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ORIGINAL LITERARY WORK DEDICATION

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Title of Project/Research Report/Dissertation/Thesis ("This Work")

BIO-HYDROGEN PRODUCTION FROM FOOD WASTE

Field of Study: **Waste to Energy**

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ABSTRACT

Fossil fuels have often served as the current energy source used for day to day activities by households, industries and transportation sectors. However, its combustion has increased the global issue of greenhouse effect, which in turn has led to global warming. With the continuous rise in global temperatures, the quest for an alternative energy source, which will be environmental friendly, is now inevitable. This study was conducted to provide support that hydrogen can be an alternative energy source. Hence, the study was undertaken to investigate the potentials of food waste substrates such as rice waste, fish waste, vegetable waste and mixed waste, in hydrogen production through anaerobic fermentation. Bio-hydrogen production was performed in lab scale reactors, using 250 mL serum bottles. The food waste was first mixed with the anaerobic sewage sludge and incubated at 37°C for 31 days (acclimatization). The anaerobic sewage sludge was then heat treated at 80°C for 15 minutes. The experiment was conducted at an initial pH of 4.0, 5.5 and 6.0 and temperature of 27°C, 35°C, and 55°C. The maximum cumulative hydrogen produced by rice, fish, vegetable and mixed food waste substrates were highest at 35ºC and at pH of 5.5 (Rice =26.97 ± 0.76 mL, fish = 89.70 ± 1.25 mL, vegetable = 42.00±1.76 mL, mixed = 108.90±1.42 mL). A comparative study of acclimatized (the different food waste substrates were mixed with anaerobic sewage sludge and incubated at 37°C for 31days) and non-acclimatized food waste substrate (food waste that was not incubated with anaerobic sewage sludge) revealed that acclimatized food waste substrate enhanced bio-hydrogen production by two fold. This was further verified using a statistical test at ($P < 0.001$). Using the Gompertz kinetic model, rice waste had the highest hydrogen production potential of 83 mL followed by mixed (74.2 mL), fish (55.80 mL) and vegetable (32.70 mL). However, the model also revealed mixed waste to have the highest rate of hydrogen

production of 60 mL/d, followed by rice (41.22 mL/d), fish (30.7 mL/d) and vegetable (16.1 mL/d). Food waste substrates such as rice, fish, vegetable and their combinations are potential substrates for hydrogen production. Addition of metal ion such as Pb ions 5 mg/L, 10 mg/L and 15 mg/L was observed to increase hydrogen production from 10.3 mL to 16.6 mL, 41.6 mL and 42.3 mL respectively. This was also the case in the column experiments where Pb ion concentrations of 5 mg/L, 10 mg/L and 15 mg/L had a maximum hydrogen yield of 42.96 mL, 124.8 mL and 157.95 mL respectively. Thus, Pb ions at these levels enhanced bio-hydrogen production.

ABSTRAK

Bahan api fosil telah sering berkhidmat sebagai sumber tenaga semasa digunakan untuk hari untuk aktiviti hari mengikut sektor pengangkutan isi rumah, industri dan. Walau bagaimanapun, pembakarannya bahan fosil ini menyebabkan meningkatkan serta masalah global sepirti isu rumah hijau dimana ianya membawa kepada pemanasan global. Dengan kenaikan berterusan dalam suhu global, usaha untuk sumber tenaga alternatif, yang akan mesra alam sekitar kini tidak dapat dielakkan. Kajian ini dijalankan untuk memberikan sokongan yang hidrogen boleh menjadi sumber tenaga alternatif. Oleh itu , kajian ini dijalankan untuk menyiasat potensi substrat sisa makanan seperti sisa beras, sisa ikan , sisa sayur-sayuran dan sisa campuran , dalam pengeluaran hidrogen melalui penapaian anaerobik. Pengeluaran bio -hidrogen telah dijalankan dalam reaktor skala makmal, menggunakan 250 mL botol serum. Sisa makanan pertama kali dicampur dengan enapcemar kumbahan anaerobik dan dieram pada 37°C selama 31 hari (penyesuaian). Enapcemar anaerobik kumbahan kemudian dirawat haba pada 80°C selama 15 minit. Eksperimen telah dijalankan pada pH awal 4.0, 5.5 dan 6.0 dan suhu 27°C, 35°C dan 55°C. Hidrogen terkumpul maksimum yang dihasilkan oleh beras , ikan , sayur-sayuran dan dicampur substrat sisa makanan adalah tertinggi pada 35ºC dan pada pH 5.5 (Rice = 26.97 ± 0.76 mL , ikan = 89,70 ± 1.25 mL, sayur-sayuran = 42.00 ± 1.76 mL, dicampur = 108.90 ± 1.42 mL). Satu kajian perbandingan aklimatisasi (yang berbeza substrat sisa makanan telah bercampur dengan enap cemar kumbahan anaerobik dan dieram pada 37°C untuk 31days) dan bukan aklimatisasi -sisa makanan substrat (sisa makanan yang tidak dieram dengan enap cemar kumbahan anaerobik) mendedahkan bahawa sisa makanan aklimatisasi substrat dipertingkatkan pengeluaran bio-hidrogen dengan dua. Ini seterusnya disahkan menggunakan ujian statistik di ($P < 0.001$). Dengan menggunakan modal kinetic Gompertz,

sisa- sisa beras didapati mengandungi kandungan hydrogen dengan kadar tertinggi sebanyak 83ml. Berikutan dengan bahan campuran (74.2 mL), Ikan (55.80 mL) dan sayur-sayuran (32.70 mL). Walau bagaimanapun, modal berikut juga menunjukkan campuran sisa- sisa didapati mengeluarkan hidrogen sebanyak 60 mL/d, diikuti nasi (41.22mL/d), ikan (32.7 mL/d) dan sayur – sayuran (16.1 mL/d). Substrat sisa makanan seperti sisa beras, sisa ikan, sisa sayur-sayuran dan gabungan mereka adalah substrat yang berpotensi untuk pengeluaran hidrogen. Tambahan metal ion seperti ion Pb 5 mg/L, 10 mg/L dan 15 mg/L telah diperhatikan untuk meningkatkan penghasilan hydrogen dari 10.3 mL ke 16.6 mL, 41.6 mL dan 42.3 mL. Ianya juga adalah satu kes di dalam kolum eksperimen dimana pemusatan ion Pb 5 mg/L, 10 mg/L dan 15 mg/L menjana hidrogen maksimum 42.96 mL, 124.8 mL dan 157.95 mL. Maka, ion Pb pada peringkat ini telah meningkatkan penghasilan bio-hidrogen.

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TABLE OF CONTENTS

Title page
Original Literary Work Dedication...ii

Abstract...iii

Abstrak...v

Acknowledgement...vii

Table of contents...viii

List of figures...xii

List of tables ...xiv

List of Plates ...xv

List of Abbreviation ...xvi

CHAPTER 1
INTRODUCTION... 1
1.1 Climate Change ... 1
1.2 Waste Disposal ... 3
1.3 Renewable Energy (RE)... 5
1.4 Problem Statement... 6
1.5 Objectives of the Study ... 8

CHAPTER 2
LITERATURE REVIEW... 9
2.1 Introduction ... 9
2.2 Municipal Solid Waste ... 9
2.2.1 MSW in Malaysia... 10
2.3. Global MSW Generation ... 12
2.4 Global MSW Composition ... 14
2.5 Solid Waste Management Practices ... 15
i) Open Dumping and Landfilling... 16
ii) Composting and Bio-gasification ... 16
iii.) 3R (Recovery, Reuse and Recycling) ... 17
2.6 Thermal Treatment ... 18
2.7 Waste to Energy...18

2.7.1 Why Convert Waste to Energy? 18
2.8 Technologies for Sustainable Energy Production 21
2.81 Incineration 23
2.8.2 Pyrolysis 23
2.8.3 Landfill 24
2.8.4 Hydrogen Production 25
2.8.4.1 Hydrogen from Biomass 26
2.8.4.2 Hydrogen from Steam Reforming of Fossil Fuels 29
2.8.4.3 Steam Reformation of Glycerol 30
2.8.4.4 Electrolysis of water 31
2.8.4.5 Bio-catalyzed Electrolysis 32
2.8.4.6 Bio-photolysis-Green Algae/Cyanobacteria 34
2.8.4.7 Photosynthetic Hydrogen Production 34
2.9 Dark Fermentation 35
2.9.1 Microbes 38
2.9.2 Temperature 40
2.9.3 pH 41
2.9.4 Substrate 42
2.9.5 Reactor 42
2.9.6 Acclimatization 44
2.9.7 Metal Ion 45
2.10 Gompertz Kinetic Model 46
2.11Food waste 48
2.11.1 Potential Environmental Benefits 48
2.11.2 Financial Considerations 49

CHAPTER 3

MATERIALS AND METHODS 51
3.1 Sludge Preparation 51
3.2. Food Waste Preparation 51
3.3 Alkalinity Determination of Sewage Sludge 52
3.4 Volatile fatty acids in Sewage Sludge 53
3.5 Ammonical Nitrogen in Sewage Sludge 53
3.6 Total Suspended Solids (TSS) of Sewage Sludge 54
3.7 Batch Fermentation 54

3.7.1 Acclimatization of food waste with Sewage Sludge 54
3.7.2 Non Acclimatization 55
3.8 Effect of Metal Ions on Bio-hydrogen production 59
3.9 Column Experiment 59
3.10 Moisture Content of Food Waste 61
3.11 Biogas Analysis 61
3.12 Statistical Analysis 62

CHAPTER 4

RESULTS AND DISCUSSION 64
4.1 Composition of Food Waste 64
4.1.1 Characteristicsof Anaerobic Sewage 65
4.2 Effect of Temperature 66
4.2.1 Effect of Temperature on Cumulative Biogas and H_2 Production Using Rice Waste as Substrate 66
4.2.2 Effect of Temperature on Cumulative H_2 production and H_2 Content Using Fish waste as Substrate 68
4.2.3 Effect of Temperature on Cumulative Biogas production and H_2 Content Using Vegetable Waste as Substrate 70
4.2.4 Effect of temperature on Cumulative Biogas Production and H_2 Content Using Mixed Food Waste as Substrate ..... .72
4.3 Effect of pH at 35^0C on Bio-hydrogen Production Using Food Waste as Substrates 75
4.3.1 Effect of pH on Cumulative biogas Production and H_2 Content of Biogas from Rice Waste 76
4.3.2 Effect of pH on Cumulative Biogas and H_2 Production of Using Fish Waste as Substrate 78
4.3.3 Effect of pH on Cumulative Biogas and H_2 Production of Vegetable Waste As Substrate 79
4.3.4 Effect of pH on Cumulative Biogas Production and H_2 Content Using Mixed Food Waste as Substrate 81
4.4 EFFECTS OF ACCLIMATIZATION 84
4.4.1 Effects of Acclimatization on Cumulative Biogas and H_2 Production Using Rice Waste as Substrate 85
4.4.2 Effects of Acclimatization on Cumulative Biogas and H_2 Production When Fish Waste was Used as Substrate 86
4.4.3 Effect of Acclimatization on Cumulative Biogas and H_2 Production Using Vegetable Waste as Substrate for Fermentation 88

4.4.4 Effect of Acclimatization on Cumulative Biogas and H_2 Production Using Mixed Food Waste as Substrate 90
4.5 Gompertz Kinetic Model 91
4.6 Effect of Metal Ions Concentration on Bio-Hydrogen Production 95
4.6.1 Effect of Metal ion Concentration of 5 mg/l of Pb on Bio-Hydrogen Production 95
4.6.2 Effect of Metal ion Concentration at 10 mg/L on Bio-H_2 Production 97
4.6.3 Effect of Metal ion Concentration at 15 mg/L on Bio-H_2 Production 98
4.7 Gompertz Kinetic Parameters for Metallic ion content 100
4.8 Column Experiments 101
4.8.1 Effect of 5 mg/L of Pb on Bio-hydrogen Production using Food Waste as a Substrate 102
4.8.2 Effect of 10 mg/L of Pb on Bio-hydrogen Production using Food Waste as a Substrate 103
4.8.3 Effect of 15 mg/L of Pb on Bio-hydrogen Production using Food Waste as a Substrate 104
CHAPTER 5
CONCLUSION 107
REFERENCES 108

LIST OF FIGURES

Figure 1.1. GHG emissions by source of CO_2eq……………………………………….…3
Figure 1.2 Objectives of Sustainable development Source…………………..…………4

Figure 2.1 Annual Waste Generation in Kuala Lumpur……………………………….……11
Figure 2.2 Global Solid Waste Composition………………..…………………….......15

Figure 2.3 World energy consumption by OECD and non-OECD countries…………20

Figure 2.4 Components of Biomass…………………………………………………....28

Figure 2.5 Methods of Using Biomass for Energy………………………………...….29
Figure 2.6 Steam reformation of fossil fuel……………………………………….....30

Figure 2.7 Schematic Diagram of Industrial water electrolysis to produce hydrogen...32

Figure 2.8 Schematic diagram of Bio-catalyzed electrolysis………………………......33

Figure 2.9 Diagram of anaerobic digestion and dark fermentation…………………....37
Figure 3.1 Schematic Diagram of Biogas Production……………………….............57

Figure 3.2 Schematic Diagram of Column Experiment on Biogas production…..…...60

Figure 4.1 Effect of temperature on Cumulative Biogas and H_2 Production Using Rice waste as Substrate……………………...……….67

Figure 4.2 Effect of Cumulative Biogas production and H_2 content Using Fish waste as Substrate...69

Figure 4.3 Effect of Temperature on Cumulative and H_2 Production Using Vegetable Waste as Substrates...................................71

Figure 4.4 Effect of temperature on Cumulative biogas production and H_2 Content Using Mixed Food waste as Substrate................................73

Figure 4.5 Effect of pH on Cumulative Biogas and H_2 Production using Rice Waste as Substrate...76

Figure 4.6 Effect of pH on Cumulative Biogas and H_2 Production of Using Fish waste as substrate...78

Figure 4.7 Effects of pH on Cumulative Biogas and H_2 Production Using Vegetable Waste as Substrate...80

Figure 4.8 Effects of pH on Cumulative Biogas and H_2 Production Using Mixed food waste as Substrate...81

Figure 4.9 Effects of Acclimatization on Cumulative Biogas and H_2 Production Using Rice Waste as Substrate..86

Figure 4.10 Effect of Acclimatization on Cumulative Biogas and H_2 Production when Fish Waste was used as Substrate...................................87

Figure 4.11 Effects of Acclimatization on Cumulative Biogas and H_2 Production Using Vegetable Waste as Substrate...................................89

Figure 4.12 Effects of Acclimatization on Cumulative Biogas and H_2 Production Using Mixed Food Waste as Substrate...............................90

Figure 4.13 Effect of metallic ion (5 mg/L of Pb) on Bio-Hydrogen Production from Food Waste...96

Figure 4.14 Effect of metallic ion (10 mg/L of Pb) on bio-hydrogen production from food waste..97

Figure 4.15 Effect of metal ion (15 mg/L of Pb) on Bio-Hydrogen production from food waste...99

Figure 4.16 Effect of Metal ions (5 mg/L of Pb) on bio-hydrogen production.............102

Figure 4.17 Effect of Metal ions (10 mg/L of Pb) on Bio-hydrogen production using food waste as substrate...104

Figure 4.18 Effect of Metal ions (15 mg/L of Pb) on Bio-hydrogen production using food waste as substrate...105

LIST OF TABLES

Table 1.1 Advantages of hydrogen as a fuel for electricity production over other fuel…………………………………………………………………….....7

Table 2.1 MSW Composition in Malaysia...12

Table 2.2 Current Urban Waste Generation and Future Projections............................13

Table 2.3 World fossil fuel reserve and consumption in 2009.....................................21

Table 2.4 Landfill CH_4 Emissions and Total GHG emissions for selected Countries..25

Table 4.1 Food waste Characteristics...65

Table 4.2 Characteristics of the Anaerobic Sewage Sludge used in this study.............66

Table 4.3 The maximum cumulative biogas and hydrogen production from different temperatures..75

Table 4.4 Maximum Cumulative Biogas and Hydrogen Production at Various pH.....84

Table 4.5 H_2 Production rate and Production Potential for Acclimatized Food Waste Substrate...92

Table 4.6 H_2 Production rate and production potential for non-acclimatized Food waste Substrate...94

Table 3.7 H_2 Production Rate and Potential..100

LIST OF PLATES

Plate 2.1 Continuous Stirred tank Bioreactor..43

Plate 2.2 Up-flow sludge blanket bioreactor..43

Plate 3.1 Food waste Collection and Separation..52

Plate 3.2 Acclimatized Food Waste Substrates..55

Plate 3.3 Food Waste in a 250 mL serum Bottle..56

Plate 3.4 Biogas Production and water displacement..58

Plate 3.5 Level of Water displaced for Biogas Measurement.............................58

Plate 3.6 Gas chromatography (GC) used for biogas analysis............................62

LIST OF ABBREVIATION

3 Rs	Reduce, Reuse and Recycle
AADS	Acclimatized Anaerobic Digester Sludge
ABR	Anaerobic Baffled Reactor
AD	Anaerobic Digestion
ADS	Anaerobic Digester Sludge
APEC	Asia Pacific Economic Cooperation
APHA	American Public Health Association
ASS	Anaerobic Sewage Sludge
BC	Before Christ
CCAR	California Climate Action Registry
CCPP	Combined Cycle Power Plant
CCS	Carbon capture and storage
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CSTR	Continuous Stirred Tank Type Bioreactor
DOE	Department of Energy
EAP	East Asia and Pacific Region

EC	European Commission
ECA	Eastern Central Asia
EE	Electrical Energy;
EET	extracellular electron transfer
EIA	Energy Information Administration
Eq	Equivalent
EREE	Energy Efficiency & Renewable Energy
EU	European Union
F/M	Food and Microbe Ratio
FC	Fuel Cell
FFAP	Free Fatty Acid Phase
FID	Flame Ionization Detector
FWL	Food Waste Leachate
FWS	Food Waste Substrates
GC	Gas Chromatography
GDP	Gross Domestic Product
GHG	Green House Gas
GW	Gigawatts
H_2	Hydrogen

H_2O	Water
HRT	Hydraulic Retention Times
ICE	Internal Combustion Engine
IPCC	Intergovernemental Panel for Climate Change
KJ	Kilojoules
KW/h	kilowatt per hour
LAB	Lactic Acid Bacteria
LCA	Latin American and the Caribbean
LHV	Lower Heating Value;
MCB	Maximum Cumulative Biogas
MCH	Maximum Cumulative Hydrogen
MEC	Microbial electrolysis cell
MENA	Middle East and North Africa
MFC	Microbial fuel cell
MSW	Municipal Solid Waste
N_2O	Nitrogen dioxide
Ni	Nickel
O_2	Oxygen
OECD	Organization for Economic Cooperation and Development countries

Pb	Lead
POME	Palm Oil Mill Effluent
R/P	Production Ration
RE	Renewable Energy
REN	Renewable Energy Network
SAR	South Asia Region
SMR	Steam Methane Reforming
SS	Sewage Sludge
TSS	Total Suspended Solids
UASB	Up-Flow Anaerobic Sludge Blanket Bioreactor
USA	United States of America
VS	Volatile Solid