

# **MANUFACTURING OF BIOGAS FROM DIGESTED PADDY STRAW USING DELTA-D TECHNOLOGY**

Sudam Weeranake

(09/8971)



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

Degree of Master of Science

Department of Chemical & Process Engineering

University of Moratuwa

Sri Lanka

March 2012



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

# **MANUFACTURING OF BIOGAS FROM DIGESTED PADDY STRAW USING DELTA-D TECHNOLOGY**

Sudam Weeranayake

(09/8970)

Thesis/Dissertation submitted in partial fulfilment of the requirements for the degree



University of Moratuwa, Sri Lanka  
ElectroMaster of Science  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

Department of Chemical & Process Engineering

University of Moratuwa

Sri Lanka

March 2012



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## DECLARATION OF THE CANDIDATE AND THE SUPERVISOR

“I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

.....

Signature

Date

The above candidate has carried out research for the Master's thesis under my supervision.

.....

Signature of the supervisor

.....

Date

## ABSTRACT

Anaerobic digestion is commonly used for waste water treatment. Technologies have been introduced and new technologies are being developed to generate biogas by anaerobic digestion of organic waste, as an integrated solution for waste treatment and for energy production from waste.

Being an agricultural country, Sri Lanka generates over five million metric tonnes of rice straw (RS) per annum as a by-product in the cultivation of rice. Currently RS is dumped or burnt without converting it to a productive output. One productive output that can be produced is biogas. National Engineering Research and Development Centre (NERDC) is one of the main state owned research and development (R & D) organisations, that has developed a patented technology, well known as **Dry Batch Biogas Technology**, to generate biogas by anaerobic digestion of RS. However, due to several technical and economic reasons (Alwis A, et al, 1997 and Perera S.A.S, 2001) manufacture of biogas from RS has been abandoned.

Professor S.A.S. Perera, Professor of Chemical and Process Engineering of the University of Moratuwa, has developed a patented technology, well known as **Delta-D Technology (DT)**, by which most types of organic waste can be rapidly digested into organic fertiliser, by using a patented digestive fluid called **Delta-D**. Currently DT is being used to convert fibrous RS into a powder, within 1 day, using DT.

In this study, experiments have been done to explore the possibility of biogas production from RS, digested by DT. Two experiment set up were conducted to do comparison of biogas production of digested rice straw and untreated rice straw.

Keywords: Anaerobic digestion, Delta-D Technology, digested rice straw, untreated rice straw, Cow dung

## **DEDICATION**

I would like to dedicate this thesis to both of my parents who were always by my side and giving their blessing, encouraging & motivating in every important events of my life.



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## ACKNOWLEDGEMENT

Completion of this thesis has been one of the most significant academic challenges I have ever had to face. Without the support, patience and guidance of the following people, this study would not have been completed. It is to them that I owe my deepest gratitude.

In the first place I would like to record my gratitude and honour to my supervisor, Prof. S.A.S Perera, Professor of Chemical and Process Engineering of University of Moratuwa, for giving me information on Delta-D Technology (DT), samples of Delta-D Digested Rice Straw Powder (DTDRSP) for my research project, for his supervision, inspiration and motivation, throughout this research project. His passion for development of technology helped me to overcome several problems I faced during the research project.

I gratefully acknowledge Dr.P.G. Rathnasiri for his advice, supervision, and crucial contribution and offering me the opportunity to do a M.Sc. study. His involvement along with his originality has triggered and nourished my intellectual maturity that I will benefit from, for a long time to come.

I am indebted to Dr. Shantha Amarasinghe, Head of the Department of Chemical and Process Engineering, University of Moratuwa, for giving me the opportunity to do the M.Sc. in the department and guiding me to conduct research successfully.

My grateful thanks go to Dr. Manisha Gunasekara for creating the path to success in M.Sc. research and giving me great support to overcome problems throughout the process of conducting research.

My heartfelt thanks to Mr. Daham Gunawardena and Charitha Udani, Norway, I am really grateful for you for the helping hand you lent me anytime and I am indeed thankful to both of you for the trouble taken to send me research articles.

I would like to extend my gratitude to my dear friends, Dilnaya Nuditha, Kasun Udana, Sumudu Karuathne for making all the things happen in my research.

I am immensely grateful to technical officer, Upul and Senior Chemist Heshan for giving me the great support by giving me required testing facilities.

Most importantly, none of these would have been possible without the love and patience of my family. I am deeply indebted to my parents, sister brother and my wife who always supported, encouraged and believed in me, in my entire endeavour.



To everybody that has been a part of my life but I failed to mention, thank you very much.

I believe that my research will make a small contribution to the research done in the field of Environmental engineering...


Sudam Weeranayake



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

# TABLE OF CONTENTS

DECLARATION OF THE CANDIDATE AND THE SUPERVISOR .....	I
ABSTRACT .....	II
DEDICATION .....	III
ACKNOWLEDGEMENT .....	IV
TABLE OF CONTENTS .....	VI
LIST OF FIGURES .....	IX
LIST OF TABLES .....	X
LIST OF ABBREVIATIONS .....	XI
LIST OF APPENDICES .....	XII
CHAPTER 1: INTRODUCTION.....	1
1.INTRODUCTION .....	2
1.1 Background .....	3
1.2 Introduction to Research Background .....	7
1.3 Research Objectives.....	9
1.4 Outline of Research Objectives .....	10
CHAPTER 2: LITERATURE REVIEW .....	11
2.LITERATURE REVIEW .....	12
2.1. The Boigas Process.....	12
2.2. The Anaerobic Digestion Process.....	12
2.3. The AD Process Basics .....	13
2.3.1. Hydrolysis .....	14
2.3.3. Acetogenesis.....	15
2.3.4. Methanogenesis .....	16
2.4. Anaerobic Co-Digestion process .....	17

2.5.	Anaerobic Digestion Process Parameters .....	17
2.5.1.	Temperature .....	18
2.5.2.	C/N ratio& Nitrogen inhibition .....	19
2.5.3.	pH level.....	21
2.5.4.	Solid content.....	21
2.5.7.	Alkalinity .....	22
2.5.7.	Hydraulic retention time (HRT).....	22
2.6.	Structure and Composition of Lignocellulosic Agro-waste.....	23
2.7.	The Necessity of Pre-treatment for Agricultural residues .....	24
2.8.	Pre-treatment Techniques.....	25
2.8.1.	Physical pre-treatment .....	25
2.8.2.	Chemical pre-treatment.....	26
2.8.3.	Physico-chemical pre-treatment .....	27
2.8.4.	Biological pre-treatment .....	28
		
CHAPTER 3: MATERIALS & METHODS .....		29
3.MATERIALS & METHODS.....		30
3.1.	Introduction to Materials and Methods.....	30
3.2.	Methodology .....	30
3.2.1.	Selection of Substrate .....	30
3.2.2.	Substrate Preparation.....	32
3.2.3.	Preparation of cow dung .....	35
3.3.	Experiment Methodology.....	35
3.3.1.	Batch experiment series A .....	35
3.3.2.	Batch experiment series B.....	38
3.4.	Analytical Test Method Used.....	39
3.4.2.	COD Analysis.....	39

3.4.3.	Analysis of TS & VS .....	40
3.4.4.	pH analysis .....	40
3.4.5.	C: N Ratio analysis .....	40
CHAPTER 4: RESULTS & DISCUSSION.....		41
4.RESULTS AND DISCUSSION.....		42
4.1.	Results of Experiment Series A.....	42
4.1.1.	Daily gas production of experiment series A.....	42
4.2.2.	Cumulative gas production & production rate of experiment series A	44
4.1.3.	COD removal efficiency for series A .....	45
4.1.4.	Degradation extent of TS & TVS in series A.....	46
4.1.5.	Methane & CO <sub>2</sub> compositions .....	47
4.2.	Results of Experiment Series B .....	48
4.2.1.	Gas production of experiment series B .....	49
4.2.2.	Degradation extent of COD,TS &VS in series B .....	51
CHAPTER 5: CONCLUSION AND SUGGESTIONS .....		52
5.CONCLUSION AND SUGGESTIONS .....		53
5.1.	Conclusions .....	53
5.2.	Recommendation .....	54
REFERENCES .....		55
APPENDICES .....		58



## LIST OF FIGURES

Figure 1-1: Biogas Cycle.....	2
Figure 1-2: Schematic of a biogas plant used for power generation .....	6
Figure 1-3: Conceptual Diagram of This Research Study in a Broader Perspective .....	10
Figure 2-1: Four Phases of AD Process .....	13
Figure 2-2: Methanogenic Bacteria.....	16
Figure 2-3: Relative growth rate of Methanogens(Angelidaki,2004) .....	18
Figure 2-4: Thermal stage and typical retention times(Seadi,2008) .....	19
Figure 2-5: Lignocelluloses Structure .....	23
Figure 2-6: Pre-treatment of Biomass .....	26
Figure 3-1: Digested Rice Straw (DDRS) .....	32
Figure 3-2: Washing off DDRS to remove residual Delta-D solution .....	33
Figure 3-3: Preparation of URS .....	34
Figure 3-4: Diagram of the batch experiment biogas unit.....	37
Figure 3-5: Experiment series A.....	37
Figure 3-6: Experiment series B .....	38
Figure 3-7: CO <sub>2</sub> volume measuring by liquid displacement Method (ORASAT) .....	39
Figure 4-1: Daily gas production of series A.....	43
Figure 4-2: Cumulative gas production of experiment series A .....	44
Figure 4-3: Average gas production rate .....	45
Figure 4-4: COD reduction of experiment series A .....	45
Figure 4-5: TS of feed & effluents of series A .....	46
Figure 4-6: Methane & CO <sub>2</sub> volume .....	47
Figure 4-7: Daily gas production series B.....	49
Figure 4-8: Cumulative gas production in series B.....	49
Figure 4-9: B samples after AD.....	50
Figure 4-10: Series A after Anaerobic digestion .....	50

## LIST OF TABLES

Table 0-1: Anaerobic Plants in the World	4
Table 0-2: Thermal & Electrical potential of Biogas in Provinces	8
Table 0-3: Nitrogen Content & C/N ratio of some agro waste	20
Table 0-4: Characteristics of DDRS	33
Table 0-5: Characteristics of URS	34
Table 0-6: Amount of water added for substrate preparation	35
Table 0-7: Characteristics of Cow Dung (CD)	35
Table 0-8: URS slurry & CD slurry mixing ratios in experiment series A	36
Table 0-9: DDRS slurry & CD slurry mixing ration in series B	38
Table 0-10: Daily gas production of series A	42
Table 0-11: Cumulative gas production & average rate of experiment series A	44
Table 0-12: TS & VS reduction in series A	47
Table 0-13: Methane CO <sub>2</sub> compositions	48
Table 0-14: Characteristic of DDRS	48
Table 0-15: TS,VS,COD reduction in series B	51

## LIST OF ABBREVIATIONS

<b>Abbreviation</b>	<b>Description</b>
ASTM	American Society for Testing and Materials
APHA	American Public Health Association
AD	Anaerobic Digestion
CD	Cow Dung
COD	Chemical Oxygen Demand
DDRS	Delta-D digested Rice Straw
FAS	Ferrous Ammonium Sulphate
KOH	Potassium Hydroxide
LCFA	Long Chain Fatty Acids
MSW	Municipal Solid Waste
TCOD	Total Chemical Oxygen Demand
RS	Rice Straw
TS	Total Solids
TVS	Total Volatile Solids
URS	Untreated Rice Straw
VFA	Volatile Fatty Acids
VSS	Volatile Suspended Solids



Total Solids ratuwa, Sri Lanka.  
Electronic Theses & Dissertations

## LIST OF APPENDICES

Appendix	Description	page
APPENDIX A	Analysis report-Feed	58
APPENDIX B	Analysis report-Effluent	61



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)