TABLE OF CONTENTS

CHAPTERS	TITLE	PAGES	
	DECLARATION	ii	
	DEDICATION	iii	
	AKNOWLEDGEMENT	iv	
	ABSTRACT	v	
	ABSTRAK	vi	
	TABLE OF CONTENTS	vii	
	LIST OF TABLES	xii	
	LIST OF FIGURES	xiv	
	LIST OF ABBREVIATIONS		
	LIST OF APPENDICES	xvii	
1	INTRODUCTION		
	1.1 Background	1	
	1.2 Problem Statement	5	

1.3	Object	tive	6	
1.4	Scope	of Research	6	
FUNI	DAMENTAL THEORY AND LITERATURE REVIEW			
2.1	Introd	uction	7	
2.2	Bioga	s	7	
	2.2.1	Production of Biogas	8	
	2.2.2	Biogas Operational Techniques	9	
		2.2.2.1 Batch Process	9	
		2.2.2.2 Continuous Process	10	
	2.2.3	Biogas Composition	10	
2.3	Anaer	obic Digestion	11	
	2.3.1	Anaerobic Digestion Process	13	
		2.3.1.1 Mesophilic Digestion	13	
		2.3.1.2 Thermophilic Digestion	13	
	2.3.2	Biochemistry of Anaerobic Digestion	14	
		2.3.2.1 Hydrolysis	16	
		2.3.2.2 Acidogenesis	16	

2

	2.3.2.3 Aceto	genesis	17
	2.3.2.4 Metha	nogenesis	17
2.3.3	Influence of F	Process Parameters in	
	Anaerobic Di	gestion	18
	2.3.3.1 Tempe	erature	18
	2.3.3.2 pH		19
	2.3.3.3 C to N	Ratio	19
	2.3.3.4 Percer	ntage of Total Solid	20
	2.3.3.5 Mixin	g	20
	2.3.3.6 Water	Content	21
	2.3.3.7 Inhibit	tory/Toxicity	21
	2.3.3.8 Ammo	onia Inhibition	22
	2.3.3.9 Sulfate	e / Sulfide Inhibition	22
	2.3.3.10	Metals Inhibition	23
	2.3.3.11	Organic Compound Inhibition	23
Bioma	ass as a Source	of Renewable Energy	23
2.4.1	Cow Manure		24

2.4

ix

		2.4.1.1 Composition of Fresh Cow Manure	25
	2.4.2	Palm Oil Mill Effluent (POME)	27
2.5	Co-Di	gestion	29
	2.5.1	Advantages of Co-Digestion	30
		2.5.1.1 Improved Nutrient Balance	31
		2.5.1.2 Optimization of Rheological Qualities	31
		2.5.1.3 Effective Utilization of DigesterVolumes	
		in Sewage Plants	31
RESI	EARCH	I METHODOLOGY	
3.1	Introd	uction	32
3.2	Feeds	tock Collection	33
3.3	Feeds	tock Preparation	34
3.4	Operation Startup		
3.5	Analytical Methods		36
	3.5.1	Total Suspended Solids (TSS)	37
	3.5.2	Total Solid (TS)	37
	3.5.3	Volatile Solid (VS)	38

		3.5.4 Chemical Oxygen Demand (COD)	38
		3.5.5 pH	39
		3.5.6 Biochemical Oxygen Demand (BOD ₅)	40
		3.5.7 Total Organic Carbon (TOC)	40
	3.6	Biogas Collection and Analysis	41
4	RES	ULTS AND DISCUSSION	
	4.1	Introduction	42
	4.2	Characteristics of Substrates	42
	4.3	Biogas Production	44
	4.4	Biogas Quality	53
5	5 Conclusion and Recommendations		
	5.1	Conclusions	55
	5.2	Recommendations	56
REFERENCES			58
Appendices A – C			65 - 73

LIST OF TABLES

TABLE NO.	TITLE PA	AGE
2.1	Average composition of biogas (Solomon and Lora, 2009)	11
2.2	Cow manure composition (Omar et al., 2008)	26
2.3	Typical Characteristics of POME (Ma, 2000)	28
3.1	Percentage of mixing of cow manure and POME for	
	anaerobic digestion.	34
4.1	Characteristics of the prepared substrates used in anaerobic	
	digestion	43
4.2	characteristics of selected parameters after 21 days of digestion	44
4.3	Percentage difference of biogas production between co-digestion	
	and digestion of POME alone	49
4.4	Percentage difference of biogas production between co-digestion	
	and digestion of cow manure alone	50
4.5	Effect of percentage of COD and VS removal towards	
	biogas production	51
4.6	Accumulated biogas production for mono and co-digestion in bat	ch
	anaerobic experiments for 21 days of digestion	52

4.7 Methane composition from different substrate composition after twenty one days of digestion. 53

TABLE OF FIGURES

FIGURE NO	TITLE	PAGE
1.1	Conversion of biomass to renewable energy (Lantz et al., 2007	') 2
2.1	Cow manure to improve C to N ratio and buffering capacity	25
2.2	Anaerobic pond: Source of Palm oil mill effluent	29
3.1	Process Flow Diagram showing methodology steps for	
	biogas production	33
3.2	Experimental setup of anaerobic digestion for biogas production	on 36
4.1	Daily biogas production for mono and co-digestion in batch	
	anaerobic experiments for 21 days of digestion.	47
4.2	Cumulative Biogas Production after 21 days of digestion	48
4.3	Effect of COD removal, % and VS removal, % towards	
	methane composition	51

LIST OF ABBREVIATIONS

ASAB	Ε	American Society of Agricultural and Biological Engineers
%	-	Percent
°C	-	Degree Celsius
±	-	More or Less
BOD	-	Biochemical Oxygen Demand
H_2	-	Hydrogen
H ₂ O	-	Water
H_2S	-	Hydrogen Sulphite
CH ₃	-	Ammonia
CH ₄	-	Methane
cm	-	Centimeter
СМ	-	Cow Manure
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
COD	-	Chemical Oxygen Demand
FID	_	Flame – Ionization Detector

- g Gram
- GC-TCD- Gas Chromatography- Thermal Conductivity Detector
- Kg Kilogram
- L Liter
- m³ Cubic Meter
- mg Milligram
- mL Milliliter
- N₂ Nitrogen
- PE Polyethylene
- POME Palm Oil Mill Effluent
- TS Total Solids
- TSS Total Suspended Solids
- VS Volatile Solids
- V_{CM} Volume of Cow Manure
- V_{POME} Volume of Palm Oil Mill Effluent

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Α	Sample of Calculation of Biogas Yield	65
В	Pictures of Experimental Apparatus and Materials	68
С	Journal Paper to be submitted for Publication	73