

**METHANE ADSORPTION MICROCALORIMETRY
BY ACTIVATED CARBON FIBRE DERIVED FROM
EMPTY FRUIT BUNCH FIBRE**

by

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	ii
TABLE OF CONTENTS.....	iv
LIST OF TABLES.....	ix
LIST OF FIGURES.....	x
LIST OF ABBREVIATIONS.....	xvii
LIST OF SYMBOLS.....	xix
ABSTRAK.....	xx
ABSTRACT.....	xxii

CHAPTER ONE–INTRODUCTION

1.1 Research background	1
1.2 Problem statement.....	5
1.3 Objectives.....	6
1.4 Novelty of research.....	7
1.5 Scope of research.....	8
1.6 Hypothesis and expected outcomes.....	9

CHAPTER TWO–LITERATURE REVIEWS

2.1 Carbon materials.....	11
2.1.1 Carbon fibres.....	13
2.1.2 Activated carbons.....	14
2.1.3 Activated carbon fibres.....	18
2.2 Advantages of activated carbon fibres.....	19
2.3 Applications of activated carbon fibres.....	23
2.3.1 Storage of methane.....	24
2.3.2 Removal of SO ₂ and NO _x	26
2.3.3 Purification of water.....	27
2.4 Methane storage by activated carbons/carbon materials.....	28

2.5	Raw materials of ACFs.....	33
2.5.1	Biomass raw materials.....	33
2.5.1(a)	Oil palm empty fruit bunch (EFB) fibres.....	34
2.6	Preparation of activated carbon fibres.....	36
2.6.1	Carbonisation.....	37
2.6.2	Activation.....	42
(a)	Physical activation.....	42
(b)	Chemical activation.....	44
2.7	Adsorption.....	47
2.7.1	Brunauer–Emmett–Teller (BET) theory.....	48
2.7.2	Density Functional Theory (DFT).....	49
2.7.3	Heat of adsorption.....	49
2.7.4	Pressure swing adsorption.....	50
2.8	Techniques of adsorption measurement.....	51
2.8.1	Volumetric technique.....	51
2.8.2	Gravimetric technique.....	52

CHAPTER THREE–RESEARCH METHODOLOGY

3.1	Introduction.....	54
3.2	Raw materials.....	55
3.2.1	EFB fibre.....	55
3.2.2	Chemicals.....	55
3.3	Preparation of activated carbon fibres from oil palm empty fruit bunch fibres.....	56
3.3.1	Acid treatment and pyrolysis (oxidative and non-oxidative) conditions.....	57
(a)	Preparation route I (pre-combustion acid treatment) and II (post-combustion acid treatment).....	57
(b)	Preparation route III (pre-pyrolysis acid treatment) and IV (post-pyrolysis acid treatment).....	58
(c)	Control samples without acid treatment.....	59
(d)	Activation.....	60

3.3.2	Preparation at different of combustion temperatures.....	61
3.3.3	Preparation at different of pyrolysis temperatures.....	62
3.4	Characterisation.....	63
3.4.1	Elemental analysis.....	63
3.4.2	Burn-off analysis.....	63
3.4.3	Thermogravimetry.....	64
3.4.4	Field emission scanning electron microscope (FE-SEM) and energy dispersive X-ray(EDX).....	64
3.4.5	Fourier transform infrared (FTIR) spectroscopy.....	65
3.4.6	X-ray diffractometry (XRD).....	66
3.4.7	Raman spectroscopy.....	66
3.4.8	Nitrogen adsorption analysis.....	67
3.4.9	Methane adsorption microcalometry.....	68
	(a) Adsorption analysis.....	68
	(b) Reusability of ACFs in methane adsorption.....	70
3.5	Summary of research methodology.....	71

CHAPTER FOUR–RESULTS AND DISCUSSION

4.1	Introduction.....	72
4.2	Characterisations of empty fruit bunch (EFB) fibre.....	73
4.2.1	Elemental analysis.....	73
4.2.2	Surface morphological and microstructural analysis.....	74
4.2.3	Thermogravimetry.....	77
	(a) Pyrolysis behaviour of raw EFB fibre and acid treated EFB fibre.....	78
	(b) Combustion behaviour of raw EFB fibre and acid treated EFBfibre.....	82
	(c) Comparison of pyrolysis and combustion behaviour.....	86
4.3	Characterisations of activated carbon fibre (ACF).....	86

4.3.1	Acid treatment and pyrolysis(oxidative and non-oxidative) conditions.....	86
(a)	Burn-off analysis of ACFs.....	88
(b)	Composition and structure analysis of ACFs.....	90
(c)	Pore characteristics in the ACFs.....	95
4.3.2	Preparation at different of combustion temperatures.....	105
(a)	Surface morphological and microstructural analysis of the ACFs combusted at different carbonisation temperatures.....	106
(b)	Pore characteristics of the ACFs combusted at different carbonisation temperatures.....	108
(c)	Surface chemistry of raw EFB fibre and ACF samples prepared at different pyrolysis temperatures.....	113
(d)	Methane adsorption and heat of adsorption of the combusted ACFs.....	115
4.3.3	Preparation at different of pyrolysis temperatures.....	118
(a)	Surface morphological and microstructural analysis of the ACFs pyrolysed at different carbonisation temperatures.....	119
(b)	Pore characteristics of the ACFs pyrolysed at different carbonisation temperatures.....	121
(c)	Surface chemistry of raw EFB fibre and ACF samples prepared at different pyrolysis temperatures.....	126
(d)	Methane adsorption and heat of adsorption of the pyrolysed ACFs.....	128
4.4	Reusability of ACFs in methane adsorption.....	132
4.5	Comparison of EFB fibre derived from ACF, commercial AC and commercial ACF.....	134
4.5.1	Surface morphological and microstructural analysis of commercial AC and commercial ACF.....	134
4.5.2	Pore characteristics of EFB fibre-derived ACF, commercial AC and commercial ACF.....	136
4.5.3	Methane adsorption of EFB fibre-derived ACF, commercial AC and commercial ACF.....	138

CHAPTER FIVE–CONCLUSION AND RECOMMENDATIONS

5.1	Conclusion.....	147
5.2	Recommendations for future research.....	149
	REFERENCES.....	150

APPENDICES

LIST OF PUBLICATIONS

LIST OF TABLES

		Page
Table 2.1	Properties of raw materials used in the manufacture of activated carbons	16
Table 2.2	Pore sizes of ACF determined by N ₂ and He adsorption	22
Table 2.3	Applications of activated carbon fibre produced from raw materials	23
Table 2.4	Carbonisation and activation conditions of agricultural residues	39
Table 3.1	The detail of chemicals in ACF processing	56
Table 3.2	Samples identification of ACF prepared in different combustion and pyrolysis condition	61
Table 3.3	Codes of the samples combusted under an oxidative atmosphere	62
Table 3.4	Codes of samples pyrolysed in nitrogen condition	63
Table 3.5	Samples identification of all ACFs prepared from EFB fibre	71
Table 4.1	Elemental analysis of the biomasses	74
Table 4.2	The identification of samples prepared in different combustion and pyrolysis condition	88
Table 4.3	Peak position, peak intensity, and R(=I _D /I _G) values of the D and G band for ACF samples	94
Table 4.4	The pore characteristic of ACFs from EFB fibre at	98

	different sequence of acid treatment	
Table 4.5	Identifications of ACFs prepared at different combustion temperatures	105
Table 4.6	Physical properties of EC85H2AC, EC130H2AC, EC160H2AC and EC250H2AC	113
Table 4.7	Identification of ACF samples pyrolysed in nitrogen condition	119
Table 4.8	Total burn-off, packing density and porous texture characterisation results of activated carbon fibres	122
Table 4.9	Comparison of pore characteristics of activated carbons derived from empty fruit bunch fibre	123
Table 4.10	Vibration bands of functional groups forACFs through pyrolysis routes	128
Table 4.11	Methane storage of ACF samples at 3.5 MPa at three different temperatures	132
Table 4.12	Methane adsorption capacity of EP600H1AP for three cycles continuously at 3.5 MPa and 298 K	133
Table 4.13	Methane adsorption capacity of EP1000H1AP for three cycles continuously at 3.5 MPa and 298 K	134
Table 4.14	Profile comparison between methane and nitrogen adsorption	140
Table 4.15	Methane adsorption capacity of activated carbon products	146

LIST OF FIGURES

		Page
Figure 2.1	Venn diagram illustrating where ACFs lie in the classification of carbon materials	11
Figure 2.2	Basic flow sheet for physical activation in activated carbons	17
Figure 2.3	Basic flow sheet for chemical activation in activated carbons	17
Figure 2.4	Number of publications on activated carbon fibres between 1980 and 2014 steadily increase in public output. The dotted line across the plot shows the best fit in a linear trend—data derived derived from ScienceDirect as of 1980-2014	19
Figure 2.5	Scanning electron microscope images of a commercial activated carbon fibre derived from phenolicresin fibres in 3k \times and 60k \times magnification respectively	20
Figure 2.6	(a) Diameters ranging of fibres, (b) Adsorption capacities of various ACFs include cellulose-based, pitch-based, PAN-based and phenol resin-based at 20 °C	21
Figure 2.7	The remains of the damaged car at the gas filling station	25
Figure 2.8	Methane adsorption isotherms of an adsorbent filled tank (ANG) and an empty tank pressurised up to 4 MPa at 298 K	26

Figure 2.9	Volume distribution of various carbon materials in adsorbent-filled gas storage vessel	30
Figure 2.10	The packing density of both ACFs and PACs versus micropore volume	31
Figure 2.11	(a) SEM micrograph for cross section of EFB precursor (500x), (b) SEM micrograph for cross section of EFB-based ACF (500x)	36
Figure 2.12	Thermal decomposition of acid treated EFB fibre under nitrogen and air conditions	41
Figure 2.13	Schematic diagram of a surface phenomenon in adsorption process	48
Figure 2.14	Schematic diagram of volumetric measurement for pure gas adsorption	52
Figure 3.1	Major steps involved in the methane and heat of adsorption by nanoporous ACF samples	54
Figure 3.2	Cleaned and dried oil palm EFB fibre	55
Figure 3.3	Flow chart of synthesis in combustion process, route I: acid treatment prior to carbonisation, control C (combustion-activation)–without acid treatment; and route II: carbonisation prior to acid treatment	58
Figure 3.4	Flow chart of synthesis in pyrolysis process, route III: acid treatment prior to carbonisation, control P (pyrolysis-activation) without acid treatment; and route IV: carbonisation prior to acid treatment	59
Figure 3.5	ACF sample derived from EFB fibre	61

Figure 3.6	Schematic diagram of experimental set-up for methane adsorption microcalorimetry	69
Figure 3.7	ACF samples are pressed into pellets for measurement of packing density	69
Figure 4.1	SEM images of the (a) external surface of raw EFB fibre, (b) cross section of raw EFB fibre under magnification 500 ×	75
Figure 4.2	EDX spectrum of external surface for raw EFB fibre (spotted on smooth flat surface)	76
Figure 4.3	EDX spectrum of external surface for raw EFB fibre (spotted on white granular grain)	77
Figure 4.4	Thermal decomposition of raw and acid treated EFB fibre under nitrogen and oxygen conditions	78
Figure 4.5	Thermal decomposition of raw and acid treated EFB fibre under nitrogen condition	79
Figure 4.6	Three major monomers of lignin	80
Figure 4.7	Thermal decomposition of raw and acid treated EFB fibre under oxygen conditions	83
Figure 4.8	Chemical structures of (a) hemicellulose and (b) cellulose	84
Figure 4.9	Overall burn-off percentage of ACF (Route I-IV) and control products in carbonisation and activation processes	90
Figure 4.10	X-ray diffractogram of ACF samples produced in combustion and pyrolysis processes	96

Figure 4.11	Three-dimensional crystal lattice of (a) graphite and (b) turbostratic structure of carbon material	92
Figure 4.12	Raman spectra of ACF samples in (a) combustion process, (b) pyrolysis process	93
Figure 4.13	Raman spectra of (a) the graphite, (b) and (c) the graphite oxide products after modification process	95
Figure 4.14	Adsorption isotherm of nitrogen at 77 K on ACF samples: (a) synthesis in combustion process, (b) synthesis in pyrolysis process	97
Figure 4.15	DFT pore size distribution of (a) EC250H2AC, EC250H2CA and EC250H2XA, (b) EP400H1AP, EP400H1PA and EP400H1XA	97
Figure 4.16	Devolatilisation of char residue after acid treatment under nitrogen condition	102
Figure 4.17(a-b)	SEM images of (a) EC85H2AC and (b) EC130H2AC at 500× magnification	107
Figure 4.17(c-d)	SEM images of (c) EC160H2AC and (d) EC250H2AC at 500× magnification	108
Figure 4.18	Nitrogen adsorption isotherms at -196 °C for samples EC85H2AC (85 °C), EC130H2AC (130 °C), EC160H2AC (160 °C) and EC250H2AC (250 °C)	109
Figure 4.19	DFT pore size distributions of EC85H2AC, EC130H2AC, EC160H2AC and EC250H2AC	111
Figure 4.20	FTIR spectra of samples (a) raw EFB fibre and ACF sample which combusted at (b) 85 °C	115

(EC85H2AC), (c) 130 °C (EC130H2AC), (d) 160 °C (EC160H2AC) and (e) 250 °C (EC250H2AC)

Figure 4.21	Methane adsorption of EC250H2 at 243 K, 263 K and 298 K	116
Figure 4.22	Heats of adsorption for EC250H2AC at 243 K, 263 K and 298 K	118
Figure 4.23(a-c)	SEM image of samples (a) EP4000H1AP, (b) EP600H1AP and (c) EP800H1AP under magnification 500×	120
Figure 4.23(d)	SEM image of samples (d) EP1000H1AP under magnification 500×	121
Figure 4.24	Nitrogen adsorption isotherms, BET surface area and pore volume analysis for ACF samples EP400H1AP, EP600H1AP, EP800H1AP and EP1000H1AP	122
Figure 4.25	Total burn-off and packing density as a function of pyrolysis temperature	125
Figure 4.26	Pore size distribution by DFT method of pyrolysed ACF samples	126
Figure 4.27	FTIR spectra of samples (a) raw EFB fibre and ACF sample which pyrolysed at (b) 400 °C (EP400H1AP), (c) 600 °C (EP600H1AP), (d) 800 °C (EP800H1AP) and (e) 1000 °C (EP1000H1AP)	127
Figure 4.28	(a) Methane adsorption isotherms of EP600H1AP and EP1000H1AP; (b) Differential heat of	131

methane adsorption of EP600H1AP and EP1000H1AP

Figure 4.29	(a) Methane adsorption isotherms of EP600H1AP, Differential heat of methane adsorption on EP600H1AP for three cycles continuously; (b) Methane adsorption isotherms of EP1000H1AP, Differential heat of methane adsorption on EP1000H1AP for three cycles continuously	133
Figure 4.30	SEM images of (a) commercial AC and (b) commercial ACF (A15)	135
Figure 4.31	TEM image of commercial ACF (A20)	136
Figure 4.32	Nitrogen adsorption isotherms at 77 K for samples EP1000H1AP, commercial AC and commercial ACF	137
Figure 4.33	DFT pore size distributions of EP1000H1AP, commercial AC and commercial ACF	138
Figure 4.34	Methane adsorption isotherms on various activated carbon products at 298K	139
Figure 4.35	Profile of the interaction potential between the adsorptive methane molecules and the adsorption pore walls	141
Figure 4.36	Profile of the interaction potential between the adsorptive methane molecules and the adsorption pore walls in (a) EFB fibre derived ACF EP1000H1AP and (b) commercial ACF	143

LIST OF ABBREVIATIONS

AC	Activated Carbon
ACF	Activated Carbon Fibre
ANG	Adsorbed Natural Gas
BET	Brunauer–Emmett–Teller
CH ₄	Methane
CNG	Compressed Natural Gas
CO ₂	Carbon Dioxide
DA	Dubinin-Astakhov
DFT	Density Functional Theory
DOE	The US Department of Energy
DR	Dubinin-Radushkevich
EDX	Energy Dispersive X-ray
EFB	Empty Fruit Bunch
FTIR	Fourier Transform Infrared
GAC	Granular Activated Carbon
H ₂ SO ₄	Sulphuric Acid
IUPAC	International Union of Pure and Applied Chemistry
KBr	Potassium Bromide
LNG	Liquefied Natural Gas
NGV	Natural Gas Fuelled Vehicle
PAC	Powdered Activated Carbon
PAN	Polyacrylonitrile
PSD	Pore Size Distribution

SEM	Scanning Electron Microscopy
SSA	Specific Surface Area
TG	Thermogravimetry
TGA	Thermogravimetric Analysis
XRD	X-ray Diffractometry

LIST OF SYMBOLS

°C	Unit of Temperature on the Celsius Scale
K	Unit of Temperature on the Kelvin Scale
Wt%	Weight Percent
%	Percent
g	Gram
kg	Kilogram
2θ	Angle of Incidence of the X-ray Beam
a.u.	Arbitrary Unit
mmol	Millimole

MIKROKALORIMETRI PENJERAPAN METANA OLEH SERAT KARBON TERAKTIF TERBITANDARIPADA SERAT TANDAN BUAH KOSONG

ABSTRAK

Serat tandan buah kosong kelapa sawit ialah satu sisa pertanian yang boleh diperolehi dengan banyak dari industry pemprosesan minyak sawit. Dalam kajian ini, serat tandan kosong digunakan sebagai bahan pelopor bagi penyediaan serat karbon teraktif untuk aplikasi penjerapan gas asli. Serat karbon teraktif dihasilkan melalui pengkarbonan, diikuti oleh fizikokimia dan pengaktifan. Pengaktifan fizikokimia dijalankan dengan menggunakan rawatan asid sulfurik diikuti oleh aliran gas CO₂. Kesan suhu pembakaran dan pirolisis yang berbeza terhadap sintesis serat kosong aktif telah dikaji. Tambahan pula, kesan rawatan asid ke atas serat tandan kosong telah dikaji dengan penggunaan asid sulfurik dan penukaran jujukan rawatan asid sebelum dan selepas pembakaran dan pirolisis. Intekalasi dan reaksi pengelupasan ke atas serat tandan kosong yang dirawat dengan asid sulfurik telah mengakibatkan kadar penurunan haba lebih tinggi berbanding dengan serat tandan kosong mentah yang tanpa rawatan asid. Luas permukaan BET dan jumlah isipadu liang yang tertinggi diperolehi masing-masing pada 1049 m²/g dan 0.45 cm³/g daripada sampel-sampel serat karbon teraktif yang dirawat dengan asid selepas pengoptimuman parameter pemprosesan. Serat karbon teraktif menunjukkan liang mikro sebagai liang utama dengan kelebaran liang 1.2 nm yang memenuhi salah satu syarat sebagai penjerap yang sempurna untuk aplikasi penjerapan gas asli. Penjerapan maksimum isipadu metana oleh serat karbon teraktif didapati mencapai 136 V/V pada 298 K and 3.5 MPa (memenuhi syarat-syarat ANG praktikal). Kapasiti penyimpanan metana bagi serat karbon teraktif terpilih ini standing dengan kapasiti karbon teraktif

komersil yang boleh didapati di pasaran, kebanyakan diperolehi daripada produk petroleum selepas merasionalisasi dengan ketumpatan pemadatan. Kerosotan prestasi yang rendah dalam penyimpanan metana daripada penjerapan operasi kitaran berikutnya menunjukkan bahawa serat karbon teraktif yang diperolehi daripada serat tandan buah kosong mempunyai penggunaan semula yang baik dan sesuai untuk aplikasi penjerapan gas asli.

METHANE ADSORPTION MICROCALORIMETRY BY ACTIVATED CARBON FIBRE DERIVED FROM EMPTY FRUIT BUNCH FIBRE

ABSTRACT

Empty fruit bunch (EFB) fibre of oil palm is an agricultural waste available abundantly from palm oil processing industry. In present work, EFB fibre was utilised as a precursor for preparation of activated carbon fibre (ACF) as an adsorbent for adsorbed natural gas (ANG) application. The ACFs were produced via carbonisation, followed by physicochemical and activation. Physicochemical activation was carried out using sulphuric acid treatment followed by CO₂ gas flow. The effects of different combustion and pyrolysis temperatures on the prepared ACFs were analysed. In addition, the effect of acid treatment on EFB fibres was further studied by switching the sequence of acid treatment before and after combustion and pyrolysis. Intercalation and exfoliation reactions on the acid-treated EFB fibre due to sulphuric acid resulted in a higher thermal degradation rate compared to raw EFB fibre without acid treatment. The highest BET surface area and total pore volume obtained amongst the ACF samples treated with acid was found to achieve values as high as 1049 m²/g and 0.45 cm³/g, respectively, after optimisation of the processing parameter. ACF exhibited predominantly micropore with pore width of 1.2 nm, which fulfil one of the requirements as an ideal adsorbent for ANG application. The maximum volumetric methane adsorption by the ACFs was observed to be 136 V/V at practical ANG conditions; viz. 298 K and 3.5 MPa. The volumetric storage capacities of these ACFs were comparable to the adsorption capacities of selected carbon materials commercially available in the market, which are mainly derived

from petroleum products after rationalising with packing density. Low deterioration in methane storage performance from subsequent adsorption cyclic operation indicated that the EFB fibre-derived ACF has good reusability, which is suitable for ANG application.

CHAPTER ONE

INTRODUCTION

1.1 Research background

Natural gas is a fossil fuel formed when layers of buried animals, plants, gases are exposed to severe heat and pressured underground over thousands of years (Agency, 2013). It is available abundantly in many countries. Natural gas composes more than 90% of methane (CH₄) which varies with locations and seasons of gas extraction (Arami-Niya et al., 2012). Another fuel which contains methane in its composition is biogas. Biogas is typically produced by anaerobic digestion or fermentation of biodegradable materials such as manure, sewage, municipal wastes, green wastes, plant materials and crops. Due to their eco-friendliness, enormous supply and costs effectiveness, both biogas and natural gas have attracted different interest from many researchers to use methane as an alternative fuel. These gases are by far the cleanest fuel because they produce sulphur dioxide, nitrogen oxide and carbon dioxide (CO₂) in minimal amounts compared to other fossil fuels such as gasoline, diesel and coal. Furthermore, they are cost effective and environmental friendly (Esteves et al., 2008, Guan et al., 2011, Zhang et al., 2010).

Natural gas and biogas are both highly promising clean energy in the automotive and other sectors. They are hydrocarbon gas mixtures consisting of primarily methane (Brady et al., 1996, Esteves et al., 2008). Biogas has the same characteristics as natural gas after the cleaning and upgrading purification processes (Esteves et al., 2008). Despite the advantages in using methane as a low cost and