	0.126	30.800	0.996	0.001	0.083	295.000	0.025	24.526
0.300	0.063	15.500	0.996	0.000	0.083	295.000	0.012	12.263
0.000	0.000	0.000	0.996	0.000	0.083	295.000	0.000	0.000

Regression Output:		
Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
15:47	42.833	B1 101-1	48.800	1.000	0.039	159.000	6.166	0.039	0.000	4.915	3.200	1.536
	42.833	B1 101-2	49.000	1.000	0.039	159.000	6.192	0.039	0.000	4.927	3.200	1.540
	42.833	B2 102-1	48.800	1.000	0.039	159.000	6.166	0.039	0.000	4.230	3.150	1.343
	42.833	B2 102-2	48.800	1.000	0.039	159.000	6.166	0.039	0.000	4.230	3.150	1.343
	42.833	B3 103-1	48.800	1.000	0.039	159.000	6.166	0.039	0.000	4.572	2.822	1.620
	42.833	B3 103-2	48.000	1.000	0.038	159.000	6.065	0.038	0.000	4.547	2.822	1.611
	42.833	B4 104-1	49.000	1.000	0.039	159.000	6.192	0.039	0.000	0.756	2.900	0.261
	42.833	B4 104-2	48.500	1.000	0.039	159.000	6.129	0.039	0.000	0.832	2.900	0.287
	42.833	B5 105-1	49.500	1.000	0.039	159.000	6.255	0.039	0.000	3.218	2.900	1.110
	42.833	B5 105-2	48.500	1.000	0.039	159.000	6.129	0.039	0.000	3.217	2.900	1.109
	42.833	T1 106-1	49.500	1.000	0.039	159.000	6.255	0.039	0.000	2.583	2.450	1.054
	42.833	T1 106-2	48.200	1.000	0.038	159.000	6.091	0.038	0.000	2.709	2.450	1.106
	42.833	T2 107-1	48.500	1.000	0.039	159.000	6.129	0.039	0.000	5.132	2.700	1.901
	42.833	T2 107-2	47.500	1.000	0.038	159.000	6.002	0.038	0.000	5.195	2.700	1.924

BATCH 1 - COC ANALYSIS: CYCLE 2
==============================

DATE OF ANALYSIS = TH/06/FEB/1992
ROOM TEMPERATURE = 22 DEG C 22.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
===================

STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	52.500	0.996	0.001	0.083	295.000	0.041	40.877
0.600	0.126	31.200	0.996	0.001	0.083	295.000	0.025	24.526
0.300	0.063	15.500	0.996	0.000	0.083	295.000	0.012	12.263
0.000	0.000	0.000	0.996	0.000	0.083	295.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
15:00	66.050	B1 101-1	33.500	1.000	0.027	159.000	4.233	0.027	1.895	6.810	3.200	2.128
	66.050	B1 101-2	33.500	1.000	0.027	159.000	4.233	0.027	1.920	6.847	3.200	2.140
	66.050	B2 102-1	28.500	1.000	0.023	159.000	3.601	0.023	2.526	6.757	3.150	2.145
	66.050	B2 102-2	29.500	1.000	0.023	159.000	3.728	0.023	2.400	6.629	3.150	2.105
	66.050	B3 103-1	27.200	1.000	0.022	159.000	3.437	0.022	2.691	7.263	2.822	2.574
	66.050	B3 103-2	27.800	1.000	0.022	159.000	3.513	0.022	2.514	7.061	2.822	2.502
	66.050	B4 104-1	21.200	1.000	0.017	159.000	2.679	0.017	3.474	4.230	2.900	1.459
	66.050	B4 104-2	23.500	1.000	0.019	159.000	2.969	0.019	3.120	3.953	2.900	1.363
	66.050	B5 105-1	40.000	1.000	0.032	159.000	5.054	0.032	1.161	4.379	2.900	1.510
	66.050	B5 105-2	41.000	1.000	0.033	159.000	5.181	0.033	0.909	4.126	2.900	1.423
	66.050	T1 106-1	39.500	1.000	0.031	159.000	4.991	0.031	1.224	3.808	2.450	1.554
	66.050	T1 106-2	40.000	1.000	0.032	159.000	5.054	0.032	0.998	3.707	2.450	1.513
	66.050	T2 107-1	27.500	1.000	0.022	159.000	3.475	0.022	2.615	7.747	2.700	2.869
	66.050	T2 107-2	28.600	1.000	0.023	159.000	3.614	0.023	2.350	7.545	2.700	2.794

BATCH 1 - COC ANALYSIS: CYCLE 2
===============================

DATE OF ANALYSIS = FRI/07/FEB/1992
ROOM TEMPERATURE = 22 DEG C 22.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
====================

STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	50.800	0.996	0.001	0.083	295.000	0.041	40.877
0.600	0.126	30.900	0.996	0.001	0.083	295.000	0.025	24.526
0.300	0.063	15.800	0.996	0.000	0.083	295.000	0.012	12.263
0.000	0.000	0.000	0.996	0.000	0.083	295.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	*NORMAL CUM COC mmol/g TS
12:38	87.683	B1 101-1	26.000	1.000	0.021	159.000	3.285	0.021	0.921	7.731	3.200	2.416
	87.683	B1 101-2	25.400	1.000	0.020	159.000	3.210	0.020	0.997	7.844	3.200	2.451
	87.683	B2 102-1	17.500	1.000	0.014	159.000	2.211	0.014	1.367	8.124	3.150	2.579
	87.683	B2 102-2	17.000	1.000	0.014	159.000	2.148	0.014	1.556	8.186	3.150	2.599
	87.683	B3 103-1	15.500	1.000	0.012	159.000	1.959	0.012	1.457	8.720	2.822	3.090
	87.683	B3 103-2	15.500	1.000	0.012	159.000	1.959	0.012	1.532	8.593	2.822	3.045
	87.683	B4 104-1	8.800	1.000	0.007	159.000	1.112	0.007	1.550	5.780	2.900	1.993
	87.683	B4 104-2	9.000	2.000	0.007	159.000	1.137	0.014	1.814	5.766	2.900	1.988
	87.683	B5 105-1	33.000	1.000	0.026	159.000	4.170	0.026	0.853	5.232	2.900	1.804
	87.683	B5 105-2	34.000	1.000	0.027	159.000	4.296	0.027	0.852	4.978	2.900	1.717
	87.683	T1 106-1	31.200	1.000	0.025	159.000	3.942	0.025	1.017	4.825	2.450	1.969
	87.683	T1 106-2	31.800	1.000	0.025	159.000	4.018	0.025	1.004	4.711	2.450	1.923
	87.683	T2 107-1	18.000	1.000	0.014	159.000	2.274	0.014	1.179	8.926	2.700	3.306
	87.683	T2 107-2	18.500	1.000	0.015	159.000	2.338	0.015	1.254	8.799	2.700	3.259

BATCH 1 - COC ANALYSIS: CYCLE 3
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DATE OF ANALYSIS = FRI/07/FEB/1992 (FOLLOWING REFLUSH)
ROOM TEMPERATURE = 22 DEG C 22.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P. (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	50.800	0.996	0.001	0.083	295.000	0.041	40.877
0.600	0.126	30.900	0.996	0.001	0.083	295.000	0.025	24.526
0.300	0.063	15.800	0.996	0.000	0.083	295.000	0.012	12.263
0.000	0.000	0.000	0.996	0.000	0.083	295.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
15:31	87.683	B1 101-1	49.200	1.000	0.039	159.000	6.217	0.039	0.000	7.731	3.200	2.416
	87.683	B1 101-2	49.000	1.000	0.039	159.000	6.192	0.039	0.000	7.844	3.200	2.451
	87.683	B2 102-1	48.800	1.000	0.039	159.000	6.166	0.039	0.000	8.124	3.150	2.579
	87.683	B2 102-2	49.800	1.000	0.040	159.000	6.293	0.040	0.000	8.186	3.150	2.599
	87.683	B3 103-1	49.800	1.000	0.040	159.000	6.293	0.040	0.000	8.720	2.822	3.090
	87.683	B3 103-2	48.500	1.000	0.039	159.000	6.129	0.039	0.000	8.593	2.822	3.045
	87.683	B4 104-1	47.600	1.000	0.038	159.000	6.015	0.038	0.000	5.780	2.900	1.993
	87.683	B4 104-2	47.500	1.000	0.038	159.000	6.002	0.038	0.000	5.766	2.900	1.988
	87.683	B5 105-1	49.200	1.000	0.039	159.000	6.217	0.039	0.000	5.232	2.900	1.804
	87.683	B5 105-2	49.000	1.000	0.039	159.000	6.192	0.039	0.000	4.978	2.900	1.717
	87.683	T1 106-1	49.200	1.000	0.039	159.000	6.217	0.039	0.000	4.825	2.450	1.969
	87.683	T1 106-2	49.600	1.000	0.039	159.000	6.268	0.039	0.000	4.711	2.450	1.923
	87.683	T2 107-1	48.400	1.000	0.038	159.000	6.116	0.038	0.000	8.926	2.700	3.306
	87.683	T2 107-2	48.800	1.000	0.039	159.000	6.166	0.039	0.000	8.799	2.700	3.259

BATCH 1 - COC ANALYSIS: CYCLE 3
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DATE OF ANALYSIS = SAT/08/FEB/1992
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	57.000	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	34.400	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	17.100	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
13:00	109.167	B1 101-1	46.200	1.000	0.037	159.000	5.838	0.037	0.340	8.071	3.200	2.522
	109.167	B1 101-2	46.600	1.000	0.037	159.000	5.888	0.037	0.264	8.108	3.200	2.534
	109.167	B2 102-1	38.500	1.000	0.031	159.000	4.865	0.031	1.263	9.387	3.150	2.980
	109.167	B2 102-2	38.000	1.000	0.030	159.000	4.802	0.030	1.451	9.637	3.150	3.059
	109.167	B3 103-1	40.000	1.000	0.032	159.000	5.054	0.032	1.199	9.918	2.822	3.515
	109.167	B3 103-2	40.000	1.000	0.032	159.000	5.054	0.032	1.036	9.629	2.822	3.412
	109.167	B4 104-1	40.500	1.000	0.032	159.000	5.118	0.032	0.859	6.639	2.900	2.289
	109.167	B4 104-2	41.500	1.000	0.033	159.000	5.244	0.033	0.720	6.487	2.900	2.237
	109.167	B5 105-1	46.800	1.000	0.037	159.000	5.914	0.037	0.264	5.496	2.900	1.895
	109.167	B5 105-2	47.000	1.000	0.037	159.000	5.939	0.037	0.214	5.192	2.900	1.790
	109.167	T1 106-1	46.500	1.000	0.037	159.000	5.876	0.037	0.302	5.127	2.450	2.093
	109.167	T1 106-2	46.500	1.000	0.037	159.000	5.876	0.037	0.352	5.063	2.450	2.067
	109.167	T2 107-1	44.000	1.000	0.035	159.000	5.560	0.035	0.518	9.443	2.700	3.498
	109.167	T2 107-2	43.500	1.000	0.035	159.000	5.497	0.035	0.631	9.430	2.700	3.492

BATCH 1 - COC ANALYSIS: CYCLE 3

DATE OF ANALYSIS = SUN/09/FEB/1992
ROOM TEMPERATURE = 20 DEG C 20.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:

STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	56.300	0.996	0.001	0.083	293.000	0.041	41.156
0.600	0.126	33.400	0.996	0.001	0.083	293.000	0.025	24.694
0.300	0.063	16.800	0.996	0.000	0.083	293.000	0.012	12.347
0.000	0.000	0.000	0.996	0.000	0.083	293.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
10:45	130.917	B1 101-1	37.200	1.000	0.030	159.000	4.701	0.030	1.101	9.171	3.200	2.866
	130.917	B1 101-2	37.800	1.000	0.030	159.000	4.776	0.030	1.075	9.183	3.200	2.870
	130.917	B2 102-1	24.500	1.000	0.019	159.000	3.096	0.019	1.738	11.125	3.150	3.532
	130.917	B2 102-2	24.400	1.000	0.019	159.000	3.083	0.019	1.688	11.325	3.150	3.595
	130.917	B3 103-1	27.000	1.000	0.021	159.000	3.412	0.021	1.611	11.529	2.822	4.086
	130.917	B3 103-2	27.000	1.000	0.021	159.000	3.412	0.021	1.611	11.240	2.822	3.983
	130.917	B4 104-1	28.500	1.000	0.023	159.000	3.601	0.023	1.484	8.123	2.900	2.801
	130.917	B4 104-2	30.800	1.000	0.024	159.000	3.892	0.024	1.319	7.806	2.900	2.692
	130.917	B5 105-1	38.400	1.000	0.031	159.000	4.852	0.031	1.024	6.520	2.900	2.248
	130.917	B5 105-2	39.000	1.000	0.031	159.000	4.928	0.031	0.974	6.165	2.900	2.126
	130.917	T1 106-1	37.000	1.000	0.029	159.000	4.675	0.029	1.163	6.290	2.450	2.568
	130.917	T1 106-2	38.000	1.000	0.030	159.000	4.802	0.030	1.037	6.100	2.450	2.490
	130.917	T2 107-1	37.000	1.000	0.029	159.000	4.675	0.029	0.850	10.293	2.700	3.812
	130.917	T2 107-2	36.500	1.000	0.029	159.000	4.612	0.029	0.850	10.280	2.700	3.807

BATCH 1 - COC ANALYSIS: CYCLE 3
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DATE OF ANALYSIS = MON/10/FEB/1992
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	53.500	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	32.000	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	16.000	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
12:27	156.617	B1 101-1	27.200	1.000	0.022	159.000	3.437	0.022	1.234	9.305	3.200	2.908
	156.617	B1 101-2	27.600	1.000	0.022	159.000	3.488	0.022	1.259	9.367	3.200	2.927
	156.617	B2 102-1	10.000	1.000	0.008	159.000	1.264	0.008	1.813	11.199	3.150	3.555
	156.617	B2 102-2	10.500	1.000	0.008	159.000	1.327	0.008	1.737	11.374	3.150	3.611
	156.617	B3 103-1	15.200	1.000	0.012	159.000	1.921	0.012	1.470	11.388	2.822	4.035
	156.617	B3 103-2	14.200	1.000	0.011	159.000	1.794	0.011	1.596	11.225	2.822	3.978
	156.617	B4 104-1	17.000	1.000	0.014	159.000	2.148	0.014	1.431	8.070	2.900	2.783
	156.617	B4 104-2	20.500	1.000	0.016	159.000	2.590	0.016	1.277	7.764	2.900	2.677
	156.617	B5 105-1	18.600	1.000	0.015	159.000	2.350	0.015	2.471	7.967	2.900	2.747
	156.617	B5 105-2	19.500	2.000	0.015	159.000	2.464	0.031	2.433	7.625	2.900	2.629
	156.617	T1 106-1	17.600	1.000	0.014	159.000	2.224	0.014	2.422	7.549	2.450	3.081
	156.617	T1 106-2	18.500	1.000	0.015	159.000	2.338	0.015	2.434	7.497	2.450	3.060
	156.617	T2 107-1	28.800	1.000	0.023	159.000	3.639	0.023	1.007	10.450	2.700	3.870
	156.617	T2 107-2	28.400	1.000	0.023	159.000	3.589	0.023	0.995	10.424	2.700	3.861

BATCH 1 - COC ANALYSIS: CYCLE 4
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DATE OF ANALYSIS = MON/10/FEB/1992 (FOLLOWING REFLUSH)
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	53.500	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	32.000	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	16.000	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
14:29	156.617	B1 101-1	52.500	1.000	0.042	159.000	6.634	0.042	0.000	9.305	3.200	2.908
	156.617	B1 101-2	52.500	1.000	0.042	159.000	6.634	0.042	0.000	9.367	3.200	2.927
	156.617	B2 102-1	51.000	1.000	0.041	159.000	6.444	0.041	0.000	11.199	3.150	3.555
	156.617	B2 102-2	51.000	1.000	0.041	159.000	6.444	0.041	0.000	11.374	3.150	3.611
	156.617	B3 103-1	51.000	1.000	0.041	159.000	6.444	0.041	0.000	11.388	2.822	4.035
	156.617	B3 103-2	50.800	1.000	0.040	159.000	6.419	0.040	0.000	11.225	2.822	3.978
	156.617	B4 104-1	50.500	1.000	0.040	159.000	6.381	0.040	0.000	8.070	2.900	2.783
	156.617	B4 104-2	50.800	1.000	0.040	159.000	6.419	0.040	0.000	7.764	2.900	2.677
	156.617	B5 105-1	51.000	1.000	0.041	159.000	6.444	0.041	0.000	7.967	2.900	2.747
	156.617	B5 105-2	51.000	1.000	0.041	159.000	6.444	0.041	0.000	7.625	2.900	2.629
	156.617	T1 106-1	51.500	1.000	0.041	159.000	6.508	0.041	0.000	7.549	2.450	3.081
	156.617	T1 106-2	51.500	1.000	0.041	159.000	6.508	0.041	0.000	7.497	2.450	3.060
	156.617	T2 107-1	52.200	1.000	0.041	159.000	6.596	0.041	0.000	10.450	2.700	3.870
	156.617	T2 107-2	52.200	1.000	0.041	159.000	6.596	0.041	0.000	10.424	2.700	3.861

BATCH 1 - COC ANALYSIS: CYCLE 4
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DATE OF ANALYSIS = TUE/11/FEB/1992
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	55.000	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	32.800	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	16.400	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
11:32	177.667	B1 101-1	45.400	1.000	0.036	159.000	5.737	0.036	0.855	10.160	3.200	3.175
	177.667	B1 101-2	45.600	1.000	0.036	159.000	5.762	0.036	0.830	10.197	3.200	3.187
	177.667	B2 102-1	40.400	1.000	0.032	159.000	5.105	0.032	1.299	12.498	3.150	3.968
	177.667	B2 102-2	40.000	1.000	0.032	159.000	5.054	0.032	1.349	12.724	3.150	4.039
	177.667	B3 103-1	43.200	1.000	0.034	159.000	5.459	0.034	0.945	12.333	2.822	4.370
	177.667	B3 103-2	42.600	1.000	0.034	159.000	5.383	0.034	0.996	12.221	2.822	4.331
	177.667	B4 104-1	43.800	1.000	0.035	159.000	5.535	0.035	0.806	8.876	2.900	3.061
	177.667	B4 104-2	44.400	1.000	0.035	159.000	5.610	0.035	0.768	8.532	2.900	2.942
	177.667	B5 105-1	45.500	1.000	0.036	159.000	5.749	0.036	0.654	8.622	2.900	2.973
	177.667	B5 105-2	46.200	1.000	0.037	159.000	5.838	0.037	0.566	8.191	2.900	2.824
	177.667	T1 106-1	46.000	1.000	0.037	159.000	5.813	0.037	0.654	8.203	2.450	3.348
	177.667	T1 106-2	45.500	1.000	0.036	159.000	5.749	0.036	0.717	8.214	2.450	3.353
	177.667	T2 107-1	49.200	1.000	0.039	159.000	6.217	0.039	0.338	10.788	2.700	3.995
	177.667	T2 107-2	49.000	1.000	0.039	159.000	6.192	0.039	0.363	10.787	2.700	3.995

BATCH 1 - COC ANALYSIS: CYCLE 4
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DATE OF ANALYSIS = WED/12/FEB/1992
ROOM TEMPERATURE = 20 DEG C 20.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	54.900	0.996	0.001	0.083	293.000	0.041	41.156
0.600	0.126	33.000	0.996	0.001	0.083	293.000	0.025	24.694
0.300	0.063	16.600	0.996	0.000	0.083	293.000	0.012	12.347
0.000	0.000	0.000	0.996	0.000	0.083	293.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
11:05	201.217	B1 101-1	35.500	1.000	0.028	159.000	4.486	0.028	1.215	11.375	3.200	3.555
	201.217	B1 101-2	36.500	1.000	0.029	159.000	4.612	0.029	1.114	11.311	3.200	3.535
	201.217	B2 102-1	28.500	2.000	0.023	159.000	3.601	0.045	1.472	13.970	3.150	4.435
	201.217	B2 102-2	27.000	1.000	0.021	159.000	3.412	0.021	1.611	14.334	3.150	4.551
	201.217	B3 103-1	32.600	1.000	0.026	159.000	4.119	0.026	1.305	13.638	2.822	4.833
	201.217	B3 103-2	32.000	1.000	0.025	159.000	4.044	0.025	1.306	13.526	2.822	4.793
	201.217	B4 104-1	33.500	1.000	0.027	159.000	4.233	0.027	1.267	10.143	2.900	3.498
	201.217	B4 104-2	34.000	1.000	0.027	159.000	4.296	0.027	1.279	9.811	2.900	3.383
	201.217	B5 105-1	38.000	1.000	0.030	159.000	4.802	0.030	0.912	9.533	2.900	3.287
	201.217	B5 105-2	39.000	1.000	0.031	159.000	4.928	0.031	0.873	9.064	2.900	3.126
	201.217	T1 106-1	37.800	1.000	0.030	159.000	4.776	0.030	1.000	9.203	2.450	3.756
	201.217	T1 106-2	37.900	1.000	0.030	159.000	4.789	0.030	0.924	9.139	2.450	3.730
	201.217	T2 107-1	45.000	1.000	0.036	159.000	5.686	0.036	0.492	11.279	2.700	4.178
	201.217	T2 107-2	45.000	1.000	0.036	159.000	5.686	0.036	0.467	11.253	2.700	4.168

BATCH 1 - COC ANALYSIS: CYCLE 4
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DATE OF ANALYSIS = TH/13/FEB/1992
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	53.500	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	31.900	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	16.000	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
9:37	223.750	B1 101-1	24.800	1.000	0.020	159.000	3.134	0.020	1.324	12.699	3.200	3.968
	223.750	B1 101-2	26.600	1.000	0.021	159.000	3.361	0.021	1.222	12.533	3.200	3.916
	223.750	B2 102-1	19.500	1.000	0.015	159.000	2.464	0.015	1.092	15.062	3.150	4.782
	223.750	B2 102-2	18.200	1.000	0.014	159.000	2.300	0.014	1.091	15.425	3.150	4.897
	223.750	B3 103-1	24.500	1.000	0.019	159.000	3.096	0.019	0.998	14.636	2.822	5.186
	223.750	B3 103-2	24.400	1.000	0.019	159.000	3.083	0.019	0.935	14.461	2.822	5.124
	223.750	B4 104-1	25.000	1.000	0.020	159.000	3.159	0.020	1.047	11.190	2.900	3.859
	223.750	B4 104-2	23.600	1.000	0.019	159.000	2.982	0.019	1.287	11.098	2.900	3.827
	223.750	B5 105-1	31.000	1.000	0.025	159.000	3.917	0.025	0.854	10.388	2.900	3.582
	223.750	B5 105-2	32.000	1.000	0.025	159.000	4.044	0.025	0.854	9.918	2.900	3.420
	223.750	T1 106-1	30.500	1.000	0.024	159.000	3.854	0.024	0.892	10.095	2.450	4.120
	223.750	T1 106-2	32.000	1.000	0.025	159.000	4.044	0.025	0.715	9.854	2.450	4.022
	223.750	T2 107-1	41.800	1.000	0.033	159.000	5.282	0.033	0.369	11.648	2.700	4.314
	223.750	T2 107-2	41.400	1.000	0.033	159.000	5.231	0.033	0.419	11.673	2.700	4.323

BATCH 1 - COC ANALYSIS: CYCLE 5
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DATE OF ANALYSIS = FRI/14/FEB/1992
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	58.200	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	34.500	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	17.000	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
11:43	249.850	B1 101-1	11.800	1.000	0.009	159.000	1.491	0.009	1.623	14.322	3.200	4.476
	249.850	B1 101-2	15.000	1.000	0.012	159.000	1.895	0.012	1.445	13.977	3.200	4.368
	249.850	B2 102-1	9.500	1.000	0.008	159.000	1.200	0.008	1.248	16.310	3.150	5.178
	249.850	B2 102-2	8.200	1.000	0.007	159.000	1.036	0.007	1.249	16.674	3.150	5.293
	249.850	B3 103-1	14.900	1.000	0.012	159.000	1.883	0.012	1.194	15.829	2.822	5.609
	249.850	B3 103-2	14.500	1.000	0.012	159.000	1.832	0.012	1.232	15.693	2.822	5.561
	249.850	B4 104-1	11.800	1.000	0.009	159.000	1.491	0.009	1.648	12.839	2.900	4.427
	249.850	B4 104-2	8.800	1.000	0.007	159.000	1.112	0.007	1.851	12.949	2.900	4.465
	249.850	B5 105-1	23.000	1.000	0.018	159.000	2.906	0.018	0.986	11.374	2.900	3.922
	249.850	B5 105-2	24.500	1.000	0.019	159.000	3.096	0.019	0.922	10.840	2.900	3.738
	249.850	T1 106-1	24.000	1.000	0.019	159.000	3.033	0.019	0.797	10.892	2.450	4.446
	249.850	T1 106-2	25.800	1.000	0.021	159.000	3.260	0.021	0.758	10.612	2.450	4.331
	249.850	T2 107-1	39.200	1.000	0.031	159.000	4.953	0.031	0.295	11.943	2.700	4.423
	249.850	T2 107-2	39.000	1.000	0.031	159.000	4.928	0.031	0.270	11.943	2.700	4.423

BATCH 1 - COC ANALYSIS: CYCLE 5
==============================

DATE OF ANALYSIS = FRI/14/FEB/1992 (FOLLOWING REFLUSH)
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	58.200	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	34.500	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	17.000	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
13:41	249.850	B1 101-1	53.200	1.000	0.042	159.000	6.722	0.042	0.000	14.322	3.200	4.476
	249.850	B1 101-2	53.200	1.000	0.042	159.000	6.722	0.042	0.000	13.977	3.200	4.368
	249.850	B2 102-1	52.400	1.000	0.042	159.000	6.621	0.042	0.000	16.310	3.150	5.178
	249.850	B2 102-2	52.400	1.000	0.042	159.000	6.621	0.042	0.000	16.674	3.150	5.293
	249.850	B3 103-1	52.600	1.000	0.042	159.000	6.647	0.042	0.000	15.829	2.822	5.609
	249.850	B3 103-2	53.000	1.000	0.042	159.000	6.697	0.042	0.000	15.693	2.822	5.561
	249.850	B4 104-1	52.500	1.000	0.042	159.000	6.634	0.042	0.000	12.839	2.900	4.427
	249.850	B4 104-2	52.200	1.000	0.041	159.000	6.596	0.041	0.000	12.949	2.900	4.465
	249.850	B5 105-1	52.200	1.000	0.041	159.000	6.596	0.041	0.000	11.374	2.900	3.922
	249.850	B5 105-2	52.400	1.000	0.042	159.000	6.621	0.042	0.000	10.840	2.900	3.738
	249.850	T1 106-1	52.200	1.000	0.041	159.000	6.596	0.041	0.000	10.892	2.450	4.446
	249.850	T1 106-2	52.600	1.000	0.042	159.000	6.647	0.042	0.000	10.612	2.450	4.331
	249.850	T2 107-1	53.000	1.000	0.042	159.000	6.697	0.042	0.000	11.943	2.700	4.423
	249.850	T2 107-2	53.000	1.000	0.042	159.000	6.697	0.042	0.000	11.943	2.700	4.423

BATCH 1 - COC ANALYSIS: CYCLE 5
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DATE OF ANALYSIS = SUN/16/FEB/1992
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	58.300	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	34.900	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	17.200	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
9:37	293.783	B1 101-1	26.000	1.000	0.021	159.000	3.285	0.021	3.395	17.717	3.200	5.537
	293.783	B1 101-2	28.200	1.000	0.022	159.000	3.563	0.022	3.117	17.094	3.200	5.342
	293.783	B2 102-1	34.500	1.000	0.027	159.000	4.359	0.027	2.220	18.530	3.150	5.883
	293.783	B2 102-2	35.600	1.000	0.028	159.000	4.498	0.028	2.081	18.755	3.150	5.954
	293.783	B3 103-1	32.400	1.000	0.026	159.000	4.094	0.026	2.511	18.340	2.822	6.499
	293.783	B3 103-2	33.800	1.000	0.027	159.000	4.271	0.027	2.384	18.077	2.822	6.406
	293.783	B4 104-1	22.600	1.000	0.018	159.000	2.856	0.018	3.736	16.575	2.900	5.716
	293.783	B4 104-2	19.200	1.000	0.015	159.000	2.426	0.015	4.128	17.078	2.900	5.889
	293.783	B5 105-1	38.000	1.000	0.030	159.000	4.802	0.030	1.753	13.127	2.900	4.526
	293.783	B5 105-2	38.200	1.000	0.030	159.000	4.827	0.030	1.753	12.593	2.900	4.342
	293.783	T1 106-1	39.000	1.000	0.031	159.000	4.928	0.031	1.626	12.519	2.450	5.110
	293.783	T1 106-2	39.000	1.000	0.031	159.000	4.928	0.031	1.677	12.289	2.450	5.016
	293.783	T2 107-1	48.000	1.000	0.038	159.000	6.065	0.038	0.590	12.533	2.700	4.642
	293.783	T2 107-2	48.400	1.000	0.038	159.000	6.116	0.038	0.539	12.482	2.700	4.623

BATCH 1 - COC ANALYSIS: CYCLE 5
==============================

DATE OF ANALYSIS = MON/17/FEB/1992
ROOM TEMPERATURE = 22 DEG C 22.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	57.700	0.996	0.001	0.083	295.000	0.041	40.877
0.600	0.126	34.400	0.996	0.001	0.083	295.000	0.025	24.526
0.300	0.063	17.000	0.996	0.000	0.083	295.000	0.012	12.263
0.000	0.000	0.000	0.996	0.000	0.083	295.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
9.47	317.950	B1 101-1	10.000	1.000	0.008	159.000	1.264	0.008	2.001	19.718	3.200	6.162
	317.950	B1 101-2	10.200	1.000	0.008	159.000	1.289	0.008	2.252	19.346	3.200	6.046
	317.950	B2 102-1	24.000	1.000	0.019	159.000	3.033	0.019	1.299	19.830	3.150	6.295
	317.950	B2 102-2	25.000	1.000	0.020	159.000	3.159	0.020	1.311	20.066	3.150	6.370
	317.950	B3 103-1	20.400	1.000	0.016	159.000	2.578	0.016	1.491	19.831	2.822	7.027
	317.950	B3 103-2	22.500	1.000	0.018	159.000	2.843	0.018	1.401	19.478	2.822	6.902
	317.950	B4 104-1	8.800	1.000	0.007	159.000	1.112	0.007	1.726	18.301	2.900	6.311
	317.950	B4 104-2	9.000	1.000	0.007	159.000	1.137	0.007	1.274	18.351	2.900	6.328
	317.950	B5 105-1	27.000	1.000	0.021	159.000	3.412	0.021	1.360	14.486	2.900	4.995
	317.950	B5 105-2	27.600	1.000	0.022	159.000	3.488	0.022	1.309	13.902	2.900	4.794
	317.950	T1 106-1	31.600	1.000	0.025	159.000	3.993	0.025	0.904	13.423	2.450	5.479
	317.950	T1 106-2	32.400	1.000	0.026	159.000	4.094	0.026	0.803	13.092	2.450	5.344
	317.950	T2 107-1	44.500	1.000	0.035	159.000	5.623	0.035	0.404	12.937	2.700	4.792
	317.950	T2 107-2	44.500	1.000	0.035	159.000	5.623	0.035	0.454	12.936	2.700	4.791

BATCH 1 - COC ANALYSIS: CYCLE 6
==============================

DATE OF ANALYSIS = MON/17/FEB/1992 (FOLLOWING REFLUSH)
ROOM TEMPERATURE = 22 DEG C 22.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	57.700	0.996	0.001	0.083	295.000	0.041	40.877
0.600	0.126	34.400	0.996	0.001	0.083	295.000	0.025	24.526
0.300	0.063	17.000	0.996	0.000	0.083	295.000	0.012	12.263
0.000	0.000	0.000	0.996	0.000	0.083	295.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err o	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
12:02	317.950	B1 101-1	54.200	1.000	0.043	159.000	6.849	0.043	0.000	19.718	3.200	6.162
	317.950	B1 101-2	54.200	1.000	0.043	159.000	6.849	0.043	0.000	19.346	3.200	6.046
	317.950	B2 102-1	54.200	1.000	0.043	159.000	6.849	0.043	0.000	19.830	3.150	6.295
	317.950	B2 102-2	54.200	1.000	0.043	159.000	6.849	0.043	0.000	20.066	3.150	6.370
	317.950	B3 103-1	54.000	1.000	0.043	159.000	6.823	0.043	0.000	19.831	2.822	7.027
	317.950	B3 103-2	54.000	1.000	0.043	159.000	6.823	0.043	0.000	19.478	2.822	6.902
	317.950	B4 104-1	53.800	1.000	0.043	159.000	6.798	0.043	0.000	18.301	2.900	6.311
	317.950	B4 104-2	53.600	1.000	0.043	159.000	6.773	0.043	0.000	18.351	2.900	6.328
	317.950	B5 105-1	54.200	1.000	0.043	159.000	6.849	0.043	0.000	14.486	2.900	4.995
	317.950	B5 105-2	54.200	1.000	0.043	159.000	6.849	0.043	0.000	13.902	2.900	4.794
	317.950	T1 106-1	54.200	1.000	0.043	159.000	6.849	0.043	0.000	13.423	2.450	5.479
	317.950	T1 106-2	54.200	1.000	0.043	159.000	6.849	0.043	0.000	13.092	2.450	5.344
	317.950	T2 107-1	54.800	1.000	0.044	159.000	6.925	0.044	0.000	12.937	2.700	4.792
	317.950	T2 107-2	54.800	1.000	0.044	159.000	6.925	0.044	0.000	12.936	2.700	4.791

BATCH 1 - COC ANALYSIS: CYCLE 6

DATE OF ANALYSIS = TH/20/FEB/1992
ROOM TEMPERATURE = 22 DEG C 22.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:

STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	56.500	0.996	0.001	0.083	295.000	0.041	40.877
0.600	0.126	33.750	0.996	0.001	0.083	295.000	0.025	24.526
0.300	0.063	16.800	0.996	0.000	0.083	295.000	0.012	12.263
0.000	0.000	0.000	0.996	0.000	0.083	295.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err oof Coef.	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
15:40	393.583	B1 101-1	9.200	2.000	0.007	159.000	1.163	0.015	5.643	25.361	3.200	7.925
	393.583	B1 101-2	8.400	2.000	0.007	159.000	1.061	0.013	5.744	25.091	3.200	7.841
	393.583	B2 102-1	25.600	1.000	0.020	159.000	3.235	0.020	3.571	23.400	3.150	7.429
	393.583	B2 102-2	26.500	1.000	0.021	159.000	3.349	0.021	3.457	23.524	3.150	7.468
	393.583	B3 103-1	19.200	1.000	0.015	159.000	2.426	0.015	4.354	24.185	2.822	8.570
	393.583	B3 103-2	21.500	1.000	0.017	159.000	2.717	0.017	4.064	23.542	2.822	8.342
	393.583	B4 104-1	8.500	1.000	0.007	159.000	1.074	0.007	5.681	23.982	2.900	8.270
	393.583	B4 104-2	18.400	1.000	0.015	159.000	2.325	0.015	4.405	22.757	2.900	7.847
	393.583	B5 105-1	20.000	1.000	0.016	159.000	2.527	0.016	4.278	18.765	2.900	6.471
	393.583	B5 105-2	23.200	1.000	0.018	159.000	2.932	0.018	3.874	17.776	2.900	6.130
	393.583	T1 106-1	32.800	1.000	0.026	159.000	4.145	0.026	2.661	16.084	2.450	6.565
	393.583	T1 106-2	33.500	1.000	0.027	159.000	4.233	0.027	2.573	15.664	2.450	6.394
	393.583	T2 107-1	46.000	1.000	0.037	159.000	5.813	0.037	1.068	14.006	2.700	5.187
	393.583	T2 107-2	45.800	1.000	0.036	159.000	5.787	0.036	1.094	14.030	2.700	5.196

BATCH 1 - COC ANALYSIS: CYCLE 6
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DATE OF ANALYSIS = FRI/21/FEB/1992
ROOM TEMPERATURE = 20 DEG C 20.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	56.300	0.996	0.001	0.083	293.000	0.041	41.156
0.600	0.126	33.900	0.996	0.001	0.083	293.000	0.025	24.694
0.300	0.063	17.000	0.996	0.000	0.083	293.000	0.012	12.347
0.000	0.000	0.000	0.996	0.000	0.083	293.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err oof Coef.	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
11:30	413.417	B1 101-1	10.000	1.000	0.008	159.000	1.264	0.008	-0.116	25.245	3.200	7.889
	413.417	B1 101-2	9.500	1.000	0.008	159.000	1.200	0.008	-0.152	24.938	3.200	7.793
	413.417	B2 102-1	29.400	1.000	0.023	159.000	3.715	0.023	-0.501	22.900	3.150	7.270
	413.417	B2 102-2	20.500	1.000	0.016	159.000	2.590	0.016	0.737	24.261	3.150	7.702
	413.417	B3 103-1	11.200	1.000	0.009	159.000	1.415	0.009	0.996	25.181	2.822	8.923
	413.417	B3 103-2	14.500	1.000	0.012	159.000	1.832	0.012	0.867	24.409	2.822	8.650
	413.417	B4 104-1	9.000	1.000	0.007	159.000	1.137	0.007	-0.070	23.912	2.900	8.246
	413.417	B4 104-2	10.900	1.000	0.009	159.000	1.377	0.009	0.933	23.690	2.900	8.169
	413.417	B5 105-1	8.500	1.000	0.007	159.000	1.074	0.007	1.437	20.202	2.900	6.966
	413.417	B5 105-2	14.500	1.000	0.012	159.000	1.832	0.012	1.081	18.857	2.900	6.502
	413.417	T1 106-1	27.800	1.000	0.022	159.000	3.513	0.022	0.606	16.689	2.450	6.812
	413.417	T1 106-2	29.200	1.000	0.023	159.000	3.690	0.023	0.517	16.181	2.450	6.605
	413.417	T2 107-1	44.400	1.000	0.035	159.000	5.610	0.035	0.166	14.171	2.700	5.249
	413.417	T2 107-2	44.000	1.000	0.035	159.000	5.560	0.035	0.191	14.221	2.700	5.267

BATCH 1 - COC ANALYSIS: CYCLE 7
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DATE OF ANALYSIS = FRI/21/FEB/1992 (FOLLOWING REFLUSH)
ROOM TEMPERATURE = 20 DEG C 20.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	56.300	0.996	0.001	0.083	293.000	0.041	41.156
0.600	0.126	33.900	0.996	0.001	0.083	293.000	0.025	24.694
0.300	0.063	17.000	0.996	0.000	0.083	293.000	0.012	12.347
0.000	0.000	0.000	0.996	0.000	0.083	293.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err oof Coef.	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
13:20	413.417	B1 101-1	53.500	1.000	0.043	159.000	6.760	0.043	0.000	25.245	3.200	7.889
	413.417	B1 101-2	53.500	1.000	0.043	159.000	6.760	0.043	0.000	24.938	3.200	7.793
	413.417	B2 102-1	54.000	1.000	0.043	159.000	6.823	0.043	0.000	22.900	3.150	7.270
	413.417	B2 102-2	53.500	1.000	0.043	159.000	6.760	0.043	0.000	24.261	3.150	7.702
	413.417	B3 103-1	53.000	1.000	0.042	159.000	6.697	0.042	0.000	25.181	2.822	8.923
	413.417	B3 103-2	53.000	1.000	0.042	159.000	6.697	0.042	0.000	24.409	2.822	8.650
	413.417	B4 104-1	51.600	1.000	0.041	159.000	6.520	0.041	0.000	23.912	2.900	8.246
	413.417	B4 104-2	53.200	1.000	0.042	159.000	6.722	0.042	0.000	23.690	2.900	8.169
	413.417	B5 105-1	53.000	1.000	0.042	159.000	6.697	0.042	0.000	20.202	2.900	6.966
	413.417	B5 105-2	53.000	1.000	0.042	159.000	6.697	0.042	0.000	18.857	2.900	6.502
	413.417	T1 106-1	53.600	1.000	0.043	159.000	6.773	0.043	0.000	16.689	2.450	6.812
	413.417	T1 106-2	53.600	1.000	0.043	159.000	6.773	0.043	0.000	16.181	2.450	6.605
	413.417	T2 107-1	54.000	1.000	0.043	159.000	6.823	0.043	0.000	14.171	2.700	5.249
	413.417	T2 107-2	54.200	1.000	0.043	159.000	6.849	0.043	0.000	14.221	2.700	5.267

BATCH 1 - COC ANALYSIS: CYCLE 7
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DATE OF ANALYSIS = WED/26/FEB/1992
ROOM TEMPERATURE = 23 DEG C 23.000
ROOM PRESSURE   = 757 mm Hg = 757/760 ATM
GC ATTENUATION   = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	49.700	0.996	0.001	0.083	296.000	0.041	40.739
0.600	0.126	29.500	0.996	0.001	0.083	296.000	0.024	24.443
0.300	0.063	14.700	0.996	0.000	0.083	296.000	0.012	12.222
0.000	0.000	0.000	0.996	0.000	0.083	296.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err oof Coef.	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
17:26	537.517	B1 101-1	6.000	1.000	0.005	159.000	0.758	0.005	5.960	31.205	3.200	9.752
	537.517	B1 101-2	6.200	1.000	0.005	159.000	0.783	0.005	5.934	30.873	3.200	9.648
	537.517	B2 102-1	11.600	1.000	0.009	159.000	1.466	0.009	5.315	28.215	3.150	8.957
	537.517	B2 102-2	11.000	1.000	0.009	159.000	1.390	0.009	5.328	29.588	3.150	9.393
	537.517	B3 103-1	6.000	1.000	0.005	159.000	0.758	0.005	5.897	31.078	2.822	11.013
	537.517	B3 103-2	6.000	1.000	0.005	159.000	0.758	0.005	5.897	30.306	2.822	10.739
	537.517	B4 104-1	5.000	2.000	0.004	159.000	0.632	0.008	5.847	29.760	2.900	10.262
	537.517	B4 104-2	4.000	1.000	0.003	159.000	0.505	0.003	6.175	29.864	2.900	10.298
	537.517	B5 105-1	5.800	2.000	0.005	159.000	0.733	0.009	5.922	26.124	2.900	9.008
	537.517	B5 105-2	6.000	1.000	0.005	159.000	0.758	0.005	5.897	24.753	2.900	8.536
	537.517	T1 106-1	18.200	2.000	0.014	159.000	2.300	0.029	4.431	21.120	2.450	8.620
	537.517	T1 106-2	22.600	1.000	0.018	159.000	2.856	0.018	3.875	20.056	2.450	8.186
	537.517	T2 107-1	35.500	1.000	0.028	159.000	4.486	0.028	2.295	16.466	2.700	6.098
	537.517	T2 107-2	33.600	1.000	0.027	159.000	4.246	0.027	2.560	16.781	2.700	6.215

BATCH 1 - COC ANALYSIS: CYCLE 8
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DATE OF ANALYSIS = WED/26/FEB/1992 (FOLLOWING REFLUSH)
ROOM TEMPERATURE = 23 DEG C 23.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	49.700	0.996	0.001	0.083	296.000	0.041	40.739
0.600	0.126	29.500	0.996	0.001	0.083	296.000	0.024	24.443
0.300	0.063	14.700	0.996	0.000	0.083	296.000	0.012	12.222
0.000	0.000	0.000	0.996	0.000	0.083	296.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err oof Coef.	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
19:04	537.517	B1 101-1	45.800	1.000	0.036	159.000	5.787	0.036	0.000	31.205	3.200	9.752
	537.517	B1 101-2	45.600	2.000	0.036	159.000	5.762	0.072	0.000	30.873	3.200	9.648
	537.517	B2 102-1	46.800	1.000	0.037	159.000	5.914	0.037	0.000	28.215	3.150	8.957
	537.517	B2 102-2	46.500	1.000	0.037	159.000	5.876	0.037	0.000	29.588	3.150	9.393
	537.517	B3 103-1	46.000	2.000	0.037	159.000	5.813	0.073	0.000	31.078	2.822	11.013
	537.517	B3 103-2	46.000	1.000	0.037	159.000	5.813	0.037	0.000	30.306	2.822	10.739
	537.517	B4 104-1	43.600	1.000	0.035	159.000	5.509	0.035	0.000	29.760	2.900	10.262
	537.517	B4 104-2	46.500	1.000	0.037	159.000	5.876	0.037	0.000	29.864	2.900	10.298
	537.517	B5 105-1	46.600	1.000	0.037	159.000	5.888	0.037	0.000	26.124	2.900	9.008
	537.517	B5 105-2	45.000	1.000	0.036	159.000	5.686	0.036	0.000	24.753	2.900	8.536
	537.517	T1 106-1	47.400	1.000	0.038	159.000	5.990	0.038	0.000	21.120	2.450	8.620
	537.517	T1 106-2	47.200	1.000	0.038	159.000	5.964	0.038	0.000	20.056	2.450	8.186
	537.517	T2 107-1	48.200	1.000	0.038	159.000	6.091	0.038	0.000	16.466	2.700	6.098
	537.517	T2 107-2	48.000	1.000	0.038	159.000	6.065	0.038	0.000	16.781	2.700	6.215

BATCH 1 - COC ANALYSIS: CYCLE 8
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DATE OF ANALYSIS = SAT/29/FEB/1992
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	50.700	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	30.200	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	15.200	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err oof Coef.	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
15:13	605.667	B1 101-1	24.500	1.000	0.019	159.000	3.096	0.019	2.655	33.860	3.200	10.581
	605.667	B1 101-2	19.500	2.000	0.015	159.000	2.464	0.031	3.226	34.098	3.200	10.656
	605.667	B2 102-1	24.200	1.000	0.019	159.000	3.058	0.019	2.819	31.033	3.150	9.852
	605.667	B2 102-2	26.000	1.000	0.021	159.000	3.285	0.021	2.553	32.142	3.150	10.204
	605.667	B3 103-1	21.500	1.000	0.017	159.000	2.717	0.017	3.023	34.100	2.822	12.084
	605.667	B3 103-2	22.400	1.000	0.018	159.000	2.830	0.018	2.946	33.252	2.822	11.783
	605.667	B4 104-1	8.000	1.000	0.006	159.000	1.011	0.006	4.464	34.224	2.900	11.801
	605.667	B4 104-2	22.400	1.000	0.018	159.000	2.830	0.018	3.008	32.873	2.900	11.335
	605.667	B5 105-1	7.000	1.000	0.006	159.000	0.885	0.006	4.967	31.091	2.900	10.721
	605.667	B5 105-2	14.500	1.000	0.012	159.000	1.832	0.012	3.818	28.572	2.900	9.852
	605.667	T1 106-1	34.000	1.000	0.027	159.000	4.296	0.027	1.656	22.776	2.450	9.296
	605.667	T1 106-2	35.500	1.000	0.028	159.000	4.486	0.028	1.441	21.497	2.450	8.774
	605.667	T2 107-1	43.500	1.000	0.035	159.000	5.497	0.035	0.556	17.022	2.700	6.304
	605.667	T2 107-2	35.000	1.000	0.028	159.000	4.423	0.028	1.605	18.386	2.700	6.810

BATCH 1 - COC ANALYSIS: CYCLE 9
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DATE OF ANALYSIS = SAT/29/FEB/1992 (FOLLOWING REFLUSH)
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	50.700	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	30.200	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	15.200	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err oof Coef.	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
16:41	605.667	B1 101-1	51.000	1.000	0.041	159.000	6.444	0.041	0.000	33.860	3.200	10.581
	605.667	B1 101-2	51.000	1.000	0.041	159.000	6.444	0.041	0.000	34.098	3.200	10.656
	605.667	B2 102-1	51.000	1.000	0.041	159.000	6.444	0.041	0.000	31.033	3.150	9.852
	605.667	B2 102-2	51.000	1.000	0.041	159.000	6.444	0.041	0.000	32.142	3.150	10.204
	605.667	B3 103-1	50.600	1.000	0.040	159.000	6.394	0.040	0.000	34.100	2.822	12.084
	605.667	B3 103-2	51.000	1.000	0.041	159.000	6.444	0.041	0.000	33.252	2.822	11.783
	605.667	B4 104-1	50.000	1.000	0.040	159.000	6.318	0.040	0.000	34.224	2.900	11.801
	605.667	B4 104-2	50.200	1.000	0.040	159.000	6.343	0.040	0.000	32.873	2.900	11.335
	605.667	B5 105-1	48.600	1.000	0.039	159.000	6.141	0.039	0.000	31.091	2.900	10.721
	605.667	B5 105-2	50.200	1.000	0.040	159.000	6.343	0.040	0.000	28.572	2.900	9.852
	605.667	T1 106-1	50.800	1.000	0.040	159.000	6.419	0.040	0.000	22.776	2.450	9.296
	605.667	T1 106-2	51.000	1.000	0.041	159.000	6.444	0.041	0.000	21.497	2.450	8.774
	605.667	T2 107-1	51.200	1.000	0.041	159.000	6.470	0.041	0.000	17.022	2.700	6.304
	605.667	T2 107-2	50.500	1.000	0.040	159.000	6.381	0.040	0.000	18.386	2.700	6.810

BATCH 1 - COC ANALYSIS: CYCLE 9
==============================

DATE OF ANALYSIS = TUE/03/MAR/1992
ROOM TEMPERATURE = 20 DEG C 20.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
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STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	51.300	0.996	0.001	0.083	293.000	0.041	41.156
0.600	0.126	30.100	0.996	0.001	0.083	293.000	0.025	24.694
0.300	0.063	15.000	0.996	0.000	0.083	293.000	0.012	12.347
0.000	0.000	0.000	0.996	0.000	0.083	293.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err oof Coef.	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
9:13	670.200	B1 101-1	30.600	1.000	0.024	159.000	3.867	0.024	2.537	36.397	3.200	11.374
	670.200	B1 101-2	32.400	1.000	0.026	159.000	4.094	0.026	2.310	36.408	3.200	11.377
	670.200	B2 102-1	24.000	1.000	0.019	159.000	3.033	0.019	3.371	34.405	3.150	10.922
	670.200	B2 102-2	25.800	1.000	0.021	159.000	3.260	0.021	3.144	35.286	3.150	11.202
	670.200	B3 103-1	21.500	1.000	0.017	159.000	2.717	0.017	3.637	37.737	2.822	13.373
	670.200	B3 103-2	20.000	1.000	0.016	159.000	2.527	0.016	3.877	37.128	2.822	13.157
	670.200	B4 104-1	20.000	1.000	0.016	159.000	2.527	0.016	3.751	37.975	2.900	13.095
	670.200	B4 104-2	21.600	1.000	0.017	159.000	2.729	0.017	3.574	36.447	2.900	12.568
	670.200	B5 105-1	13.400	2.000	0.011	159.000	1.693	0.021	4.409	35.500	2.900	12.242
	670.200	B5 105-2	26.500	1.000	0.021	159.000	3.349	0.021	2.955	31.527	2.900	10.871
	670.200	T1 106-1	34.400	1.000	0.027	159.000	4.347	0.027	2.032	24.808	2.450	10.126
	670.200	T1 106-2	35.200	1.000	0.028	159.000	4.448	0.028	1.956	23.453	2.450	9.572
	670.200	T2 107-1	41.800	1.000	0.033	159.000	5.282	0.033	1.147	18.169	2.700	6.729
	670.200	T2 107-2	26.600	1.000	0.021	159.000	3.361	0.021	2.980	21.366	2.700	7.913

BATCH 1 - COC ANALYSIS: CYCLE 9
==============================

DATE OF ANALYSIS = TUE/10/MAR/1992
ROOM TEMPERATURE = 21 DEG C 21.000
ROOM PRESSURE = 757 mm Hg = 757/760 ATM
GC ATTENUATION = 16

STANDARD CALIBRATION:
===================

STANDARD (mL Air)	O2 CONC. (mL O2)	PEAK HT. (# SQ)	P (atm)	V (L)	R	T (K)	mmol O2 (/mL Air)	umol O2 (/mL Air)
1.000	0.210	53.800	0.996	0.001	0.083	294.000	0.041	41.016
0.600	0.126	32.500	0.996	0.001	0.083	294.000	0.025	24.610
0.300	0.063	16.400	0.996	0.000	0.083	294.000	0.012	12.305
0.000	0.000	0.000	0.996	0.000	0.083	294.000	0.000	0.000

Regression Output:

Constant	0.001	0.000
Std Err of Y Est	0.000	0.000
R Squared		1.000
No. of Observation	0.795	4.000
Degrees of Freedom	0.002	3.000
X Coefficient(s)	0.001	
Std Err oof Coef.	0.000	

TIME	CUM TIME (HRS)	SAMPLE	PEAK HT. (# SQ)	V sample (mL)	mmol O2 (/mL hs)	(V)hs (mL)	O2 Conc. mmol O2	O2 Lost mmol O2	O2 CONSUMED mmol O2	CUM CONSUMED mmol O2	S*TSi	NORMAL CUM COC mmol/g TS
15:30	838.200	B1 101-1	8.800	1.000	0.007	159.000	1.112	0.007	2.730	39.128	3.200	12.227
	838.200	B1 101-2	8.800	1.000	0.007	159.000	1.112	0.007	2.956	39.364	3.200	12.301
	838.200	B2 102-1	8.000	1.000	0.006	159.000	1.011	0.006	2.003	36.407	3.150	11.558
	838.200	B2 102-2	8.200	1.000	0.007	159.000	1.036	0.007	2.203	37.489	3.150	11.901
	838.200	B3 103-1	8.000	1.000	0.006	159.000	1.011	0.006	1.689	39.426	2.822	13.971
	838.200	B3 103-2	7.200	1.000	0.006	159.000	0.910	0.006	1.602	38.730	2.822	13.724
	838.200	B4 104-1	6.600	1.000	0.005	159.000	0.834	0.005	1.677	39.652	2.900	13.673
	838.200	B4 104-2	7.000	1.000	0.006	159.000	0.885	0.006	1.828	38.275	2.900	13.198
	838.200	B5 105-1	6.800	1.000	0.005	159.000	0.859	0.005	0.813	36.313	2.900	12.522
	838.200	B5 105-2	7.500	1.000	0.006	159.000	0.948	0.006	2.380	33.906	2.900	11.692
	838.200	T1 106-1	8.200	1.000	0.007	159.000	1.036	0.007	3.283	28.091	2.450	11.466
	838.200	T1 106-2	8.600	1.000	0.007	159.000	1.087	0.007	3.333	26.786	2.450	10.933
	838.200	T2 107-1	25.600	1.000	0.020	159.000	3.235	0.020	2.014	20.182	2.700	7.475
	838.200	T2 107-2	7.200	1.000	0.006	159.000	0.910	0.006	2.430	23.796	2.700	8.813

APPENDIX D

DAD DIGESTER EFFICIENCIES

EFFICIENCY FOR CONTROL REACTORS THROUGHOUT EXPERIMENTAL RUN

	Mbi	SUM mf*VSf	SUM md*VSd	Mbf	EFF (decimal)	EFF (%)
M6	540.90	877.36	650.31	398.35	0.42	42.13
M1	959.58	1777.15	1217.41	894.38	0.35	35.17
M2	903.31	1332.86	943.05	989.78	0.23	22.76

PERIOD A EFFICIENCY FOR INOCULATED REACTORS

	Mbi	SUM mf*VSf	SUM md*VSd	Mbf	EFF (decimal)	EFF (%)
M3	984.47	1153.51	796.41	990.96	0.30	30.40
M4	943.80	865.14	619.55	1011.75	0.21	20.53
M5	1002.20	1153.51	831.88	1035.40	0.25	25.01
T2	461.31	853.08	662.08	419.52	0.27	27.29

PERIOD B EFFICIENCY FOR INOCULATED REACTORS

	Mbi	SUM mf*VSf	SUM md*VSd	Mbf	EFF (decimal)	EFF (%)
M3	990.96	801.86	653.60	1100.69	0.05	4.81
M4	1011.75	601.39	500.27	1055.77	0.09	9.50
M5	1035.40	801.86	686.16	1038.76	0.14	14.01
T2	419.52	532.29	415.66	498.83	0.07	7.01

EFFICIENCY FOR T1 USING A +/- 10 gram BALANCE

	Mbi	SUM mf*VSf	SUM md*VSd	Mbf	EFF (decimal)	EFF (%)
T1	335.63	446.90	329.59	387.46	0.15	14.65