

# Compression of bio oil fraction of empty fruit bunch (EFB) and palm kernel shell (PKS) by thermal distillation

Deana Qarizada<sup>1,2</sup>, Erfan Mohammadian<sup>1</sup>, Azil Bahari Alias<sup>1</sup>, Suriatie Binti Mat Yusuf<sup>1</sup>,  
Abdul Qayom Rajabi<sup>2</sup>, Humapar Azhar Rahimi<sup>3,4</sup>

<sup>1</sup>Faculty of Chemical Engineering (FKK), university Technology MARA, Shah Alam, Selangor, Malaysia 40450

<sup>2</sup>Faculty of Chemical Engineering, Jawzjan University, Jawzjan, Afghanistan

<sup>3</sup>Faculty of Education, Jawzjan University, Jawzjan, Afghanistan

<sup>4</sup>Faculty of Education, Shaheed Prof, Rabbani University, Kabul Afghanistan

Corresponding author email address: deanaqarizada11@gmail.com

**Abstract:** The air contamination is a wide problem in the world and it is formed from the internal combustion of fuel that produces greenhouse gases such as CO and SO<sub>2</sub> stable released to the environment. Therefore, to reduce the instant fossil fuel greenhouse gases, the conventional fuel needs to be replaced with organic crude fuels (unconventional fuels). Hence, the objective of this study is to compare and characterize the bio oil fractions of EFB and PKS thermal distillation to utilizing to alternative fossil fuel. Bio oil fractions have been produced from pyrolysis bio oil in a column reactor at 120°C. The calorific value of EFB and PKS bio oil fractions were 26 MJ/kg, and 32 MJ/kg. The pH of PKS and EFB bio oil fractions were 2.72, and 3 respectively. GC – MS analysis showed that the phenol and its derivative are the dominant products in the bio oil fractions. Especially, EFB bio oil fractions were included phenol and its derivative.

**Keywords** - Renewable energy, Oil palm, Fast pyrolysis, Thermal distillation, Fraction of bio oil.

## 1. INTRODUCTION:

According to Abdullah & Sulaim (2013), renewable energy is one of the unique aspects of resource in Malaysia. The oil palm is self-sufficient in energy, PPF, EFB and PKS using as fuel to generate steam in waste fuel boilers for processing, and power generation with steam turbines. The palm oil mill uses dry fiber yield, crude EFB, including nearly 60% water instead of using fuel in boilers (Abdullah, Sulaiman, & Gerhauser, 2011; INTECH, n.d.). Empty fruit bunches (EFB) is combined of an approximation of 45-50% cellulose, 25-35% of hemicelluloses and lignin. However, its proximate chemical manufacturer reported by previous researchers (Azizan et al., n.d.).

To Lim Meng Hon (2010), Malaysia is the forefront in technology in oil palm industry and production in both plantations (upstream) and oleo chemical (downstream) products for the global markets. Annually, 4.48 million hectares area planted it generates 17.73 million tons of palm oil. Indonesia is the first supplier with 44.8% and Malaysia produced about 41% of the world's palm oil. Malaysia was the highest percentage of vegetable oil and fats tread of global in 2008. Many types of biomass produced by palm oil industry such as palm kernel shells (PKS), empty fruit bunch (EFB), fronds and trunks. Biomass can be changed into energy by using some ways such as thermo chemical conversion, biochemical conversion, and extraction of oil from oil-bearing seeds (Vakili et al., 2015). Isroi et al. (2012) stated that empty fruit bunch and lignocelluloses residual remains are the crude oil palm (CPO) raw materials in the mill. OPEFB used large quantity because of low commercial value and constitutes, it is included 82.4% hollocellulose and 17.6% lignin. OPEFB has high carbohydrate content. This biomass can be changed into bio-fuel by different methods such as combustion, liquification, gasification, and pyrolysis (Veses et al., 2015).

Fast pyrolysis is one of the methods that can improve the properties of the biomass to the next level of advancement. The product yield of fast pyrolysis are bio-oil 70%, and char and gas at around 15%, each (Abdullah, Sulaiman, & Gerhauser, 2011). Pyrolysis is dependent on the thermo chemical process. Bio-oil is the liquid fuel that burns in diesel engines or boilers and it is of high density and oxygenated liquid (Abdullah, Gerhauser, & Bridgwater, 2007). Hence, utilization of bio oil from fast pyrolysis necessitates some form of thermo distillation to improve the heating value and storage stability of bio oil.

Ramirez, Brown, & Rainey (2015) mentioned Distillation is a separation method, where its fractional components have different boiling range. There are many types of distillation methods and processes that can be used to determine the characteristic and fractional of the feed stocks. Pyrolysis of bio-oil uses the distillation for characterization purposes. The temperatures in this method are used at different range.

## 2. METHODOLOGY:

### 2.1 Material and Method

In this research, the utilized raw material is empty fruit bunch (EFB) and PKS that were obtained and gathered from a palm oil mill industry Selangor, Malaysia. The nitrogen gas was used in the pyrolysis process. The particle size of EFB was 10 – 30 mm. The density of bulk was around 0.67g/mL. The moisture content of EFB was around 9 wt%. Fig1 (a) showed the EFB.



The particle size of PKS was 10- 20 mm. The density of bulk was around 0.56g/mL. The moisture content of EFB was around 8 wt%. Fig1 (b) showed the PKS.

## 2.2 Pyrolysis procedure

For bio oil production of biomass has been pyrolyzed in a laboratory scale fixed bed reactor, which shown in Fig. 2.2 the reactor was with the size of 50 cm high and 10 cm i.d, and it made of stainless steel. About 5kg of the raw material placed in a batch reactor. The utilized reactor was positioned vertically, and the nitrogen gas was injected from the bottom of the reactor with amount/ speed of 200ml/min for replacing the air from the reactor. The gases of bio mass formed by pyrolysis inside the reactor bring out by nitrogen from the top of the reactor. For cooling of the mixture, the gas used tow condensers. In the first condenser gas cooled using dry ice, which the temperature was reduced to 60°C. The second condenser temperature was reduced by circulation of iced water to around 5°C (Asadullah, 2007).



Fig. 2.2 Pyrolysis reactor for production of bio-oil

## 2.3 Bio oil Distillation

The method which was used in this study to improve the bio oil is through reactor and stirring hotplate which helped the process of distillation via some modifications. Prior to all, the first step is to put the bio oil inside the reactor and heat it around 120°C with stirring hotplate. As the result, 10 fractions were collected from it.

## 2.4 Characterization of bio oil and bio oil fractions

The pH, viscosity, density, heating value, the water content of crude bio oil and bio oil fractions were measured, the pH value, higher heating value, moisture content, density, and ultimate analysis. Densities of bio oil and bio oil fraction were measured at 25°C by using the hydrometer. The PH of bio oil and bio oil fraction was measured by digital PH meter toledo™. The bomb calorimeter was used to determine the higher heating value. The (satorius™ Model- MA35) analyzer used to determine the bio oil and bio oil fraction water content. All the analysis is shown in table3.1.

## 2.5 Chemical characterization of bio oil and bio oil fractions

The GC – MS and FTIR spectra were used on different bio oil and bio oil fractions samples to determine the chemical compositions. The chemical composition of bio oil and bio oil fraction were determined by utilizing a GC – MS – QP2010 equipment with a capillary column coated with Rtx – 5MS (60 m × 0.25 mm i.d, 0.25µm film thickness). The bio oil and bio oil fractions individual group of compounds can be identified by comparing the mass spectra data with NIST08 library data. A semi-quantitative analysis of each compound was performed by the peak area ratio of the individual compounds with the total cumulative area of all compounds. The Perkin Elmer Spectrum GX FT – IR spectrometer between 4000 and 400 cm<sup>-1</sup> used to determine the functional group of bio oil and bio oil fractions (Asadullah et al., 2013; Asadullah, 2007).

## 3. RESULT AND DISCUSSION:

### 3.1. Proximate and ultimate analysis of PKS and EFB

The particle size of EFB and PKS were in the range of 10-30 mm, and 10-20 mm respectively. The bulk density of PKS and EFB were around 0.56g/mL, and 0.670g/mL respectively. The moisture content of PKS was 9 wt %. From proximate analysis of PKS, and EFB, the volatile fraction, fixed carbon, ash were 54 wt %, 22 wt %, 16 wt %, 60 wt %, 17 wt %, and 14 wt % respectively. Moreover, the ultimate analysis of EFB and PKS provided the C, H, N, and O content, these were 58.1 wt %, 4.1 wt %, 37.8 wt %, 49.8 wt %, 5.4 wt %, 44.8 wt % respectively. The moisture content of EFB was 12wt %.

### 3.2. Characterization of bio oils and bio oil fractions

#### 3.2.1. Physical characterization of bio oils and bio oil fractions

The Moisture content of PKS and EFB bio oil were 9 wt %, 12 wt %, and for PKS and EFB bio oil fractions at 120°C were around 16 wt %, 21 wt % respectively. Table 3.1 showed the physical and chemical properties of bio oil and bio oil fractions, it was due to the high moisture content of the feed stock. The pH of PKS and EFB bio oil were in 25°C around 3.7, 3.7, and for bio oil fraction it were 2.72, and 3, which PKS and EFB bio oil were comparable with Asadullah's (2007) finding but bio oil fractions are lower than bio oil derived from bagasse. The density of PKS and EFB bio oil were 1.04g/mL while the PKS and EFB bio oil fraction density were 0.99g/mL, and 0.97g/mL, which the EFB and PKS bio oil fraction are similar whit Makibar, Miguel, & Makibar (2012) results of bio oil derived from EFB bio oil but it is higher than EFB and PKS bio oil. The HHV of EFB and PKS bio oils, PKS and EFB bio oil fractions were 20 -21MJ/kg, 22MJ/kg, 32MJ/kg, and 26MJ/kg respectively, these were higher than Sukiran, Kartini, Bakar, & Chin (2009) results from bio oil derived from EFB 20 -21MJ/kg.

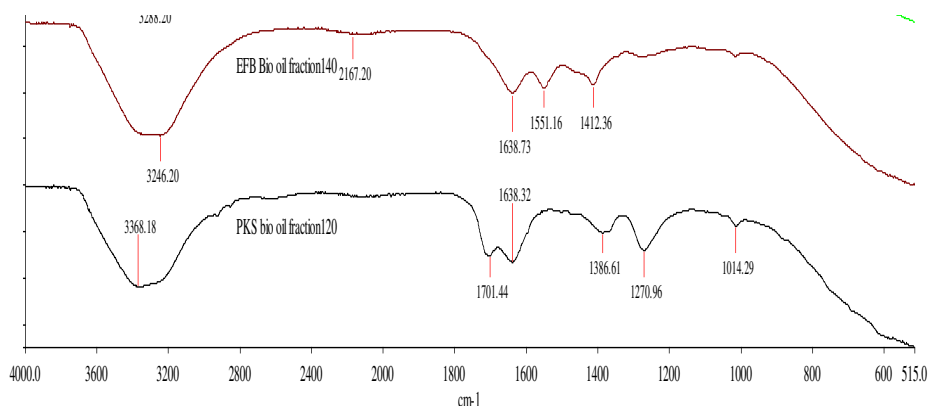
**Table3.1 Properties of Bio oil and Bio oil fractions**

properties	Bio oil fractions		Bio oils	
	PKS – 120	EFB - 120	PKS	EFB
Moisture content (wt %)	16	21	50	40
pH	2.72	3	3.7	3.2
Density (g/mL)	0.99	0.97	1.04	1.04
Elemental analysis				
Carbon	65.63	48	42- 50	50- 65
Hydrogen	6.3	6.1	6	5.5
Oxygen	27.81	45.65	40	42
Nitrogen	0.14	0.12	0- 0.13	0.11
Sulpher	0.12	0.13	0.012	0.012
HHV (MJ/kg)	32	26	22	20- 21

### 3.3 Chemical analysis of bio oil fraction

The FT- IR spectroscopy EFB and PKS bio oil fractions as shown in Fig 3 indicate that the bio oil fractions consisted oxygenated organic compounds. Based on Figure 1, the band between 3366 – 3400cm<sup>-1</sup> indicated the O – H stretching vibration which attributed to phenol and alcohol in bio oil fractions [2]. The board band between 2169 – 2200m<sup>-1</sup> is indicated C = O stretching vibration (Chemistry, Gebouw, & Gebouw, n.d.). The C = O stretching vibration between 1702 - 1780 cm<sup>-1</sup> indicated the presence of the conjugated aldehydes, ketones, carboxylic acids. The C=C stretching vibration between 1637- 1650 cm<sup>-1</sup> indicated the presence of conjugated alkene[2]. The C = C stretching vibration between 1386 - 1450 cm<sup>-1</sup> which indicated the presence of mono and polycyclic substituted aromatic group [3].The C - O stretching vibration between 1269 - 1300 cm<sup>-1</sup> which indicated the presence of alcohol (Abdullah, Sulaiman, & Gerhausser, 2011). The C - O stretching vibration between 1014 and 1200 cm<sup>-1</sup> which indicated the presence of carbonyl component (Sukiran, Loh, & Bakar, 2016). Based on FTIR results and literature, the EFB and PKS bio oil fractions at the temperature of 100°C, and 140 °C are comparable. The major compounds in

the bio oil fractions are phenol and its derivatives, which are also attributed in the FT – IR spectrum of PKS bio oil fraction.



**Fig3.1 FTIR spectra of bio oil fraction**

The GC- MS analysis identifies the compounds and their semi quantitative composition product at 140°C was characterized utilizing GC- MS. The possible group of compounds of the bio oil fraction was founded to be the phenol and its derivatives. While, from the GC – MS results the EFB bio oil fraction was more oxygenated than PKS bio oil fraction. Some of the possible compounds are listed in Table 3.2.

**Table 3.2.possible compounds of bio oil fractions according to the GC – MS**

Possible compounds	Molecular formula	Peak, area%	
		EFB	PKS
2-Pyrrolidinone	C <sub>4</sub> H <sub>7</sub> NO	2.233	2.03
Dextroamphetamine	C <sub>9</sub> H <sub>13</sub> N	6.077	2.63
1,3,5-Trioxane	C <sub>3</sub> H <sub>6</sub> O <sub>3</sub>	9.591	1.13
Butanedinitrile	C <sub>4</sub> H <sub>4</sub> N <sub>2</sub>	1.052	1.13
Furfural	C <sub>4</sub> H <sub>3</sub> OCHO	9.168	7.07
2-Furanmethanol	C <sub>5</sub> H <sub>6</sub> O <sub>2</sub>	1.873	2.99
5-Vinyl-pyrazole	C <sub>5</sub> H <sub>6</sub> N <sub>2</sub>	9.355	2.99
5-Amino-3-methylpyrazole	C <sub>4</sub> H <sub>7</sub> N <sub>3</sub>	1.951	1.91
2-Cyclopenten-1-one, 2-methyl	C <sub>6</sub> H <sub>8</sub> O	9.744	2.88

The HHV of bio oil compounds decries due to oxygenated compounds to be used as fuel utilization and transportation. The oxygenated compounds can be reduced by using same methods such as hydro cracking, Hydrodeoxygenation, and hydro treating (Hyung, Chul, & Jin, 2014).

**4. CONCLUSION:**

The distilled EFB and PKS bio oil were investigated to produce bio oil fractions in a column reactor. The bio oil fractions produced up to distillation temperature 120 °C. The GC- MS analysis showed that the EFB bio oil fraction phenol and its derivative are higher than PKS bio oil fraction. The FTIR analysis indicated the group of oxygenated compounds in bio oil fractions.

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### Deana Qarizada's Biography

Deana Qarizada was born in 1988 in Jawzjan Province, Afghanistan. She graduated from Department of Organic Synthesis and inorganic synthesis, Chemical Engineering Faculty, Jawzjan University in 2009. She is working as a lecturer in the same department at Jawzjan University. Currently, she is pursuing her Master's degree in Chemical Engineering Faculty at University Technology Mara in Malaysia. She has published in a number of national and international journals, such as Science Letters and International Journal of Innovative Research and Scientific Studies. Additionally, one of her research article was presented by an Afghan-Turk High School student in a competition and won silver and bronze medals. Qarizada also participated in various conferences in Kabul Poly Technique University, Jawzjan University, and University Technology Mara (UITM) and received certificates of completion.