HORSE MANURE DERIVED BIOFUEL PRODUCTION VIA MICROWAVE INDUCED PYROLYSIS

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ABSTRACT

Uncontrollable amount and unsystematic management of generated wastes due to the ever-increasing global population of human and animal have led to the alarming environmental pollution and health issues. Thus, waste-to-product transformation process is gaining popularity in recent years as this allows for the conversion of zero-value waste into beneficial end products. Horse manure (HM) is deemed to be a feasible feedstock for waste-to-energy transformation through thermochemical conversion. Conventional HM management methods, such as natural composting, have led to undesirable environmental pollution. The aim of this study was to determine the feasibility of HM to be converted into bio-products through microwave pyrolysis. The decomposition and kinetics behaviour of HM were investigated through thermogravimetric analyser (TGA) at temperatures of 27-900 °C and heating rates of 1-10 °Cmin^{-1}. The feedstock experienced rapid decomposition at temperatures between 190 °C and 400 °C under oxygen-free environment. Such a decomposition process was found to be endothermic and endergonic in nature, giving an activation energy of approximately 148.5-300.1 kJ/mol. The finding suggested that pyrolysis is the preferred thermal conversion pathway. A lab-scale microwave-heated pyrolysis reactor was then setup for the decomposition process of HM whilst collecting end products in the form of solid (bio-char), liquid (bio-oil) and gas (bio-gas). The produced bio-gas consists up to 70.2 vol% of syngas (H_2 and CO) along with CH_4 (12.6 to 23.4 vol%), making it a gaseous fuel candidate for heat/power generation. Although the bio-oil is made up of oxygenated compounds that resulted in low heating value (6.2-15.8 MJ/kg), its high phenolic content (up to 79 wt.%) remains useful for application as bio-chemical product. The bio-char derived from the microwave pyrolysis of HM is highly porous (surface area of up to 698.4 m^{2}g^{-1}), having potential as bio-adsorbent products. The bio-char produced also gained in heating value (up to 111.1%), indicating solid fuel-like properties. The optimum pyrolysis process parameter in yielding desired amount of end products was measured statistically through a full factorial design (FFD). The results indicated AC/HM ratio as the most influential factor, followed by temperature and carrier gas flow rate. Optimization of the end products suggested that a process condition with AC/HM ratio of 2.0, N_2 flow rate of 0.5 Lmin^{-1} and temperature of 550 °C, giving end product yields of 13.5 wt.% of bio-char, 32.5 wt.% of bio-oil and 39.2 wt.% of bio-gas. Lastly, a life-cycle-analysis was also conducted and the results show that HM feedstock is more environmentally friendly as compared to swine manure, when both are processed through pyrolysis. The management of HM through pyrolysis is also found to be the preferred pathway as compared to incineration, anaerobic digestion and natural composting. Overall, the study demonstrated that microwave-induced pyrolysis has the potential to thermochemically-convert HM into beneficial end products. Coupling this with the positive outcome from the life-cycle-analysis, it could be further summarised that HM is indeed a viable feedstock to be considered for valorisation purposes through microwave-induced pyrolysis.

ABSTRAK

Populasi manusia dan haiwan yang semakin meningkat telah mengakibatkan penambahan jumlah sisa buangan. Pengurusan sisa buangan yang tidak sistematik telah menyebabkan masalah pencemaran alam sekitar dan akan mempengaruhi kesihatan manusia. Oleh itu, proses transformasi sisa ke bio-produk semakin popular di kalangan ahli sains kerana ini memungkinkan transformasi sisa yang bernilai sifar kepada produk yang bermanfaat. Najis kuda (HM) adalah sejenis sisa yang mempunyai potensi untuk diubah menjadi sumber tenaga melalui penukaran therma-kimia. Secara konvensional, pengurusan HM dijalankan melalui kompos semula jadi dan kaedah ini telah mengakibatkan pencemaran alam sekitar. Tujuan kajian ini adalah untuk menentukan penukaran HM kepada bio-produk melalui proses pirolisis gelombang mikro. Tingkah laku penguraian dan kinetik HM diselidik melalui penganalisis termogravimetrik (TGA) pada suhu 27-900 ℃ dan kadar pemanasan 1-10 ℃min^{-1}. Kadar penguraian yang tertinggi adalah pada suhu antara 190 ℃ sehingga 400 ℃ di bawah persekitaran bebas oksigen. Proses penguraian sedemikian bersifat endotermik dan endergonik. Di samping itu, tenaga pengaktifan yang diperlukan adalah sebanyak 148.5-300.1 kJ/mol. Data menunjukkan pirolisis merupakan kaedah yang sesuai untuk memproses HM. Sebuah reaktor pirolisis gelombang mikro berskala makmal telah dihasilkan untuk proses penguraian HM. Produk akhir dalam bentuk pepejal (bio-arang), cecair (bio-minyak) dan gas (bio-gas) telah dikumpulkan. Bio-gas yang dihasilkan terdiri daripada 70.2 vol% syn-gas (H_2 dan CO) dan CH_4 (12.6 hingga 23.4 vol%). Ia mempunyai potensi sebagai bahan bakar untuk penjanaan haba / tenaga. Walaupun bio-minyak mempunyai sebatian beroksigen yang tinggi menghasilkan nilai pemanasan yang rendah (6.2-15.8 MJ/kg), namun kandungan fenoliknya yang tinggi (hingga 79 wt.%) tetap berpotensi untuk digunakan sebagai produk bio-kimia. Bio-arang mempunyai luas permukaan yang tinggi (698.4 m^2g^{-1}) dan berpotensi dijadikan produk bio-penyerap. Bio-arang yang dihasilkan juga mengalami kenaikan dalam nilai pemanasan (hingga 111.1%), menunjukkan potensi sebagai bahan bakar dalam bentuk pepejal. Parameter optimum untuk menghasilkan jumlah produk yang tertinggi diukur secara statistik melalui reka bentuk faktorial penuh (FFD). Hasil kajian menunjukkan nisbah AC/HM sebagai faktor yang paling berpengaruh, diikuti oleh suhu dan kadar aliran gas. Pengoptimuman produk akhir mencadangkan bahawa proses pirolisis perlu dijalankan dengan nisbah AC/HM 2.0, kadar aliran N_2 0.5 $Lmin^{-1}$ dan suhu 550 ℃. Hasil produk akhir dianggarkan sebanyak pada 13.5 wt.% bio-arang, 32.5 wt.% bio-minyak dan 39.2 wt.% bio-gas. Analisis kitaran hidup juga dijalankan dan diputuskan bahawa ia lebih mesra alam berbanding dengan pirolisis sisa khinzir. Pengurusan HM melalui pirolisis dilaporkan sebagai cara yang lebih mesra alam berbanding dengan pembakaran, pencernaan anaerobik dan kompos semula jadi. Secara keseluruhannya, kajian menunjukkan bahawa pirolisis yang dijalankan melalui gelombang mikro berpotensi untuk mengubah HM kepada produk akhir yang lebih bermanfaat. Tambahan dapatan kajian dari analisis kitaran hidup, ia dapat disimpulkan bahawa HM sememangnya sejenis bahan sisa yang dapat dinaik taraf kepada produk yang berguna melalui proses pirolisis dengan gelombang mikro.

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LIST OF ABBREVIATIONS

AC	-	Activated Carbon
AKTS	-	Advanced Kinetics and Technology Solution
ANOVA	-	Analysis of variance
AP	-	Acidification potential
BBD	-	Box-Behnken design
BET	-	Brunauer-Emmett-Teller
CCD	-	Central composite design
DAEM	-	Distributed Activation Energy Model
DF	-	Degree of freedom
DOE	-	Design of experiments
DTG	-	Derivative Thermogravimetry
EDX	-	Energy dispersive X-ray
EIA	-	Energy Information Administration
EP	-	Eutrophication potential
FESEM	-	Field emission scanning electron microscopy
FFD	-	Full Factorial design
FWO	-	Flynn-Wall-Ozawa
G	-	Graphite
GC-MS	-	Gas Chromatography Mass Spectroscopy
GC-TCD	-	Gas Chromatography Thermal Conductivity Detector
GHG	-	Greenhouse gas
GWP	-	Global warming potential
HDPE	-	High-density polyethylene
HHV	-	Higher heating value
HM	-	Horse Manure
HTL	-	Hydrothermal liquefaction
HTP	-	Human toxicity potential
KAS	-	Kissinger-Akahira-Sunose
LCA	-	Life cycle analysis
LHV	-	Lower heating value

MIP	-	Microwave-induced pyrolysis
MSW	-	Municipal solid waste
NREL	-	National Renewable Energy Laboratory
ODP	-	Ozone depletion potential
PAHs	-	Polycyclic aromatic hydrocarbons
PID	-	Proportional-Integral-Derivative
POCP	-	Photo-oxidant formation potential
R		Universal gas constant
RC	-	Residue char
RSM	-	Response surface methodology
SB model	-	Šesták and Berggren model
SMS	-	Spent mushroom substrate
TG	-	Thermogravimetry
TGA	-	Thermogravimetric analysis
TNB	-	Tenaga National Berhad
U.S.	-	United States

LIST OF SYMBOLS

α	-	Rate of mass loss
β	-	Heating rate
ε''	-	Dielectric loss factor
ε'	-	Dielectric constant
$f(\alpha)$	-	Kinetics reaction model
$d\alpha/dt$	-	Conversion rate
$\tan \delta$	-	Loss tangent
λ_0	-	microwave wavelength in free space
Sj^2	-	Residual sum of square
m_0	-	Initial mass
m_f	-	Final mass
E_α	-	Activation energy
t_α	-	Time to reach specific conversion
F_j	-	F-test statistical analysis
D_p	-	Penetration depth
K_B	-	Boltzman constant
A	-	Pre-exponential factor
c	-	velocity of light in free space
f	-	frequency of the electromagnetic wave
h	-	Plank constant
k	-	Constant of decomposition rate
T	-	temperature
t	-	time

CHAPTER 1

INTRODUCTION

1.1 Introduction

Modernisation and technological advancements have brought the world into a new era of information and technology. However, the comfort of living brought by such technological advancements has led our planet to be drained of its natural resources, particularly for the use of energy generation. The U.S. Energy Information Administration reported that the world energy consumption has increased by more than 50% from the 1990s to the present time as shown in Figure 1.1. It has been predicted that this trend will continue into the next decade (EIA, 2017).

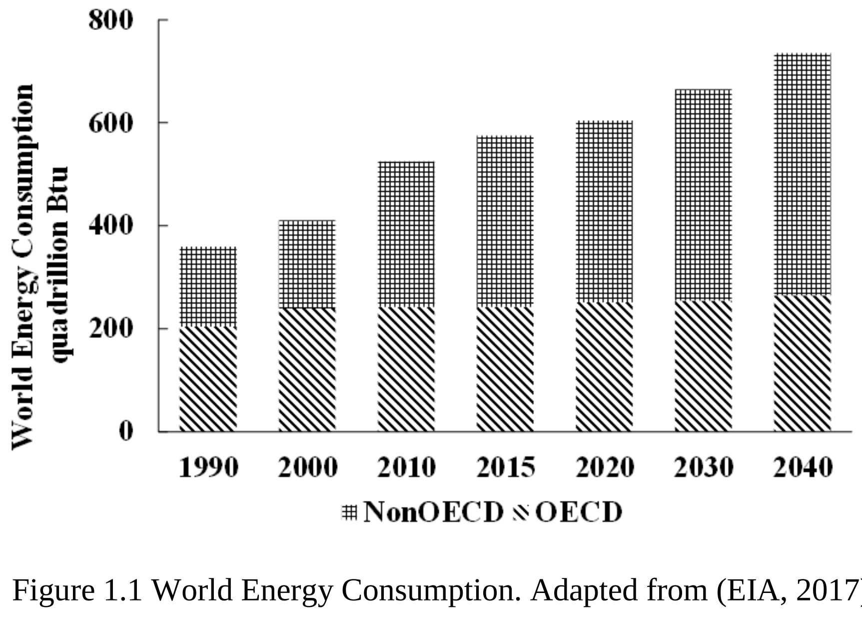

Figure 1.1 World Energy Consumption. Adapted from (EIA, 2017)

Petroleum has thus far been the main fuel supply for energy generation. Based on the current state of crude oil production, the energy demand could no longer be met by relying solely on this fuel source (Andruleit et al., 2015). Therefore, alternative fuel resources for energy generation are being explored. Figure 1.2 indicates that renewable energy will experience a slow but steady growth due to its cleaner power generation and never ending supplies (EIA, 2017). Renewable energies can also be sourced from the sun (solar energy), wind (wind energy), water (hydro energy), earths' heat (geothermal energy) and biomass.

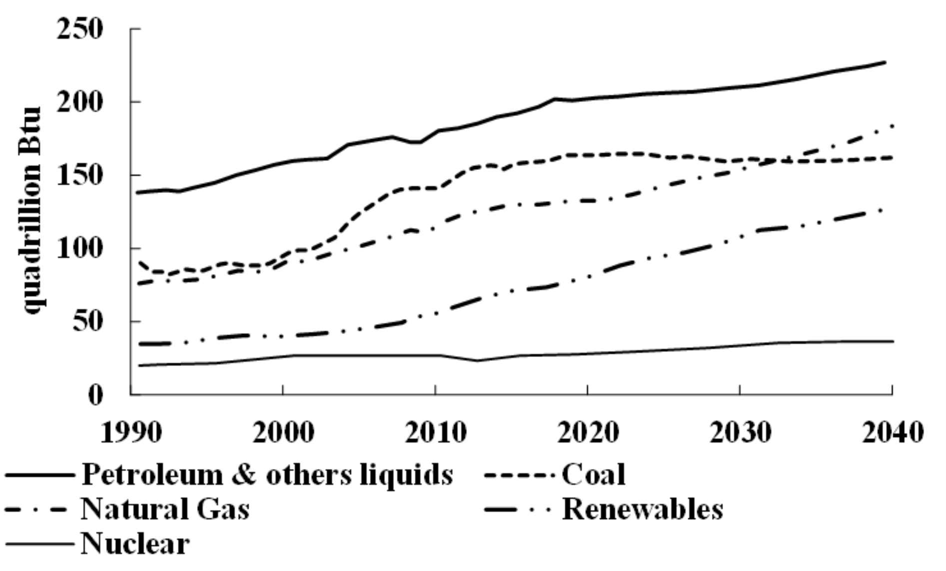

Figure 1.2 World Energy Consumption by Energy Source. Adapted from (EIA, 2017)

Among the above-mentioned renewables, solar energy will not be available all the time and can only be harvested at particular periods during the day. Moreover, weather changes will pose as the main obstacle in solar energy harvesting. On the other hand, wind energy can only be harvested at certain parts of the world, mostly along high hills area or seaside, where wind speed is sufficiently strong. Even though hydro energy can be harvested all-year-round, building of a dam has been known to lead to undesired deforestation and significant changes in landscape. Another alternative is to resort to geothermal energy, which is only available in limited regions on earth (Kádár, 2014; Mohtasham, 2015).

Of all the above mentioned renewable energies, biomass remains as the only source, which is available to all parts of the world in abundance and varieties. Biomass comes in various forms, comprising of woods, crops, garbage, manure, alcohol fuels and landfill gas. Energy extraction from biomass waste can be done through various conversion methods. Among them are thermochemical conversion and biochemical conversion techniques.

Thermochemical conversion methods include: 1) combustion, 2) pyrolysis, 3) torrefaction and 4) gasification. These methods involve the usage of heat, with or without the presence of oxygen, to convert biomass into valuable end-products. On the other hand, biochemical conversion methods include: 1) anaerobic/aerobic digestion and 2) fermentation. These methods mainly involve the usage of enzymes, bacteria or microorganism to breakdown biomass feedstock in producing valuable end-products. Both methods generate end-products in the form of solid, liquid and/or gas. Among these conversion methods, pyrolysis has been demonstrated to be effective in producing value-added end-products in the form of solid (bio-char), liquid (bio-oil) and/or gas (bio-gas/syngas) (Prithiraj & Kauchali, 2017). Besides this, pyrolysis has also been shown to emit smaller quantity of pollutants, such as SO_x, NO_x and CO_x, when compared with combustion and gasification thermochemical conversion methods (Cao et al., 2014).

Pyrolysis can also be referred to as the thermal decomposition of material under intense heat within an inert atmosphere. There are numerous chemical reactions that take place during pyrolysis, which complicates the prediction of the thermochemical conversion behaviour and the reactivity of different feedstock. To have a more detailed insight into the thermochemical conversion process during pyrolysis reaction, a kinetics analysis is typically conducted on the sample feedstock (Balasundram et al., 2017). The data obtained through such a kinetics analysis is capable of providing useful technical insights for designing and building an effective pyrolysis rig. For this purpose, the thermo-gravimetric analysis (TGA) can be used to determine kinetics parameters (Cai et al., 2018). Through this analysis, activation energy, which refers to the minimum energy to initiate chemical reaction of the sample, could be determined.

The present study aims to first explore the valorisation of horse manure (HM) through pyrolysis using thermogravimetric analysis in assessing its potential as a beneficial feedstock in bioenergy harvesting. Thermal decomposition kinetics of HM is then determined through iso-conversional method. A microwave pyrolysis rig is then designed for the thermal decomposition of HM under varying pyrolysis process parameters (e.g. temperature, carrier gas flow rate and catalyst ratio). A statistical analysis is then carried out to ascertain a mathematical model that correlates thermal decomposition product yield and pyrolysis process parameters, such as operating temperature, carrier gas flow rate and catalyst ratio. Finally, the end-products will be characterised accordingly. Based on the proposed quantitative and qualitative analysis, relevant and suitable applications for the thermally decomposed HM end-products would then be identified.

1.2 Problem Background

Biomass and bio-wastes have been studied as renewable fuel sources due to its carbon neutral properties (Lam et al., 2018; Ng et al., 2017; Samiran et al., 2016). Animal manure is an abundant biomass waste source, where its amount can be totalled up to 2.62 x 10^{13} kg/year on a worldly basis. These values far exceed the amount produced by human population (Penakalapati et al., 2017). Existing manure managing facilities have been deemed to not be capable of coping with this overwhelming amount of manure. A report by The Food and Agriculture Organization of the United Nations stated states that about 75% of manure produce globally were left on permanent meadows and pastures while only 25% of the manures were treated in manure management system (FAOSTAT, 2019). The unattended manure has directly/indirectly led to the worsening of land, water, air and sight pollution. In fact, these manures possess the potential to be converted into valuable end-products (Janković, 2018) through different chemical conversion process. Traditionally, these manures are only used to fertilise crops or just being buried in landfills. However, due to the implementation of stricter environment regulation, there is an urgent need for different disposal ways in order to minimize land and water pollution (Ro et al., 2007).

HM is one of the many types of biomass waste sources with the potential to be converted into biofuels through thermochemical conversion process. Conventional methods in managing HM in Malaysia and other countries include composting for fertilizers, anaerobic digestion for biogas and incineration for power production. As a matter of fact, these methods have contributed to environmental pollutions in one way or another. Thus, alternative methods in effectively managing the HM are required. Interestingly, it has been reported in literature that animal manure is a potential candidate for biofuel production through thermochemical conversion process. To date, HM is seldom being studied as a thermal decomposition feedstock due to the lack of mass loss behaviour and kinetic properties.

Among the available thermal decomposition processes (eg: torrefaction, combustion, gasification) considered in valorising HM, pyrolysis is preferred as it could yield usable amount of end products in all three forms of solid, liquid and gas. Moreover, the process emits a lower amount of gaseous pollutants when compared with other thermal decomposition methods. The commonly adopted heating mechanisms for the pyrolysis process can be divided into two categories: 1. Conventional heating and 2. Microwave heating. Microwave heating is deemed to be more superior when compared with conventional methods as it transfers heat through radiative means by heating the feedstock internally, thus, promoting a more uniformed heating across the feedstock.

To date, it is also to note that a swine manure pyrolysis facility has been setup in Belgium with an annual operation capacity of 7,000 ton (Rajabi Hamedani et al., 2019). Even though biomass wastes are commonly assumed to be carbon neutral sources, the entire pyrolysis process on swine manure was interestingly reported to have a significant undesirable impact on the environment when evaluated through a Life Cycle Analysis. Therefore, it is essential to conduct proper environmental impact evaluation in assessing the overall environmental effects of the entire microwave-induced pyrolysis process based on the usage of HM as the feedstock.

1.3 Problem Statement

The increase in worldwide energy demand has prompted the search for alternative green renewable fuel. Biofuel has been widely explored and used for energy production in order to cope with the increasing energy demand. However, the energy supply and demand gap are still large. Increasing the production of first-generation biofuel, which is mainly derived from food sources, such as animal fat and vegetable oil, could increase the competition between resources for food consumptions and biofuel production (Naik et al., 2010). Hence, it is only imperative that biofuel production emphasis is shifted towards second-generation biofuel manufactured from biomass in order to diversify the biofuel resources.

From the literature, the thermal decomposition of HM has not been explored extensively. This might probably be due to the lack of insight and understanding on the behaviour of HM during thermal decomposition. In view of the current HM managing methods (composition, anaerobic digestion and incineration), which is not environmentally sustainable, alternative processing route is required. Thermal decomposition using microwave pyrolysis is proposed in the present study to upgrade HM into higher value end products. In accordance to the focus of second generation biofuel on waste-to-energy concept, the present study aims to microwave-pyrolyse HM in producing useful alternative second-generation bio-fuel.

1.4 Research Objectives

In order to achieve the aim of the study, the objectives of the investigation are:

(a) To determine the thermal decomposition kinetics and thermodynamic properties of HM using thermal-gravimetric analysis (TGA).

(b) To derive a correlation between the end-product yield of thermal-decomposed HM and the process parameters using design of experiment (DOE) method.

(c) To identify potential final usage of bio-products derived from the thermal decomposition of HM at different process parameters.

(d) To evaluate the environmental impact of HM-based microwave pyrolysis plant in Peninsula Malaysia through cradle-to-gate Life Cycle Analysis.

1.5 Research Questions

The research questions to be answered during this study have been formulated as follow:

(a) What is the thermal decomposition kinetics and thermodynamics properties of HM?

(b) How does the thermal decomposition of HM process parameters correlate with the end-product composition?

(c) What is the possible end usage of bio-products obtained from thermal decomposition of HM?

(d) Is HM a feasible feedstock for pyrolysis in terms of economy, energy balance and environmental effects?

1.6 Research Scopes

The scope covered by the present study is listed below:

(a) To determine the kinetics properties of HM during pyrolysis through thermal decomposition using a thermogravimetric analyser

(b) To design and built a pyrolysis rig implementing microwave heating technique

(c) To quantify end-products (solid, liquid and gas) of thermally decomposed HM at varying process parameters

(d) To correlate thermal decomposition process parameters (temperature, AC/HM ratio and carrier gas flow rate) with the yield of end-products using DOE method

(e) To propose possible applications based on the distinct properties of produced end-products

(f) To evaluate the economic, energy yield and environmental impact on process of microwave pyrolysis on HM

1.7 Research Framework

The framework for the present study is presented in Figure 1.3. In this research, the kinetics and thermodynamic properties of HM is determined using TGA. A microwave rig, capable of thermal decomposition, is developed. The yield of end-products at different combinations of thermal decomposition process parameters will be recorded. A mathematical model, correlating thermal decomposition process parameters with the yield of end-products, will be derived. The fuel-based properties of thermally decomposed HM end-products are then obtained. Through quantitative and qualitative approaches, relevant and suitable applications for these end-products will then be proposed, ensuring effective usage of the derived second-generation biofuel. Lastly, a life-cycle analysis has been conducted on a microwave pyrolysis plant situated in Peninsula Malaysia and its environmental impact is assessed and compared with existing pyrolysis plant.

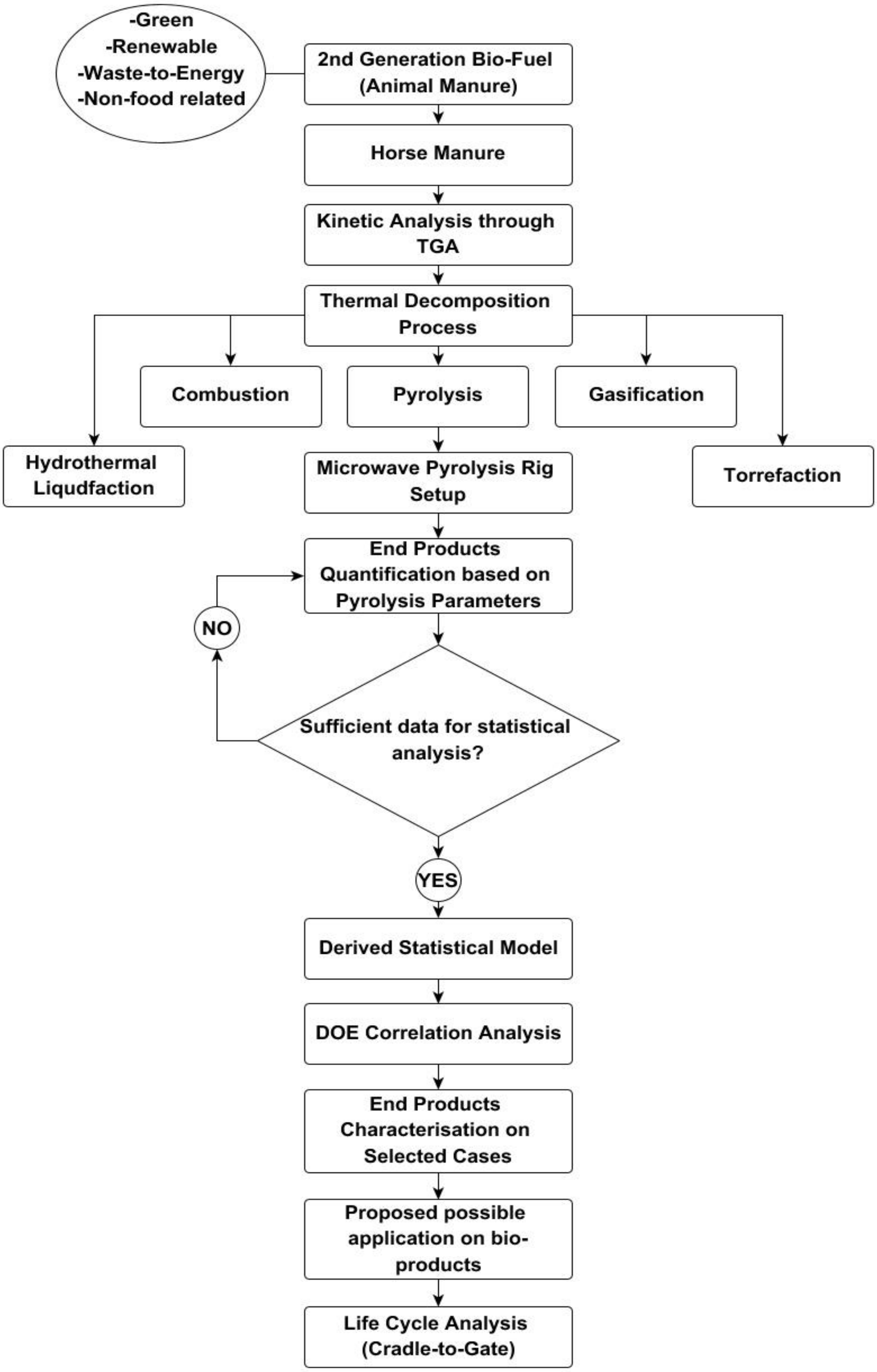

Figure 1.3 Research Framework

1.8 Research Deliverables

At the end of this study, it is expected that the following outcomes will be delivered:

(a) The thermal decomposition kinetics and thermodynamic properties of HM will be determined.

(b) A correlation between end-product yield and thermal decomposition process parameters will be established using design of experiment (DOE) method.

(c) Possible end usage of bio-products derived from microwave pyrolysis of HM will be identified.

(d) The environmental impacts of a microwave pyrolysis plant that process HM will be evaluated

From the derived correlation, it will then be possible to optimize the thermal decomposition process parameters for HM feedstock, depending on the desired end-product composition. A life cycle analysis will be conducted for HM using cradle-to-gate method and the feasibility in terms of economics, energy yield and environmental impacts will be presented. It is also noted that the derived framework can be adapted accordingly for thermal decomposition of various types of feedstock.

1.9 Significance of Study

The study explores the thermal decomposition of HM and the potential use of its end products. The first part of the study attends to the need to evaluate the mass loss behavior and kinetics properties of HM, which has yet to be reported in literature. The discovered properties of HM under thermal decomposition can then be applied to deduce possible processing methods for HM. The subsequent part of the study implements microwave heating in pyrolysis, presenting the integration of non-conventional heating mechanism that improves overall heating efficiency for such a thermal conversion process. Through statistical analysis, a correlation between process parameters and product yield is derived, providing an essential fundamental foundation in the upsizing of pyrolysis reactor size. Such a correlation, coupled with fuel-based properties/characteristics, could prove to be essential in deciding on the potential usage of HM thermal decomposition end-products as a new and effective source of second-generation biofuel. The end products obtained in each phase (solid, liquid and gas) from pyrolysis of HM are also characterized to identify their respective potential end usages. Finally, the life-cycle analysis conducted in the last part of the study provides further evidence on the feasibility of HM-based microwave pyrolysis process when adopted at an industrial-scale. Overall, it is also to highlight that the entire study also presents a fundamental platform that can be duplicated to evaluate the valorisation of any other types of biomass waste.

1.10 Summary

This chapter introduces the research problem, aims and objectives of the present study. The scope and significance of the study are also being highlighted. The following chapter covers the relevant literature review, corresponding to the research objectives identified in this chapter.

REFERENCES

Abas, F.Z., Ani, F.N., and Zakaria, Z.A. (2018) 'Microwave-assisted production of optimized pyrolysis liquid oil from oil palm fiber', *Journal of Cleaner Production. 182*, pp. 404-413.

Abd-Elghany, M., Elbeih, A., and Hassanein, S. (2016) 'Thermal behavior and decomposition kinetics of rdx and rdx/htpb composition using various techniques and methods', *Central European Journal of Energetic Materials. 13*(3), pp. 714-735.

Abd-Elghany, M., Klapötke, T.M., and Elbeih, A. (2017) 'Thermal behavior and decomposition kinetics of bis(2,2,2-trinitroethyl)-oxalate as a high energy dense oxidizer and its mixture with nitrocellulose', *Propellants, Explosives, Pyrotechnics. 42*(12), pp. 1373-1381.

Abd-Elghany, M., Klapötke, T.M., Elbeih, A., and Zeman, S. (2017) 'Investigation of different thermal analysis techniques to determine the decomposition kinetics of ε-2,4,6,8,10,12-hexanitro-2,4,6,8,10,12hexaazaisowurtzitane with reduced sensitivity and its cured pbx', *Journal of Analytical and Applied Pyrolysis. 126*, pp. 267–274.

Adams, P.W.R., Shirley, J.E.J., and McManus, M.C. (2015) 'Comparative cradle-to-gate life cycle assessment of wood pellet production with torrefaction', *Applied Energy. 138*, pp. 367-380.

AIM. (2013) 'National biomass strategy 2020: New wealth creation for malaysia’s biomass industry', *Agencies Inovasi Malaysia.* pp. 1-37.

Alipour Moghadam, R., Yusup, S., Azlina, W., Nehzati, S., and Tavasoli, A. (2014) 'Investigation on syngas production via biomass conversion through the integration of pyrolysis and air–steam gasification processes', *Energy Conversion and Management. 87*, pp. 670-675.

Alkurdi, S.S.A., Al-Juboori, R.A., Bundschuh, J., and Hamawand, I. (2019) 'Bone char as a green sorbent for removing health threatening fluoride from drinking water', *Environ Int. 127*, pp. 704-719.

ALPA Powder Tech. Cum-f hammer mill. In.

Andruleit, H., Babies, H.G., Fleig, S., Ladage, S., Mebner, J., Pein, M., Rebscher, D., Schauer, M., Schmidt, S., and Goeme, G.V. (2015) 'Energy study - reserves, resources and availability of energy resources', *Federal Institute for Geosciences and Natural Resources (BGR).* pp. 1-180.

Angin, D., and Sensoz, S. (2014) 'Effect of pyrolysis temperature on chemical and surface properties of biochar of rapeseed (brassica napus l.)', *International Journal of Phytoremediation. 16*(7-12), pp. 684-693.

Antunes, E., Jacob, M.V., Brodie, G., and Schneider, P.A. (2018) 'Microwave pyrolysis of sewage biosolids: Dielectric properties, microwave susceptor role and its impact on biochar properties', *Journal of Analytical and Applied Pyrolysis. 129*, pp. 93-100.

Arazo, R.O., Genuino, D.A.D., Luna, M.D.G., and Capareda, S.C. (2017) 'Bio-oil production from dry sewage sludge by fast pyrolysis in an electrically-heated fluidized bed reactor', *Sustainable Environment Research. 27*(1), pp. 7-14.

Ateş, F., Pütün, E., and Pütün, A.E. (2004) 'Fast pyrolysis of sesame stalk: Yields and structural analysis of bio-oil', *Journal of Analytical and Applied Pyrolysis. 71*(2), pp. 779-790.

Auta, M., Ern, L.M., and Hameed, B.H. (2014) 'Fixed-bed catalytic and non-catalytic empty fruit bunch biomass pyrolysis', *Journal of Analytical and Applied Pyrolysis. 107*, pp. 67-72.

Autaa, M., Erna, L.M., and Hameeda, B.H. (2014) 'Fixed-bed catalytic and non-catalytic empty fruit bunch biomass pyrolysis', *Journal of Analytical and Applied Pyrolysis. 107*, pp. 67-72.

Bakar, D.R.A., and Anandarajah, G. (2015). *Sustainability of bioenergy in malaysia with reference to palm oil biomass: Adopting principles governing bioenergy policy in the uk*. Paper presented at the Energy and Sustainability V: Special Contributions.

Balasundram, V., Ibrahim, N., Samsudin, M.D.H., Md. Kasmani, R., Abd Hamid, M.K., Isha, R., and Hasbullah, H. (2017) 'Thermogravimetric studies on the catalytic pyrolysis of rice husk', *Chemical Engineering Transactions. 56*, pp. 427-432.

Banar, M. (2015) 'Life cycle assessment of waste tire pyrolysis', *Fresenius Environmental Bulletin. 24*, pp. 1215-1226.

Barker, J.C., and Hodges, S.C. (2002) 'Livestock manure production rates and nutrient content', *NORTH CAROLINA AGRICULTURAL CHEMICALS MANUAL.* pp. 1-4.

Bartocci, P., Bidini, G., Asdrubali, F., Beatrice, C., Frusteri, F., and Fantozzi, F. (2018) 'Batch pyrolysis of pellet made of biomass and crude glycerol: Mass and energy balances', *Renewable Energy. 124*, pp. 172-179.

Batista, E.M.C.C., Shultz, J., Matos, T.T.S., Fornari, M.R., Ferreira, T.M., Szpoganicz, B., de Freitas, R.A., and Mangrich, A.S. (2018) 'Effect of surface and porosity of biochar on water holding capacity aiming indirectly at preservation of the amazon biome', *Scientific Reports. 8*(1), pp. 10677.

Batool, S., Idrees, M., Hussain, Q., and Kong, J. (2017) 'Adsorption of copper (ii) by using derived-farmyard and poultry manure biochars: Efficiency and mechanism', *Chemical Physics Letters. 689*, pp. 190-198.

Bayrakdar, A., Sürmeli, R.Ö., and Çalli, B. (2017) 'Dry anaerobic digestion of chicken manure coupled with membrane separation of ammonia', *Bioresource Technology. 244*(1), pp. 816-823.

Boateng, A., Jung, H., and Adler, P. (2006) 'Pyrolysis of energy crops including alfalfa stems, reed canarygrass, and eastern gamagrass☆', *Fuel. 85*(17-18), pp. 2450-2457.

Bouchera, M.E., Chaalab, A., and Roy, C. (2000) 'Bio-oils obtained by vacuum pyrolysis of softwood bark as a liquid fuel for gas turbines. Part i: Properties of bio-oil and its blends with methanol and a pyrolytic aqueous phase', *Biomass and Bioenergy. 19*, pp. 337–350.

Bridgwater, A.V. (2012) 'Review of fast pyrolysis of biomass and product upgrading', *Biomass and Bioenergy. 38*, pp. 68-94.

Bridgwater, A.V., and Bridge, S.A. (1991). *A review of biomass pyrolysis and pyrolysis technologies*. London: Elsevier Science.

Bridgwater, A.V., and Peacocke, G.V.C. (2000) 'Fast pyrolysis processes for biomass', *Renewable and Sustainable Energy Reviews. 4*, pp. 1-73.

Brown, M.E., Maciejewski, M., Vyazovkin, S., Nomen, R., Sempere, J., Burnham, A., Opfermann, J., Strey, R., Anderson, H.L., Kemmler, A., Keuleers, R., Janssens, J., Desseyn, H.O., Li, C.R., Tang, T.B., Roduit, B., Malek, J., and Mitsuhashi, T. (2000) 'Computational aspects of kinetic analysis part a: The ictac kinetics project-data, methods and results', *Thermochimica Acta. 355*, pp. 125-143.

Buah, W.K., Cunliffe, A.M., and Williams, P.T. (2007) 'Characterization of products from the pyrolysis of municipal solid waste', *Process Safety and Environmental Protection. 85*(5), pp. 450-457.

Burton, J., Economics (2018, 4th April 2018). The world leaders in coconut production. Retrieved from https://www.worldatlas.com/articles/the-world-leaders-in-coconut-production.html. Accessed on: 1st October.

Cai, J., Xu, D., Dong, Z., Yu, X., Yang, Y., Banks, S.W., and Bridgwater, A.V. (2018) 'Processing thermogravimetric analysis data for isoconversional kinetic analysis of lignocellulosic biomass pyrolysis: Case study of corn stalk', *Renewable and Sustainable Energy Reviews. 82*, pp. 2705-2715.

Cantrell, K.B., Hunt, P.G., Uchimiya, M., Novak, J.M., and Ro, K.S. (2012) 'Impact of pyrolysis temperature and manure source on physicochemical characteristics of biochar', *Bioresour Technol. 107*, pp. 419-428.

Cao, H., Xin, Y., Wang, D., and Yuan, Q. (2014) 'Pyrolysis characteristics of cattle manures using a discrete distributed activation energy model', *Bioresour Technol. 172*, pp. 219-225.

Cao, H.L., Xin, Y., Wang, D.L., and Yuan, Q.X. (2014) 'Pyrolysis characteristics of cattle manures using a discrete distributed activation energy model', *Bioresour Technol. 172*, pp. 219-225.

Cao, J.P., Huang, X., Zhao, X.Y., Wei, X.Y., and Takarada, T. (2015) 'Nitrogen transformation during gasification of livestock compost over transition metal and ca-based catalysts', *Fuel. 140*, pp. 477-483.

CEC, Clean Energy Compression (2016). How clean is natural gas? Greenhouse gas emissions by the numbers Retrieved from https://www.cleanenergyfuels.com/compression/blog/natgassolution-part-1-clean-natural-gas-stack-race-reduce-emissions/. Accessed on: 30-1-.

Çepelioğullar, Ö., and Pütün, A.E. (2013) 'Thermal and kinetic behaviors of biomass and plastic wastes in co-pyrolysis', *Energy Conversion and Management. 75*, pp. 263-270.

Chen, G., He, S., Cheng, Z., Guan, Y., Yan, B., Ma, W., and Leung, Y.C. (2017) 'Comparison of kinetic analysis methods in thermal decomposition of cattle manure by themogravimetric analysis', *Bioresource Technology. 243*, pp. 69-77.

Chen, J., Fan, X., Jiang, B., Mu, L., Yao, P., Yin, H., and Song, X. (2015) 'Pyrolysis of oil-plant wastes in a tga and a fixed-bed reactor: Thermochemical behaviors, kinetics, and products characterization', *Bioresour Technol. 192*, pp. 592-602.

Cheng, J., Pan, Y., Yao, J., Wang, X., Pan, F., and Jiang, J. (2016) 'Mechanisms and kinetics studies on the thermal decomposition of micron poly (methyl methacrylate) and polystyrene', *Journal of Loss Prevention in the Process Industries. 40*, pp. 139-146.

Chiong, M.C., Chong, C.T., Ng, J.H., Tran, M.V., Lam, S.S., Valera-Medina, A., and Mohd Jaafar, M.N. (2019) 'Combustion and emission performances of coconut, palm and soybean methyl esters under reacting spray flame conditions', *Journal of the Energy Institute. 92*(4), pp. 1034-1044.

Chiu, C.P., Yeh, S.I., Tsai, Y.C., and Yang, J.T. (2017) 'An investigation of fuel mixing and reaction in a ch4/syngas/air premixed impinging flame with varied h2/co proportion', *Energies. 10*(7).

Chong, C.T., Mong, G.R., Ng, J.H., Chong, W.W.F., Ani, F.N., Lam, S.S., and Ong, H.C. (2019) 'Pyrolysis characteristics and kinetic studies of horse manure using thermogravimetric analysis', *Energy Conversion and Management. 180*, pp. 1260-1267.

Chowdhury, Z.Z., Karim, M.Z., Ashraf, M.A., and Khalid, K. (2016) 'Influence of carbonization temperature on physicochemical properties of biochar derived from slow pyrolysis of durian wood (durio zibethinus) sawdust', *Bioresources. 11*(2), pp. 3356-3372.

Christina, (2015). Equestrian malaysia. *Equestrian Asia.* Retrieved from https://equestrianasia.com/countries/equestrian-malaysia/. Accessed on: 2019.

Cole Hill Associates. (2004). *Bio-oil commercialization plan*. Retrieved from

Collot, A.G., Zhuo, Y., Dugwell, D.R., and Kandiyoti, R. (1999) 'Co-pyrolysis and co-gasification of coal and biomass in bench-scale fixedbed and fluidised bed reactors', *Fuel. 78*, pp. 667–679.

Cook, R., Farm Centric (2018). World cattle inventory: Ranking of countries. Retrieved from http://beef2live.com/story-world-cattle-inventory-ranking-countries-0-106905. Accessed on: 23 October.

Cross, P. (2017) 'The great manure crisis of 2017', *HiPoint Agro Bedding Crop.* pp. 1-50.

Dai, L., Fan, L., Liu, Y., Ruan, R., Wang, Y., Zhou, Y., Zhao, Y., and Yu, Z. (2017) 'Production of bio-oil and biochar from soapstock via microwave-assisted co-catalytic fast pyrolysis', *Bioresour Technol. 225*, pp. 1-8.

Das, K.C., Garcia-perez, M., Bibens, B., and Melear, N. (2008) 'Slow pyrolysis of poultry litter and pine woody biomass: Impact of chars and bio-oils on microbial growth', *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering. 43*(7), pp. 714-724.

Das, P., and Tiwari, P. (2017) 'Valorization of packaging plastic waste by slow pyrolysis', *Resources, Conservation & Recycling. 128*, pp. 69-77.

De Caprariis, B., De Filippis, P., Petrullo, A., and Scarsella, M. (2017) 'Hydrothermal liquefaction of biomass: Influence of temperature and biomass composition on the bio-oil production', *Fuel. 208*, pp. 618-625.

De Conto, D., Silvestre, W.P., Baldasso, C., and Godinho, M. (2016) 'Performance of rotary kiln reactor for the elephant grass pyrolysis', *Bioresour Technol. 218*, pp. 153-160.

Dominguez, A., Fernandez, Y., Fidalgo, B., Pis, J.J., and Menendez, J.A. (2008) 'Bio-syngas production with low concentrations of co2 and ch4 from microwave-induced pyrolysis of wet and dried sewage sludge', *Chemosphere. 70*(3), pp. 397-403.

Domínguez, A., Menéndez, J.A., Fernández, Y., Pis, J.J., Nabais, J.M.V., Carrott, P.J.M., and Carrott, M.M.L.R. (2007) 'Conventional and microwave induced pyrolysis of coffee hulls for the production of a hydrogen rich fuel gas', *Journal of Analytical and Applied Pyrolysis. 79*(1-2), pp. 128-135.

Dominguez, A., Menendez, J.A., Inguanzo, M., and Pis, J.J. (2006) 'Production of bio-fuels by high temperature pyrolysis of sewage sludge using conventional and microwave heating', *Bioresour Technol. 97*(10), pp. 1185-1193.

Domínguez, A., Menéndez, J.A., Inguanzo, M., and Pís, J.J. (2005) 'Investigations into the characteristics of oils produced from microwave pyrolysis of sewage sludge', *Fuel Processing Technology. 86*, pp. 1007-1020.

Domínguez, A., Menéndez, J.A., Inguanzo, M., and Pís, J.J. (2006) 'Production of bio-fuels by high temperature pyrolysis of sewage sludge using conventional and microwave heating', *Bioresource Technology. 97*, pp. 1185–1193

Dong, Q., Li, H., Niu, M., Luo, C., Zhang, J., Qi, B., Li, X., and Zhong, W. (2018) 'Microwave pyrolysis of moso bamboo for syngas production and bio-oil upgrading over bamboo-based biochar catalyst', *Bioresource Technology. 266*, pp. 284-290.

Earing, J. (2011) 'Fiber digestion in horses', *Forage Focus-Equine.*

EIA. (2017) 'International energy outlook 2017', *U.S. Energy Information Administration.* pp. 1-151.

Encinar, J.M., Beltran, F.J., Bernalte, A., Ramiro, A., and Gonzalez, J.F. (1996) 'Pyrolysis of two agricultural residues: Olive and grape bagasse. Influence of particle size and temperature', *Biomass and Bioenergy. 11*(5), pp. 397-409.

Encinar, J.M., Beltrán, F.J., Ramiro, A., and González, J.F. (1997) 'Catalyzed pyrolysis of grape and olive bagasse. Influence of catalyst type and chemical treatment', *Ind. Eng. Chem. Res., 36*, pp. 4176-4183.

Entec. (2002) 'Market survey of marine distillates with 0.2% sulphur content'.

Envitech. Industrial gas cleaning system - quencher. In.

Eriksson, O., Hadin, Å., Hennessy, J., and Jonsson, D. (2016) 'Life cycle assessment of horse manure treatment', *Energies. 9*(12), pp. 1011.

Fabian, E.E. (2019) 'Horse stable manure management', *The Pennsylvania State University.* pp. 1-16.

Fahmi, R., Bridgwater, A.V., Donnison, I., Yates, N., and Jones, J.M. (2008) 'The effect of lignin and inorganic species in biomass on pyrolysis oil yields, quality and stability', *Fuel. 87*(7), pp. 1230-1240.

Fang, Z., Smith, R.L., and Qi, X. (2014). *Production of biofuels and chemicals with microwave*: Springer Netherlands.

FAO. (2006) 'Global horse population', *Food and Agriculture Organization of the United Nations.*

FAOSTAT, Food and Agriculture Organization of the United Nations (2019). Environment statistics. Retrieved from http://www.fao.org/economic/ess/environment/data/livestock-manure/en/. Accessed on: 8 October.

Farm Energy, CenUSA Bioenergy (2019). Biochar: Prospects of commercialization. Retrieved from https://farm-energy.extension.org/biochar-prospects-of-commercialization/. Accessed on: 13 Dec.

Fernandez-Lopez, M., Pedrosa-Castro, G.J., Valverde, J.L., and Sanchez-Silva, L. (2016) 'Kinetic analysis of manure pyrolysis and combustion processes', *Waste Management. 58*, pp. 230-240.

Fernández, Y., Arenillas, A., Dı´ez, M.A., Pis, J.J., and Menéndez, J.A. (2009) 'Pyrolysis of glycerol over activated carbons for syngas production', *J. Anal. Appl. Pyrolysis. 84*, pp. 145–150.

Fernández, Y., and Menéndez, J.A. (2011) 'Influence of feed characteristics on the microwave-assisted pyrolysis used to produce syngas from biomass wastes', *Journal of Analytical and Applied Pyrolysis. 91*, pp. 316–322.

Fonts, I., Azuara, M., Gea, G., and Murillo, M.B. (2009) 'Study of the pyrolysis liquids obtained from different sewage sludge', *Journal of Analytical and Applied Pyrolysis. 85*(184-191).

Fonts, I., Azuara, M., Gea, G., and Murillo, M.B. (2009) 'Study of the pyrolysis liquids obtained from different sewage sludge', *Journal of Analytical and Applied Pyrolysis. 85*(1-2), pp. 184-191.

FPI. (2007) 'Standard test method to qualify single-use foodservice packaging for use in microwave ovens', *Foodservice Packaging Institute.*

Friedl, A., Padouvas, E., Rotter, H., and Varmuza, K. (2005) 'Prediction of heating values of biomass fuel from elemental composition', *Analytica Chimica Acta. 544*(1-2), pp. 191-198.

Frišták, V., Pipíška, M., and Soja, G. (2018) 'Pyrolysis treatment of sewage sludge: A promising way to produce phosphorus fertilizer', *Journal of Cleaner Production. 172*, pp. 1772-1778.

Ganesapillai, M., Manara, P., and Zabaniotou, A. (2016) 'Effect of microwave pretreatment on pyrolysis of crude glycerol–olive kernel alternative fuels', *Energy Conversion and Management. 110*, pp. 287-295.

Garcia, A.N., Font, R., and Marcilla, A. (1995) 'Kinetic study of the flash pyrolysis of municipal solid waste in a fluidized bed reactor at high temperature', *Journal of Analytical and Applied Pyrolysis. 31*, pp. 101-121.

García, A.N., Font, R., and Marcilla, A. (1995) 'Kinetic study of the flash pyrolysis of municipal solid waste in a fluidized bed reactor at high temperature', *Journal of Analytical and Applied Pyrolysis. 31*, pp. 101-121.

González-Vázquez, M.P., García, R., Gil, M.V., Pevida, C., and Rubiera, F. (2018) 'Comparison of the gasification performance of multiple biomass types in a bubbling fluidized bed', *Energy Conversion and Management. 176*, pp. 309-323.

Google Map, (2019). Accessed on: 20 Nov.

Guizani, C., Valin, S., Billaud, J., Peyrot, M., and Salvador, S. (2017) 'Biomass fast pyrolysis in a drop tube reactor for bio oil production: Experiments and modeling', *Fuel. 207*, pp. 71-84.

Gupta, G.K., and Mondal, M.K. (2019) 'Bio-energy generation from sagwan sawdust via pyrolysis: Product distributions, characterizations and optimization using response surface methodology', *Energy. 170*, pp. 423-437.

Hayden, F., and Croisier, A. (2005) 'Transmission of avian influenza viruses to and between humans', *The Journal of Infectious Diseases. 192*, pp. 1311-1314.

Henan Green Eco-Equipment. (2020). Green eco-equipment. In: China.

Heo, H.S., Park, H.J., Park, Y.K., Ryu, C., Suh, D.J., Suh, Y.W., Yim, J.H., and Kim, S.S. (2010) 'Bio-oil production from fast pyrolysis of waste furniture sawdust in a fluidized bed', *Bioresour Technol. 101 Suppl 1*, pp. S91-96.

Heo, H.S., Park, H.J., Park, Y.K., Ryu, C.K., Suh, D.J., Suh, Y.W., Yim, J.H., and Kim, S.S. (2010) 'Bio-oil production from fast pyrolysis of waste furniture sawdust in a fluidized bed', *Bioresource Technology. 101*, pp. S91–S96.

Hirschmann, R. (2019). Horse production in malaysia from 2005 to 2017. Retrieved Nov 13, 2019 https://www.statista.com/statistics/659853/malaysia-horse-production/

Hong, Y., Chen, W., Luo, X., Pang, C., Lester, E., and Wu, T. (2017) 'Microwave-enhanced pyrolysis of macroalgae and microalgae for syngas production', *Bioresource Technology. 237*, pp. 47-56.

Hong, Y., Chen, W., Luo, X., Pang, C., Lester, E., and Wu, T. (2017) 'Microwave-enhanced pyrolysis of macroalgae and microalgae for syngas production', *Bioresour Technol. 237*, pp. 47-56.

Horsetalk, horsetalk.co.nz (2007). World horse population estimated at 58 million. Accessed on: 23 October.

Hosoya, T., Kawamoto, H., and Saka, S. (2007) 'Cellulose-hemicellulose and cellulose-lignin interactions in wood pyrolysis at gasification temperature.', *Journal of Analytical and Applied Pyrolysis. 80*(1), pp. 118-125.

Hossain, M.K., Strezov, V., Chan, K.Y., Ziolkowski, A., and Nelson, P.F. (2011) 'Influence of pyrolysis temperature on production and nutrient properties of wastewater sludge biochar', *Journal of Environmental Management. 92*, pp. 223-228.

Hossain, M.K., Strezov, V., and Nelson, P.F. (2009) 'Thermal characterisation of the products of wastewater sludge pyrolysis', *Journal of Analytical and Applied Pyrolysis. 85*(1-2), pp. 442-446.

Hu, M., Chen, Z., Wang, S., Guo, D., Ma, C., Zhou, Y., Chen, J., Laghari, M., Fazal, S., Xiao, B., Zhang, B., and Ma, S. (2016) 'Thermogravimetric kinetics of lignocellulosic biomass slow pyrolysis using distributed activation energy model, fraser–suzuki deconvolution, and iso-conversional method', *Energy Conversion and Management. 118*, pp. 1-11.

Huang, X., Cao, J.P., Zhao, X.Y., Wang, J.X., Fan, X., Zhao, Y.P., and Wei, X.Y. (2016) 'Pyrolysis kinetics of soybean straw using thermogravimetric analysis', *Fuel. 169*, pp. 93-98.

Huang, Y.F., Kuan, W.H., Lo, S.L., and Lin, C.F. (2008) 'Total recovery of resources and energy from rice straw using microwave-induced pyrolysis', *Bioresour Technol. 99*(17), pp. 8252-8258.

Huang, Y.F., Kuan, W.H., Lo, S.L., and Lin, C.F. (2008) 'Total recovery of resources and energy from rice straw using microwave-induced pyrolysis', *Bioresource Technology. 99*, pp. 8252–8258.

IBI, International Biochar Initiative (2018). State of the biochar industry 2014. Retrieved from https://biochar-international.org/state-of-the-biochar-industry-2014/. Accessed on: 11-12-.

iContainers, (2019). Shipment from america to malaysia (miami-to-klang). Retrieved from https://www.icontainers.com/quotes/FCL/CATOR/PORT/CA/MYPKG/PORT/MY/?dv20=1&dv40=0&hc40=0&freight=true. Accessed on: 18 Nov.

Idrees, M., Batool, S., Kalsoom, T., Yasmeen, S., Kalsoom, A., Raina, S., Zhuang, Q., and Kong, J. (2018) 'Animal manure-derived biochars produced via fast pyrolysis for the removal of divalent copper from aqueous media', *Journal of environmental management. 213*, pp. 109-118.

Idrees, M., Batool, S., Kalsoom, T., Yasmeen, S., Kalsoom, A., Raina, S., Zhuang, Q., and Kong, J. (2018) 'Animal manure-derived biochars produced via fast pyrolysis for the removal of divalent copper from aqueous media', *J Environ Manage. 213*, pp. 109-118.

Idris, R., Chong, C.T., and Ani, F.N. (2019) 'Microwave-induced pyrolysis of waste truck tyres with carbonaceous susceptor for the production of diesel-like fuel', *Journal of the Energy Institute. 92*(6), pp. 1831-1841.

Inguanzo, M., Domınguez, A., Menendez, J.A., Blanco, C.G., and Pis, J.J. (2002) 'On the pyrolysis of sewage sludge: The influence of pyrolysis conditions on solid, liquid and gas fractions', *Journal of Analytical and Applied Pyrolysis. 63*, pp. 209-222.

Inguanzo, M., Domínguez, A., Menéndez , J.A., Blanco, C.G., and Pis, J.J. (2002) 'On the pyrolysis of sewage sludge: The influence of pyrolysis conditions on solid, liquid and gas fractions', *Journal of Analytical and Applied Pyrolysis. 63*, pp. 209–222.

IOWA State University. (2005). *Listeriosis*. The centre for food security and public health: Institute for International Cooperation in Animal Biologics.

Islam, M.A., Asif, M., and Hameed, B.H. (2015) 'Pyrolysis kinetics of raw and hydrothermally carbonized karanj (pongamia pinnata) fruit hulls via thermogravimetric analysis', *Bioresour Technol. 179*, pp. 227-233.

Islam, M.N., Beg, M.R.A., and Islam, M.R. (2005) 'Pyrolytic oil from fixed bed pyrolysisnof municipal solid waste and its characterization', *Renewable Energy. 30*, pp. 413-420.

Jahirul, M., Rasul, M., Chowdhury, A., and Ashwath, N. (2012) 'Biofuels production through biomass pyrolysis —a technological review', *Energies. 5*(12), pp. 4952-5001.

Janković, B. (2015) 'Devolatilization kinetics of swine manure solid pyrolysis using deconvolution procedure. Determination of the bio-oil/liquid yields and char gasification', *Fuel Processing Technology. 138*, pp. 1-13.

Janković, B. (2018) 'Devolatilization kinetics of swine manure solid pyrolysis using deconvolution procedure. Determination of the bio-oil/liquid yields and char gasification', *Fuel Processing Technology. 138*, pp. 1-13.

Jeong, Y.W., Choi, S.K., Choi, Y.S., and Kim, S.J. (2015) 'Production of biocrude-oil from swine manure by fast pyrolysis and analysis of its characteristics', *Renewable Energy. 79*, pp. 14-19.

Jia, Y., Shi, S., Liu, J., Su, S., Liang, Q., Zeng, X., and Li, T. (2018) 'Study of the effect of pyrolysis temperature on the cd2+ adsorption characteristics of biochar', *Applied Sciences. 8*(7).

Jiang, H., Cheng, Z., Zhao, T., Liu, M., Zhang, M., Li, J., Hu, M., Zhang, L., and Li, J. (2014) 'Pyrolysis kinetics of spent lark mushroom substrate and characterization of bio-oil obtained from the substrate', *Energy Conversion and Management. 88*, pp. 259-266.

Jones, S., (2012). Comparing microwave to conventional heating and drying systems. *Chemical Product Processing for Heating, Drying and Applications Involving Chemical Reactions.* Retrieved from https://www.manufacturing.net/home/article/13149658/comparing-microwave-to-conventional-heating-drying. Accessed on: 11-12.

Kádár, P. (2014) 'Pros and cons of the renewable energy application', *Acta Polytechnica Hungarica. 11*(4), pp. 211-224.

Kan, T., Strezov, V., and Evans, T.J. (2016) 'Lignocellulosic biomass pyrolysis: A review of product properties and effects of pyrolysis parameters', *Renewable and Sustainable Energy Reviews. 57*, pp. 1126-1140.

Karatepe, N., and Kucukbayrak, S. (1993) 'Proximate analysis of some turkish lignites by thermogravimetry nilgiin', *Thermochimica Acta. 213*, pp. 147-150.

Karatepe, N., and Küçükbayrak, S. (1993) 'Proximate analysis of some turkish lignites by thermogravimetry', *Thermochimica Acta. 213*, pp. 147-115.

Khadka, R. (2010). *Global horse population with respect to breeds and risk status.* Institute of Animal Breeding and Husbandry, European Master in Animal Breeding and Genetics. Retrieved from https://stud.epsilon.slu.se/7676/

Khoo, H.H. (2019) 'Lca of plastic waste recovery into recycled materials, energy and fuels in singapore', *Resources, Conservation & Recycling. 145*, pp. 67-77.

Kilby, E.R. (2007). The demographics of the u.S. Equine population. In A. N. Rowan & D. J. Salem (Eds.), *The state of the animals* (pp. 175-205). Washington, DC: Humane Society Press.

Kim, S.W. (2016) 'Pyrolysis conditions of biomass in fluidized beds for production of bio-oil compatible with petroleum refinery', *Journal of Analytical and Applied Pyrolysis. 117*, pp. 220-227.

Kim, Y., and Parker, W. (2008) 'A technical and economic evaluation of the pyrolysis of sewage sludge for the production of bio-oil', *Bioresource Technology. 99*, pp. 1409–1416.

Kim, Y.S., Kim, Y.S., and Kim, S.H. (2010) 'Investigation of thermodynamic parameters in the thermal decomposition of plastic waste-waste lube oil compounds', *Environ. Sci. Technol., 44*, pp. 5313–5317.

Kloss, S., Zehetner, F., Dellantonio, A., Hamid, R., Ottner, F., Liedtke, V., Schwanninger, M., Gerzabek, M.H., and Soja, G. (2012) 'Characterization of slow pyrolysis biochars: Effects of feedstocks and pyrolysis temperature on biochar properties', *Journal of Environmental Quality. SPECIAL SECTION*, pp. 990-1000.

Kok, L.P., Boon, M.E., and Smi, H.M. (1993) 'The problem of hot spots in microwave equipment used for preparatory techniques-theory and practice', *Scanning. 15*, pp. 100-109.

Kok, L.P., Boon, M.E., and Smid, H.M. (1993) 'The problem of hot spots in microwave equipment used for preparatory techniques-theory and practice', *Scanning. 15*, pp. 100-109.

Kopinke, F.D., Bach, G., and Zimmermann, G. (1993) 'New results about the mechanism of tle fouling in steam crackers', *Journal of Analytical and Applied Pyrolysis. 27*(1), pp. 45-55.

Kwon, E.E., Jeon, E.C., Castaldi, M.J., and Jeon, Y.J. (2013) 'Effect of carbon dioxide on the thermal degradation of lignocellulosic biomass', *Environ Sci Technol. 47*(18), pp. 10541-10547.

Lam, S.S., Lee, X.Y., Nam, W.L., Phang, X.Y., Liew, R.K., Yek, P.N.Y., Ho, Y.L., Ma, N.L., and Rosli, M.H.N. (2018) 'Microwave vacuum pyrolysis conversion of waste mushroom substrate into biochar for use as growth medium in mushroom cultivation', *Journal of Chemical Technology & Biotechnology.*

Lammel, G., and Graßl, H. (1995) 'Greenhouse effect of nox', *Environmental Science and Pollution Research. 2*(1), pp. 40-45.

Laug, O.B. (1988) 'Evaluation of a test method for measuring microwave oven cooking efficiency', *Institute for Applied Technology National Bureau of Standards Washington, D C.* pp. 1-29.

Lee, J., Choi, D., Ok, Y.S., Lee, S.R., and Kwon, E.E. (2017) 'Enhancement of energy recovery from chicken manure by pyrolysis in carbon dioxide', *Journal of Cleaner Production. 164*, pp. 146-152.

Lee, S.R., Lee, J., Lee, T., Tsang, Y.F., Jeong, K.H., Oh, J.I., and Kwon, E.E. (2017) 'Strategic use of co 2 for co-pyrolysis of swine manure and coal for energy recovery and waste disposal', *Journal of CO2 Utilization. 22*, pp. 110-116.

Leonelli, C., and Veronesi, P. (2015). Microwave reactors for chemical synthesis and biofuels preparation. In *Production of biofuels and chemicals with microwave* (pp. 17-40).

Li, A.M., Li, X.D., Li, S.Q., Ren, Y., Chi, Y., Yan, J.H., and Cen, K.F. (1999) 'Pyrolysis of solid waste in a rotary kiln: Influence of final pyrolysis temperature on the pyrolysis products', *Journal of Analytical and Applied Pyrolysis. 50*, pp. 149-162.

Li, H., Lu, J., Zhang, Y., and Liu, Z. (2018) 'Hydrothermal liquefaction of typical livestock manures in china: Biocrude oil production and migration of heavy metals', *Journal of Analytical and Applied Pyrolysis.*

Li, L., Rowbotham, J.S., Christopher, G.H., and Dyer, P.W. (2013). An introduction to pyrolysis and catalytic pyrolysis: Versatile techniques for biomass conversion. In *New and future developments in catalysis* (pp. 173-208).

Li, R., Zeng, K., Soria, J., Mazza, G., Gauthier, D., Rodriguez, R., and Flamant, G. (2016) 'Product distribution from solar pyrolysis of agricultural and forestry biomass residues', *Renewable Energy. 89*, pp. 27-35.

Li, W., Qi, D., Robert, C., Brown, David, L., and Mark, M.W. (2017) 'The impacts of biomass properties on pyrolysis yields, economic and environmental performance of the pyrolysis-bioenergy-biochar platform to carbon negative energy', *Bioresource Technology. 241*, pp. 959–968.

Li, Y., Zhang, R., He, Y., Zhang, C., Liu, X., Chen, C., and Liu, G. (2014) 'Anaerobic co-digestion of chicken manure and corn stover in batch and continuously stirred tank reactor (cstr)', *Bioresour Technol. 156*, pp. 342-347.

Liew, R.K., Azwar, E., Y., Y.P.N., Lim, X.Y., Cheng, C.K., Ng, J.H., Jusoh, A., Lam, W.H., Ibrahim, M.D., Ma, N.L., and Lam, S.S. (2018) 'Microwave pyrolysis with koh/naoh mixture activation: A new approach to produce micro-mesoporous activated carbon for textile dye adsorption', *Bioresour Technol. 266*, pp. 1-10.

Liew, R.K., Nam, W.L., Chong, M.Y., Phang, X.Y., Su, M.H., Yek, P.N.Y., Ma, N.L., Cheng, C.K., Chong, C.T., and Lam, S.S. (2018) 'Oil palm waste: An abundant and promising feedstock for microwave pyrolysis conversion into good quality biochar with potential multi-applications', *Process Safety and Environmental Protection. 115*, pp. 57-69.

Liew, R.K., Nam, W.L., Chong, M.Y., Phang, X.Y., Su, M.H., Yek, P.N.Y.u., Ma, N.L., Cheng, C.K., Chong, C.T., and Lam, S.S. (2017) 'Oil palm waste: An abundant and promising feedstock for microwave pyrolysis conversion into good quality biochar with potential multi-applications', *Process Safety and Environmental Protection.*

Liu, X., Li, Z., Zhang, Y., Feng, R., and Mahmood, I.B. (2014) 'Characterization of human manure-derived biochar and energy-balance analysis of slow pyrolysis process', *Waste Manag. 34*(9), pp. 1619-1626.

LNG Industry, (2015). Sinocoking reports sales of us$5 million. Retrieved from https://www.lngindustry.com/regasification/05052015/syngas-sales-strong-in-first-quarter-686/. Accessed on: 13 Dec.

Lopez, G., Alvarez, J., Amutio, M., Mkhize, N.M., Danon, B., van der Gryp, P., Görgens, J.F., Bilbao, J., and Olazar, M. (2017) 'Waste truck-tyre processing by flash pyrolysis in a conical spouted bed reactor', *Energy Conversion and Management. 142*, pp. 523-532.

Lu, Q., Yang, X., and Zhu, X. (2008) 'Analysis on chemical and physical properties of bio-oil pyrolyzed from rice husk', *Journal of Analytical and Applied Pyrolysis. 82* pp. 191-198.

Lu, Q., Yang, X., and Zhu, X. (2008) 'Analysis on chemical and physical properties of bio-oil pyrolyzed from rice husk', *Journal of Analytical and Applied Pyrolysis. 82*, pp. 191-198.

Luo, S., Xiao, B., Hu, Z., Liu, S., Guan, Y., and Cai, L. (2010) 'Influence of particle size on pyrolysis and gasification performance of municipal solid waste in a fixed bed reactor', *Bioresource Technology. 101*, pp. 6517–6520.

Maia, A.A.D., and C., M. (2016) 'Kinetic parameters of red pepper waste as biomass to solid biofuel', *Bioresource Technology. 204*, pp. 157-163.

Maines, T.R., Jayaraman, A., Belser, J.A., Wadford, D.A., Pappas, C., Zeng, H., Gustin, K.M., Pearce, M.B., Viswanathan, K., Shriver, Z.H., Raman, R., Cox, N.J., Sasisekharan, R., Katz, J.M., and Tumpey, T.M. (2009) 'Transmission and pathogenesis of swine-origin 2009 a(h1n1) influenza viruses in ferrets and mice', *Science. 325*, pp. 484-487.

Marine Traffic, (2020). Voyage information - kuala lumpur express. Retrieved from https://www.marinetraffic.com/en/ais/details/ships/shipid:152182/mmsi:218284000/imo:9343730/vessel:KUALA_LUMPUR_EXPRESS. Accessed on: 19 Jan.

Menéndez, J.A., Dominguez, A., Inguanzo, M., and Pis, J.J. (2004) 'Microwave pyrolysis of sewage sludge: Analysis of the gas fraction', *J. Anal. Appl. Pyrolysis. 71*, pp. 657–667.

Menéndez, J.A., Inguanzo, M., and Pis, J.J. (2002) 'Microwave-induced pyrolysis of sewage sludge', *Water Research. 36*, pp. 3261–3264.

Meredith, R.J. (1998). *Engineers' handbook of industrial microwave heating by* UK: The Institution of Electrical Engineers, Technology & Engineering.

Mishra, R.K., and Mohanty, K. (2018) 'Pyrolysis kinetics and thermal behavior of waste sawdust biomass using thermogravimetric analysis', *Bioresource Technology. 215*, pp. 63-74.

Mohtasham, J. (2015) 'Review article-renewable energies', *Energy Procedia. 74*, pp. 1289-1297.

Moltó, J., Font, R., Gálvez, A., and Conesa, J.A. (2009) 'Pyrolysis and combustion of electronic wastes', *Journal of Analytical and Applied Pyrolysis. 84*(1), pp. 68-78.

Morin, M., Pécate, S., Hémati, M., and Kara, Y. (2016) 'Pyrolysis of biomass in a batch fluidized bed reactor: Effect of the pyrolysis conditions and the nature of the biomass on the physicochemical properties and the reactivity of char', *Journal of Analytical and Applied Pyrolysis. 122*, pp. 511-523.

Murillo, R., Aranda, A., Aylón, E., Callén, M.S., and Mastral, A.M. (2006) 'Process for the separation of gas products from waste tire pyrolysis', *Industrial & Engineering Chemistry Research. 455*, pp. 1734-1738.

Mushtaq, F., Abdullah, T.A.T., Mat, R., and Ani, F.N. (2015) 'Optimization and characterization of bio-oil produced by microwave assisted pyrolysis of oil palm shell waste biomass with microwave absorber', *Bioresource Technology. 190*, pp. 442-450.

Naik, S.N., Goud, V.V., Rout, P.K., and Dalai, A.K. (2010) 'Production of first and second generation biofuels: A comprehensive review', *Renewable and Sustainable Energy Reviews. 14*(2), pp. 578-597.

Nanda, S., Dalai, A.K., Gökalp, I., and Kozinski, J.A. (2016) 'Valorization of horse manure through catalytic supercritical water gasification', *Waste Management. 52*, pp. 147-158.

Ng, J.-H., Leong, S.K., Lam, S.S., Ani, F.N., and Chong, C.T. (2017) 'Microwave-assisted and carbonaceous catalytic pyrolysis of crude glycerol from biodiesel waste for energy production', *Energy Conversion and Management. 143*, pp. 399-409.

Ng, J.H., Leong, S.K., Lam, S.S., Ani, F.N., and Chong, C.T. (2017) 'Microwave-assisted and carbonaceous catalytic pyrolysis of crude glycerol from biodiesel waste for energy production', *Energy Conversion and Management. 143*, pp. 399-409.

Ng, J.H., Leong, S.K., Lam, S.S., Ani, F.N., and Chong, C.T. (2017) 'Microwave-assisted and carbonaceous catalytic pyrolysis of crude glycerol from biodiesel waste for energy production', *Energy Conversion and Management. 143*, pp. 399–409.

NIST, (2018). National instiure of standards and technology. *NIST Chemistry WebBook, SRD 69.* Retrieved from https://webbook.nist.gov/chemistry/. Accessed on: -10-14.

Notteboom, T., and Cariou, P. (2009) 'Fuel surcharge practices of container shipping lines: Is it about cost recovery or revenue-making', *Proceedings of the 2009 International Association of Maritime Economists (IAME) Conference.*

Omar, R., Idris, A., Yunus, R., Khalid, K., and Aida Isma, M.I. (2011) 'Characterization of empty fruit bunch for microwave-assisted pyrolysis', *Fuel. 90*, pp. 1536-1544.

Onay, O., Beis, S.H., and Kockar, O.M. (2001) 'Fast pyrolysis of rape seed in a well-swept fixed-bed reactor', *Journal of Analytical and Applied Pyrolysis. 58-59*, pp. 995–1007.

Onay, O., Beis, S.H., and Kockar, O.M. (2001) 'Fast pyrolysis of rape seed in a well-swept fixed-bed reactor', *Journal of Analytical and Applied Pyrolysis 58–59 (2001) 995–1007. 58-59*, pp. 995-1007.

Onay, O., and Kockar, O.M. (2003) 'Slow, fast and flash pyrolysis of rapeseed', *Renewable Energy. 28*(15), pp. 2417-2433.

Onay, O., and Kockar, O.M. (2003) 'Slow, fast and flash pyrolysis of rapeseed', *Renewable Energy. 28*, pp. 2417–2433.

Ong, B.H.Y., Walmsley, T.G., Atkins, M.J., and Walmsley, M.R.W. (2018) 'Hydrothermal liquefaction of radiata pine with kraft black liquor for integrated biofuel production', *Journal of Cleaner Production. 199*, pp. 737-750.

Ong, C.L., Babin, J., Chen, J.T., Liew, K.E., and Roda, J.M. (2016) 'Designing model for biomass transport cost of biofuel refinery in malaysia', *The 5th Burapha University International Conference.*

Otero, M., Lobato, A., Cuetos, M.J., Sanchez, M.E., and Gomez, X. (2011) 'Digestion of cattle manure: Thermogravimetric kinetic analysis for the evaluation of organic matter conversion', *Bioresour Technol. 102*(3), pp. 3404-3410.

Paradela, F., Pinto, F., Ramos, A.M., Gulyurtlu, I., and Cabrita, I. (2009) 'Study of the slow batch pyrolysis of mixtures of plastics, tyres and forestry biomass wastes', *Journal of Analytical and Applied Pyrolysis. 85*, pp. 392–398.

Park, H.J., Dong, J., Jeon, J., Park, Y., Yoo, K., Kim, S.J., Kim, J.K., and Kim, S.J. (2008) 'Effects of the operating parameters on the production of bio-oil in the fast pyrolysis of japanese larch', *Chemical Engineering Journal. 143*(1-3), pp. 124-132.

Peacocke, G.V.C., and Bridgwater, A.V. (1994) 'Ablative plate pyrolysis of biomass for liquids', *Biomass and Bioenergy. 7*(1-6), pp. 147-154.

PEMANDU. (2015) 'Solid waste management lab ', *Government Transformation Programme of Malaysia's Performance Management And Delivery Unit.*

Penakalapati, G., Swarthout, J., Delahoy, M.J., McAliley, L., Wodnik, B., Levy, K., and Freeman, M.C. (2017) 'Exposure to animal feces and human health: A

systematic review and proposed research priorities', *Environ Sci Technol. 51*(20), pp. 11537-11552.
Piskorz, J., Radlein, D., and Scott, D.S. (1986) 'On the mechanism of the rapid pyrolysis of cellulose', *Journal of Analytical and Applied Pyrolysis. 9*(2), pp. 121-137.
Popescu, C. (1996) 'Integral method to analyze the kinetics of heterogeneous reactions under non-isothermal conditions: A variant on the ozawa-flynn-wall method', *Thermochimica Acta. 285*, pp. 309-323.
Presciutti, A., Asdrubali, F., Baldinelli, G., Rotili, A., Malavasi, M., and Di Salvia, G. (2018) 'Energy and exergy analysis of glycerol combustion in an innovative flameless power plant', *Journal of Cleaner Production. 172*, pp. 3817-3824.
Prithiraj, S., and Kauchali, S. (2017) 'Yields from pyrolysis of refinery residue using a batch process', *South African Journal of Chemical Engineering. 24*, pp. 95-115.
Putun, A. (2004) 'Rice straw as a bio-oil source via pyrolysis and steam pyrolysis', *Energy. 29*(12-15), pp. 2171-2180.
Pütün, A.E., Uzun, B.B., Apaydin, E., and Pütün, E. (2005) 'Bio-oil from olive oil industry wastes: Pyrolysis of olive residue under different conditions', *Fuel Processing Technology. 87*, pp. 25-32.
Pütün, A.E., Uzun, B.B., Apaydin, E., and Pütün, E. (2005) 'Bio-oil from olive oil industry wastes: Pyrolysis of olive residue under different conditions', *Fuel Processing Technology. 87*(1), pp. 25-32.
Qu, T., Guo, W., Shen, L., Xiao, J., and Zhao, K. (2011) 'Experimental study of biomass pyrolysis based on three major components: Hemicellulose, cellulose, and lignin', *Industrial & Engineering Chemistry Research. 50*(18), pp. 10424-10433.
Rahman, A.N.E., Khaleel Akmal, M.A., and Prasad, K.B.S. (2001) 'Pyrolysis of solid waste', *Journal of Scientific & Industrial Research. 60*, pp. 52-59.
Rahman, A.N.E., Khaleel Akmal, M.A., and Prasad, K.B.S. (2001) 'Pyrolysis of solid wastes', *Journal of Scientific & Industrial Research. 60*, pp. 52-59.
Rajabi Hamedani, S., Kuppens, T., Malina, R., Bocci, E., Colantoni, A., and Villarini, M. (2019) 'Life cycle assessment and environmental valuation of biochar production: Two case studies in belgium', *Energies. 12*(11).
Ravikumar, C., Kumar, P.S., Subhashni, S.K., Tejaswini, P.V., and Varshini, V. (2017) 'Microwave assisted fast pyrolysis of corn cob, corn stover, saw dust and rice straw: Experimental investigation on bio-oil yield and high heating values', *Sustainable Materials and Technologies. 11*, pp. 19-27.
Ravikumar, C., Senthil Kumar, P., Subhashni, S.K., Tejaswini, P.V., and Varshini, V. (2017) 'Microwave assisted fast pyrolysis of corn cob, corn stover, saw dust and rice straw: Experimental investigation on bio-oil yield and high heating values', *Sustainable Materials and Technologies. 11*, pp. 19-27.
Reeb, C.W., Hays, T., Venditti, R.A., Gonzalez, R., and Kelley, S. (2014) 'Supply chain analysis, delivered cost, and life cycle assessment of oil palm empty fruit bunch biomass for green chemical production in malaysia', *BioResources. 9*(3), pp. 5385-5416.
Ro, K.S., Cantrell, K., Elliott, D., and Hunt, P.G. (2007) 'Catalytic wet gasification of municipal and animal wastes', *Ind. Eng. Chem. Res. 46*, pp. 8839-8845.
Ro, K.S., Cantrell, K.B., and Hunt, P.G. (2010) 'High-temperature pyrolysis of blended animal manures for producing renewable energy and value-added biochar', *Industrial & Engineering Chemistry Research. 49*, pp. 10125-10131.

Ro, K.S., Cantrell, K.B., Hunt, P.G., Ducey, T.F., Vanotti, M.B., and Szogi, A.A. (2009) 'Thermochemical conversion of livestock wastes: Carbonization of swine solids', *Bioresource Technology. 100,* pp. 5466–5471.

Robinson, J.P., Dodds, C., Stavrinides, A., Kingman, S.W., Katrib, J., Wu , Z., Medrano, J., and Overend, R. (2015) 'Microwave pyrolysis of biomass: Control of process parameters for high pyrolysis oil yields and enhanced oil quality.', *Energy & Fuels.* pp. 1-26.

Roy, C., Yang, J., Blanchette, D., Korving, L., and De Caumia, B. (1997) 'Evelopment of a novel vacuum pyrolysis reactor with improved heat transfer potential', *Developments in Thermochemical Biomass Conversion.* pp. 351-367.

Saladini, F., Patrizi, N., Pulselli, F.M., Marchettini, N., and Bastianoni, S. (2016) 'Guidelines for emergy evaluation of first, second and third generation biofuels', *Renewable and Sustainable Energy Reviews. 66*, pp. 221-227.

Salema, A.A., Ani, F.N., Mouris, J., and Hutcheon, R. (2017) 'Microwave dielectric properties of malaysian palm oil and agricultural industrial biomass and biochar during pyrolysis process', *Fuel Processing Technology. 166*, pp. 164-173.

Salema, A.A., and Ani, F.S. (2011) 'Microwave induced pyrolysis of oil palm biomass', *Bioresource Technology. 102*, pp. 3388–3395.

Samiran, N.A., Mohd Nazri, M.J., Ng, J.H., Lam, S.S., and Chong, C.T. (2016) 'Progress in biomass gasification technique-with focus on malaysian palm biomass for syngas production', *Renewable and Sustainable Energy Reviews. 62*, pp. 1047-1062.

Sánchez, M.E., Menéndez, J.A., Domínguez, A., Pisb, J.J., Martíneza, O., Calvoa, L.F., and Bernadc, P.L. (2009) 'Effect of pyrolysis temperature on the composition of the oils obtained from sewage sludge', *Biomass and Bioenergy. 33*, pp. 933-940.

Scheirs, J., Camino, G., and Tumiatti, W. (2001) 'Overview of water evolution during the thermal degradation of cellulose', *European Polymer Journal. 37*, pp. 933-942.

Sensoz, S., Demiral, I., and Ferdi Gercel, H. (2006) 'Olive bagasse (olea europea l.) pyrolysis', *Bioresour Technol. 97*(3), pp. 429-436.

Şensöz, S., Demiral, I., and Gerçelb, H.F. (2006) 'Olive bagasse (olea europea l.) pyrolysis', *Bioresource Technology. 97*, pp. 429–436.

Şensöz, S., and Kaynar, I. (2006) 'Bio-oil production from soybean (glycine max l.); fuel properties of bio-oil', *Industrial Crops and Products. 23*, pp. 99-105.

Şensöz, S., and Kaynar, İ. (2006) 'Bio-oil production from soybean (glycine max l.); fuel properties of bio-oil', *Industrial Crops and Products. 23*(1), pp. 99-105.

SHINCCI. Belt-type sludge dryer. In: China.

Šimon, P. (2004) 'Isoconversional methods', *Journal of Thermal Analysis and Calorimetry. 76*, pp. 123–132.

Skoulou, V.K., Manara, P., and Zabaniotou, A.A. (2012) 'H2 enriched fuels from co-pyrolysis of crude glycerol with biomass', *Journal of Analytical and Applied Pyrolysis. 97*, pp. 198-204.

Slopiecka, K., Bartocci, P., and Fantozzi, F. (2012) 'Thermogravimetric analysis and kinetic study of poplar wood pyrolysis', *Applied Energy. 97*, pp. 491–497.

Solar, J., de Marco, I., Caballero, B.M., Lopez-Urionabarrenechea, A., Rodriguez, N., Agirre, I., and Adrados, A. (2016) 'Influence of temperature and residence time in the pyrolysis of woody biomass waste in a continuous screw reactor', *Biomass and Bioenergy. 95*, pp. 416-423.

Spath, P.L., and Mann, M.K. (2000) 'Life cycle assessment of a natural gas combined-cycle power generation system', *National Renewable Energy Laboratory*.
STEIN, Y.S., and ANTAL, M.J. (1983) 'A study of the gas-phase pyrolysis of glycerol', *Journal of Analytical and Applied Pyrolysis. 4*, pp. 283-296.
Stripple, H. (2001). *Life cycle assessment of road a pilot study for inventory analysis*. Retrieved from Gothenburg, Sweden:
Sutton, D., Kelleher, B., and Ross, J.R.H. (2001) 'Review of literature on catalysts for biomass gasification', *Fuel Processing Technology. 73*, pp. 155-173.
Tavasoli, A., Aslan, M., Salimi, M., Balou, S., Pirbazari, S.M., Hashemi, H., and Kohansal, K. (2018) 'Influence of the blend nickel/porous hydrothermal carbon and cattle manure hydrochar catalyst on the hydrothermal gasification of cattle manure for h2 production', *Energy Conversion and Management. 173*, pp. 15-28.
TheSunDaily. (2018). Govt assures malaysia will not become world's solid waste bin. *The Sun Daily*. Retrieved from http://www.thesundaily.my/news/2018/07/31/govt-assures-malaysia-will-not-become-worlds-solid-waste-bin
Thornton, P.K. (2010) 'Livestock production: Recent trends, future prospects', *Philos Trans R Soc Lond B Biol Sci. 365*(1554), pp. 2853-2867.
Tian, Y., Zhou, X., Lin, S., Ji, X., Bai, J., and Xu, M. (2018) 'Syngas production from air-steam gasification of biomass with natural catalysts', *Sci Total Environ. 645*, pp. 518-523.
TNB. (2014) 'Electricity tariff schedule'.
Tran, K.Q., Bach, Q.V., Trinh, T.T., and Seisenbaeva, G. (2014) 'Non-isothermal pyrolysis of torrefied stump – a comparative kinetic evaluation', *Applied Energy. 136*, pp. 759-766.
Tripathi, M., Sahu, J.N., Ganesan, P., and Dey, T.K. (2015) 'Effect of temperature on dielectric properties and penetration depth of oil palm shell (ops) and ops char synthesized by microwave pyrolysis of ops', *Fuel. 153*, pp. 257-266.
Troy, S.M., Nolan, T., Leahy, J.J., Lawlor, P.G., Healy, M.G., and Kwapinski, W. (2013) 'Effect of sawdust addition and composting of feedstock on renewable energy and biochar production from pyrolysis of anaerobically digested pig manure', *Biomass and Bioenergy. 49*, pp. 1-9.
Tsai, W.T., Huang, C.N., Chen, H.R., and Cheng, H.Y. (2015) 'Pyrolytic conversion of horse manure into biochar and its thermochemical and physical properties', *Waste and Biomass Valorization. 6*(6), pp. 975-981.
Tsai, W.T., Huang, C.N., Chen, H.R., and Cheng, H.Y. (2015) 'Pyrolytic conversion of horse manure into biochar and its thermochemical and physical properties', *Waste Biomass Valor. 6*, pp. 975-981.
Tsai, W.T., Lee, M.K., and Chang, Y.M. (2006) 'Fast pyrolysis of rice straw, sugarcane bagasse and coconut shell in an induction-heating reactor', *Journal of Analytical and Applied Pyrolysis. 76*(1-2), pp. 230-237.
Tsai, W.T., Lee, M.K., and Chang, Y.M. (2006) 'Fast pyrolysis of rice straw, sugarcane bagasse and coconut shell in an induction-heating reactor', *J. Anal. Appl. Pyrolysis. 76*, pp. 230–237.
Turmanova, S.C., Genieva, S.D., Dimitrova, A.S., and Vlaev, L.T. (2008) 'Non-isothermal degradation kinetics of filled with rise husk ash polypropene composites', *Express Polymer Letters. 2*(2), pp. 133-146.

Urban, B., Shirazi, Y., Maddi, B., Viamajal, S., and Varanasi, S. (2017) 'Flash pyrolysis of oleaginous biomass in a fluidized-bed reactor', *Energy & Fuels.* pp. 1-36.
Urban, B., Shirazi, Y., Maddi, B., Viamajala, S., and Varanasi, S. (2017) 'Flash pyrolysis of oleaginous biomass in a fluidized-bed reactor', *Energy Fuels.* pp. 1-36.
Valliyappan, T., Bakhshi, N.N., and Dalai, A.K. (2008) 'Pyrolysis of glycerol for the production of hydrogen or syn gas', *Bioresource Technology. 99*, pp. 4476–4483.
Vlaev, L.T., Georgieva, V.G., and Genieva, S.D. (2007) 'Products and kinetics of non–isothermal decomposition of vanadium(iv) oxide compounds', *Journal of Thermal Analysis and Calorimetry. 88*(3), pp. 805–812.
Vlaev, L.T., Markovska, I.G., and Lyubchev, L.A. (2003) 'Non-isothermal kinetics of pyrolysis of rice husk', *Thermochimica Acta. 406*, pp. 1-7.
Vyazovkin, S., and Wight, C.A. (1999) 'Model-free and model-fitting approaches to kinetic analysis of isothermal and nonisothermal data', *Thermochimica Acta. 340-341*, pp. 53-68.
Wan Mahari, W.A., Chong, C.T., Cheng, C.K., Lee, C.L., Hendrata, K., Peter, N.Y.Y., Ma, N.L., and Lam, S.S. (2018) 'Production of value-added liquid fuel via microwave co-pyrolysis of used frying oil and plastic waste', *Energy. 162*, pp. 309-317.
Wan, Y., Chen, P., Zhang, B., Yang, C., Liu, Y., Lin, X., and Ruan, R. (2009) 'Microwave-assisted pyrolysis of biomass: Catalysts to improve product selectivity', *Journal of Analytical and Applied Pyrolysis. 86*(1), pp. 161-167.
Wang, H., Wang, L., and Shahbazi, A. (2015) 'Life cycle assessment of fast pyrolysis of municipal solid waste in north carolina of USA', *Journal of Cleaner Production. 87*, pp. 511-519.
Wang, Q., Han, K., Gao, J., Li, H., and Lu, C. (2017) 'The pyrolysis of biomass briquettes: Effect of pyrolysis temperature and phosphorus additives on the quality and combustion of bio-char briquettes', *Fuel. 199*, pp. 488-496.
Wang, S. (2003). *High-efficiency separation of bio-oil*.
Wang, X., Wu, J., Chen, Y., Pattiya, A., Yang, H., and Chen, H. (2018) 'Comparative study of wet and dry torrefaction of corn stalk and the effect on biomass pyrolysis polygeneration', *Bioresource Technology. 258*, pp. 88-97.
Wang, Y., Dai, L., Fan, L., Shan, S., Liu, Y., and Ruan, R. (2016) 'Review of microwave-assisted lignin conversion for renewable fuels and chemicals', *Journal of Analytical and Applied Pyrolysis. 119*, pp. 104-113.
Warnecke, R. (2000) 'Gasification of biomass: Comparison of fixed bed and fluidized bed gasifier', *Biomass and Bioenergy. 18*, pp. 489-497.
Wartell, B.A., Krumins, V., Alt, J., Kang, K., Schwab, B.J., and Fennell, D.E. (2012) 'Methane production from horse manure and stall waste with softwood bedding', *Bioresour Technol. 112*, pp. 42-50.
Wei, Y., Tang, J., Xie, J., and Shen, C. (2019) 'Molten alkali carbonates pyrolysis of digestate for phenolic productions', *Journal of Cleaner Production. 225*, pp. 143-151.
Wettayavong, S., Sangnoi, S., Kaewtrakulchai, N., and Eiad-Ua, A. (2018) 'Characterization of carbon fibers from thai horse manure via hydrothermal carbonization', *Materials Today: Proceedings. 5*(5), pp. 10940-10945.

Wiinikka, H., Johansson, A., Sandström, L., and Öhrman, O.G.W. (2017) 'Fate of inorganic elements during fast pyrolysis of biomass in a cyclone reactor', *Fuel. 203*, pp. 537–547.

Wu, H., Hanna, M.A., and Jones, D.D. (2012) 'Thermogravimetric characterization of dairy manure as pyrolysis and combustion feedstocks', *Waste Management & Research. 30*(10), pp. 1066 –1071.

Xin, Y., Cao, H., Yuan, Q., Wang, D., and Liu, Y. (2017) 'Kinetic analysis of cattle manure pyrolysis process with a novel two-step method: Pseudo-component model coupled with multipeak gaussian fitting', *Environmental Progress & Sustainable Energy. 00*(00), pp. 1-8.

Xin, Y., Cao, H., Yuan, Q., Wang, D., and Liu, Y. (2018) 'Kinetic analysis of cattle manure pyrolysis process with a novel two-step method: Pseudo-component model coupled with multipeak gaussian fitting', *Environmental Progress & Sustainable Energy. 37*(5), pp. 1618-1625.

Xu, Y., and Chen, B. (2013) 'Investigation of thermodynamic parameters in the pyrolysis conversion of biomass and manure to biochars using thermogravimetric analysis', *Bioresource Technology. 149*, pp. 485-493.

Xue, Y., Zhou, S., Brown, R.C., Kelkar, A., and Bai, X. (2015) 'Fast pyrolysis of biomass and waste plastic in a fluidized bed reactor', *Fuel. 156*, pp. 40-46.

Yaman, S. (2004) 'Pyrolysis of biomass to produce fuels and chemical feedstocks', *Energy Conversion and Management. 45*(5), pp. 651-671.

Yang, H., Yan, R., Chen, H., Ho Lee , D.H., and Zheng, C. (2007) 'Characteristics of hemicellulose, cellulose and lignin pyrolysis', *Fuel. 86*, pp. 1781-1788.

Yang, H., Yan, R., Chin, T., Liang, D.T., Chen, H., and Zheng, C. (2004) 'Thermogravimetric analysis-fourier transform infrared analysis of palm oil waste pyrolysis', *Energy & Fuels. 18*, pp. 1814-1821.

Yang, H.P., Yan, R., Chin, T., Liang, D.T., Chen, H.P., and Zheng, C.G. (2004) 'Thermogravimetric analysis-fourier transform infrared analysis of palm oil waste pyrolysis', *Energy & Fuels. 18*, pp. 1814-1821.

Ye, C., Huang, H., Li, X.D., Li, W.G., and Feng, J. (2017) 'The oxygen evolution during pyrolysis of hunlunbuir lignite under different heating modes', *Fuel. 207*, pp. 85-92.

Yerrayya, A., Suriapparao, D.V., Natarajan, U., and Vinu, R. (2018) 'Selective production of phenols from lignin via microwave pyrolysis using different carbonaceous susceptors', *Bioresour Technol. 270*, pp. 519-528.

Yin, S., Dolan, R., Harris, M., and Tan, Z. (2010) 'Subcritical hydrothermal liquefaction of cattle manure to bio-oil: Effects of conversion parameters on bio-oil yield and characterization of bio-oil', *Bioresource Technology. 101*(10), pp. 3657-3664.

Yon, R., Food and Fertilizer Technology Centre for the Asian and Pacific Region (2016, Oct. 26, 2017). Revival of coconut industry in malaysia. Retrieved from http://ap.fftc.agnet.org/ap_db.php?id=806. Accessed on: 1st October.

Yu, J., Paterson, N., Blamey, J., and Millan, M. (2017) 'Cellulose, xylan and lignin interactions during pyrolysis of lignocellulosic biomass', *Fuel. 191*, pp. 140–149.

Yuan, X., He, T., Cao, H., and Yuan, Q. (2017) 'Cattle manure pyrolysis process: Kinetic and thermodynamic analysis with isoconversional methods', *Renewable Energy. 107*, pp. 489-496.

Yurdakul, S. (2016) 'Determination of co-combustion properties and thermal kinetics of poultry litter/coal blends using thermogravimetry', *Renewable Energy. 89*, pp. 215-223.
Zeng, J., Xiao, R., Zhang, H., Wang, Y., Zeng, D., and Ma, Z. (2017) 'Chemical looping pyrolysis-gasification of biomass for high h 2 /co syngas production', *Fuel Processing Technology. 168*, pp. 116-122.
Zhang, H., Gao, Z., Ao, W., Li, J., Liu, G., Fu, J., Ran, C., Liu, Y., Kang, Q., Mao, X., and Dai, J. (2017) 'Microwave pyrolysis of textile dyeing sludge in a continuously operated auger reactor', *Fuel Processing Technology. 166*, pp. 174-185.
Zhang, J., Tiana, Y., Zhu, J., Zuo, W., and Yin, L. (2014) 'Characterization of nitrogen transformation during microwave-induced pyrolysis of sewage sludge', *Journal of Analytical and Applied Pyrolysis. 105*, pp. 335–341.
Zhang, J., Zuo, W., Tian, Y., Yin, L., Gong, Z., and Zhang, J. (2017) 'Release of hydrogen sulfide during microwave pyrolysis of sewage sludge: Effect of operating parameters and mechanism', *J Hazard Mater. 331*, pp. 117-122.
Zhang, S., Su, Y., Xu, D., Zhu, S., Zhang, H., and Liu, X. (2018) 'Assessment of hydrothermal carbonization and coupling washing with torrefaction of bamboo sawdust for biofuels production', *Bioresource Technology. 258*, pp. 111-118.
Zhao, B., Xu, X., Xu, S., Chen, X., Li, H., and Zeng, F. (2017) 'Surface characteristics and potential ecological risk evaluation of heavy metals in the bio-char produced by co-pyrolysis from municipal sewage sludge and hazelnut shell with zinc chloride', *Bioresour Technol. 243*, pp. 375-383.
Zhao, C., Jiang, E., and Chen, A. (2017) 'Volatile production from pyrolysis of cellulose, hemicellulose and lignin', *Journal of the Energy Institute. 90*(6), pp. 902-913.
Zheng, J. (2007) 'Bio-oil from fast pyrolysis of rice husk: Yields and related properties and improvement of the pyrolysis system', *J. Anal. Appl. Pyrolysis. 80*, pp. 30-35.
Zheng, J.L., and Kong, Y.P. (2010) 'Spray combustion properties of fast pyrolysis bio-oil produced from rice husk', *Energy Conversion and Management. 51*, pp. 182-188.
Zhong, Z.W., Song, B., and Zaki, M.B.M. (2010) 'Life-cycle assessment of flash pyrolysis of wood waste', *Journal of Cleaner Production. 18*(12), pp. 1177-1183.
Zhou, S., Han, L., Huang, G., Yang, Z., and Peng, J. (2018) 'Pyrolysis characteristics and gaseous product release properties of different livestock and poultry manures: Comparative study regarding influence of inherent alkali metals', *Journal of Analytical and Applied Pyrolysis. 134*, pp. 343-350.
Zhu, L., Zhao, N., Tong, L., and Lv, Y. (2018) 'Structural and adsorption characteristics of potassium carbonate activated biochar', *RSC Advances. 8*(37), pp. 21012-21019.
Zhu, X., Zhang, Y., Li, S., and Zhu, X. (2019) 'Optimizing the distribution of pyrolysis syngas from bio-oil distillation residue by adding bituminous coal under different induction conditions', *Fuel. 238*, pp. 59-65.
Zuo, W., Tian, Y., and Ren, N. (2011) 'The important role of microwave receptors in bio-fuel production by microwave-induced pyrolysis of sewage sludge', *Waste Manag. 31*(6), pp. 1321-1326.

Zuo, W., Tian, Y., and Ren, N. (2011) 'The important role of microwave receptors in bio-fuel production by microwave-induced pyrolysis of sewage sludge', *Waste Management. 31*, pp. 1321–1326.

LIST OF PUBLICATIONS

Journal with Impact Factor

(a) Mong, G. R., Chong, C. T., Ng, J. H., Chong, W. W. F., Lam, S. S., Ong, H. C., Ani, F. N. (2020) Microwave Pyrolysis for Valorisation of Horse Manure Biowaste. Energy Conversion and Management 220, 113074. https://doi.org/10.1016/j.enconman.2020.113074. **(Q1, IF:7.181)**

(b) Chiong, M. C., Valera-Medina, A., Chong, W. W. F., Chong, C. T., Mong, G. R., Mohd Jaafara, M. N. (2020) Effects of swirler vane angle on palm biodiesel/natural gas combustion in swirl-stabilised gas turbine combustor. Fuel 227, 118213. https://doi.org/10.1016/j.fuel.2020.118213. **(Q1, IF:5.128)**

(c) Chong, C. T., Mong, G. R., Ng, J. H., Chong, W. W. F., Ani, F. N., Lam, S. S., and Ong, H. C. (2019) Pyrolysis characteristics and kinetic studies of horse manure using thermogravimetric analysis. Energy Conversion and Management 180, 1260–1267. https://doi.org/10.1016/j.enconman.2018.11.071. **(Q1, IF:7.181)**

(d) Chong, C. T., Ng, J. H., Ariz, M. S., Mong, G. R., Shahril, N., Ting, S. T., and Zulkifli, M. F. (2019) Impact of gas composition variations on flame blowout and spectroscopic characteristics of lean premixed swirl flames. Process Safety and Environmental Protection 128, 1–13. https://doi.org/10.1016/j.psep.2019.05.015. **(Q1, IF:4.384)**

Indexed Journals

(c) Mong, G. R., Ng, J. H., Chong, W. W. F., Ani, F. N., Lam, S. S., and Chong, C. T. (2019) Kinetic study of horse manure through thermogravimetric analysis. Chemical Engineering Transaction, 72, 241-246. https://doi.org/10.3303/CET1972041. **(INDEXED by SCOPUS)**

(d) Mong, G. R., Chong, C. T., Ng, J. H., Lam, S. S., Chong, W. W. F., and Ani, F. N. (2020) Pyrolysing horse manure via microwave-induced heating for bioenergy recovery. Chemical Engineering Transaction, 78, 139-144. https://doi.org/ 10.3303/CET2078024. **(INDEXED by SCOPUS)**

(e) Mong, G. R., Chong, C. T., Ashokkumar, V., Ng, J. H., and Chong, W. W. F. (2020) Determination of the Activation Energy and Kinetics Properties of Algae (Sargassum Polycystum) via Thermogravimetric Analysis. Chemical Engineering Transaction, 78, 133-138. https://doi.org/ 10.3303/CET2078023. **(INDEXED by SCOPUS)**

Indexed Conference Proceedings

(f) Mong, G. R., Ng, J. H., Chong, W. W. F., Ani, F. N., Lam, S. S., and Chong, C. T. (2018) Kinetic study of horse manure through thermogravimetric analysis. In 2018 Proceedings of the 4th International Conference on Low Carbon Asia (pp 186). **(INDEXED by SCOPUS)**

(g) Mong, G. R., Chong, C. T., Ng, J. H., Lam, S. S., Chong, W. W. F., and Ani, F. N. (2019) Pyrolysing horse manure via microwave-induced heating for bioenergy recovery. In 2019 The 5th International Conference on Low Carbon Asia & Beyond – ICLCA 2019. **(INDEXED by SCOPUS)**

(h) Mong, G. R., Chong, C. T., Ashokkumar, V., Ng, J. H., and Chong, W. W. F. (2019) Determination of the Activation Energy and Kinetics Properties of Algae (Sargassum Polycystum) via Thermogravimetric Analysis. In 2019 The 5th International Conference on Low Carbon Asia & Beyond – ICLCA 2019. **(INDEXED by SCOPUS)**