AJAB

Asian J Agri & Biol. 2017;5(4):337-345.

Original Research Article

The re-extraction of oil from oil palm empty fruit bunch residues and oil palm mesocarp fibers and measures in reducing greenhouse gas emission

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Received:
August 30, 2017

Accepted:
October 11, 2017

Published:
December 17, 2017

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Abstract

Oil palm Mill (POM) produces oil palm empty fruit bunches (EFBs) and oil palm mesocarp fibers (OPMF) which still contain oil and carotenoids. POM utilizes EFB_S and OPMF as a fuel to heat up the boiler and to generate electrical energy leading to the dissolve of oil and carotenoids in vain and causes greenhouse gas (GHG). The research is aimed at isolating and investigating the quantity and quality of oil of EFB_S and OPMF, OPMF oil characteristics comprising of fatty acid composition and antioxidant activity and to determine the effect of GHG emission reduction after OPMF oil is macerated. The residual sample used is collected from 4 POMs. Oil isolation was done by maceration. EFB_S and OPMF were compared with a hexane ratio of 1:20 (w/w), while the duration for maceration lasted for 48 hours in a room with temperature. Oil quantity parameters include residual oil content with soxhlet method and macerated oil yield. Oil quality parameters include: carotenoid levels, deterioration of bleachability index (DOBI) and free fatty acids (FFA). OPMF oil characteristics included oil fatty acid composition which was determined by GC method and antioxidant activity with 1,1-Diphenyl-2-picrylhydrazyl (DPPH) and GHG reduction by emission factor method. The quantity and quality of oil isolated from OPMF residues is higher than oil isolated from EFB_S due to: oil content was higher by 3.91% (2.86% in EFB_S), oil yield was 3.47% (2.26% in EFB_S) carotenoid levels were higher at 2305 ppm (915.25 ppm in EFB_S), DOBI is higher by 3.49 (1.14 in EFB_S), and FFA is lower by 9.68% (21.58% in EFB_S). The fatty acid in OPMF oil has generally the same composition as the CPO fatty acid which is dominated by palmitic acid by C16:0 and oleic acid by C18:1, respectively at an average of 30.31% at CPO of 44.0%) and 33.22% at CPO of 39.2%). OPMF Oil antioxidant activity half maximal inhibitory concentration (IC_{50}) was at 8.49 ppm. The effect of GHG emission reduction after OPMF oil macerated could reach 88.77% of the total amount of GHG emissions resulted from OPMF burning before maceration.

Keywords: EFB_S, OPMF Oil, Carotenoids, DOBI, Antioxidants, GHG

Introduction

Since 2006, Indonesia has become the largest producer of Crude Palm Oil (CPO) in the world with an increased statistics over the years. In 2015, Indonesia's CPO production reached 33.26 million tons (PASPI, 2015). In 2016, it increased to 34.5 million tons (GAPKI, 2017) and the number projected to reach 38.7 million tons in 2017 (Firman dan Putra, 2017). Palm Oil Mill (POM) as the CPO producer industry of oil palm fresh fruit bunches (FFB) is loaded with residues or wastes. Ohimain et al. (2013) argued that the processing of FFB can only produce 20-30% of CPO, while the residue can reach 60-70%. One ton of FFB produces 12-15% residues of Oil Palm Mesocarp Fibers (OPMF), 20-23%, of oil palm empty fruit bunches (EFB_S), 5-7% of shells and 35% of wastewater (Nasution et al., 2014). The increased production of CPO every year has an impact on the increased number of OPMF and EFB_S. In 2016, the number of EFB_S and OPMF produced by POM were 31.38 million tons and 17.89 million tons respectively, increased to 37.81 million tons and 21.56 Million tons by 2020 (Media Perkebunan, 2016). EFB_S and OPMF residues still contain oil and carotenoids. Yunos et. al. (2015) claim that EFB_S contains 3-7% of oil and carotenoids of 405 ppm with a Deterioration of Bleaching Index (DOBI) value of 1.94-2.43. While OPMF contains 5-11% of oil and carotenoid of 1,400-1,600 ppm with the DOBI value of 2,8-3,0 (Subramaniam et al., 2013). At present, at OPM, the residues of EFB_S and OPMF are used as a fuel to generate steam in the boiler as well as to generate electrical energy (Hassan et al, 2013, Olisa and Kotingo, 2014) leaving oil and carotenoids contained in the residues of EFB_S and OPMF are fruitlessly vanished in burn and thus generated greenhouse gas (GHG) emissions. GHG emissions resulted from the burning of EFB_S and OPMF residues leads to the increased amount of GHG from OPM, as is stated by Bessou et al. (2014) that POM produces GHG emissions coming from a wastewater pool with an average of 1.67 tons of CO2 equivalent to a production 1 ton of CPO each. Scroeder et al (2006) puts forth that carotenoids contained in palm oil are dominated by β-carotene (60%) and α-carotene (34%) which therefore make it potential as a provitamin A. The potential of vitamin A (retinol equivalent) in palm oil is 15 times greater compared to that of in carrots or 300 times that of in tomatoes (Sundram et al., 2003). Not only as a provitamin A, palm oil carotenoids can also serve as food coloring and the power of antioxidants (Jaswir et al., 2011 and Rymbai et al., 2011). The purpose of this research is to isolate and to investigate the quantity and quality of oil from EFB_S and OPMF as well as to determine OPMF oil characteristics including fatty acid composition and antioxidant activity and to determine the effect of GHG emission reduction after OPMF maceration.

Materials and Methods

Materials and equipment

Raw materials of EFBs and OPMF were used in this research. The chemicals consisted of technical hexane and hexane p.a (Merck), Sodium hydroxide (Brataco), potassium hydroxide (Brataco), and DPPH (Sigma-Aldrich). The equipments used in this research were a bucket / a barrel for maceration, a soxhlet app., a vacuum distillation unit, a memmert oven, a Shimadzu UV-1700 UV-VIS Spectrophotometer, and a Shimadzu GC-14B gas chromatography.

Places and Procedures for Waste Sampling

Samples of EFBS and OPMF were collected from 4 POM_S (2 POMs belong to PT Perkebunan Nusantara with a Harvest Sorting Value (HSV) of ≥ 80 and 2 POM_S owned by private plantation companies representing POMs with an HSV of ≤ 80). The 4 POMs are located in North Sumatera Province and the capacity of TBS is 30 tons / hour. EFBs were collected from the empty bunch conveyor station and the OPMF were collected from the cake breaker conveyor station. Each EFBs and OPMF were inserted into separate and weighed weavers. Waste sampling was done 2 times which wasa at 10.00 WIB and at 15.00 WIB. The types and quantities of EFBs and OPMF samples are presented in Table 1.

Table – 1: Type and Number of Sample collected from 4 POMs

Name of OPM	Type of Waste			
	Morning OPM (Kg)	Afternoon EFBs (Kg)	Morning OPMF (Kg)	Afternoon OPMF (Kg)
OPM "A"	84	80	26	35
OPM "B"	32	38	51	62
OPM "C"	30	35	73	91
OPM "D"	38	42	75	83
Total	379		496	

Procedure for EFBS and OPMF Oil Maceration

EFBs and OPMF (each morning and afternoon) are weighed 4-10 kg (depending on the size of the bucket or barrel in which the maceration is done). Then they were macerated with hexan. The number of EFBS and OPMF were compared with a solvent ratio of 1:20 (w/v). One kg of EFBs or OPMF was immersed in a 20 L hexan (Masni, 2004). The maceration lasted for 48 hours at a room with temperature. During maceration, the bucket or the barrel was tightly sealed to avoid hexane loss for evaporation. Upon completion of maceration, the EFBS or OPMF were removed from the maceration barrel and were drained until the hexane leaved no drips. Then, the oil dissolved in the hexane was separated by firstly performing normal distillation at a temperature of 70^0C and secondly by performing vacuum distillation at a temperature 50- 55^0C. The oil obtained from the distillation products was heated in the oven at a temperature of 70^0C for the purpose of evaporating the remaining hexane in the oil. The heating process lasted for as long as the oil viscosity reached a constant state. Once the oil viscosity reached a constant state, then an analysis was conducted on the parameters of quantity and quality of oil.

Parameters of EFBS and OPMF Oil Quantity

The oil quantity parameter consisted of residual oil content and maceration product (oil yield). The residual oil content of EFBS and OPMF was determined by sokhlet method, while oil yield was determined by applying the following formula:

$$Oil\ yield\ (\%) = \frac{(Weight\ of\ the\ macerated\ oil\ (g))}{(Weight\ of\ waste\ (g))}$$

Procedure for determining Residual Oil Content (Naibaho, 1998)

The samples of 10g EFBS or OPMF residues were inserted into the extraction thimble moistened with hexane. Then, the extraction thimble containing the sample was placed into the soxhlet. The extraction flask was weighed using an analytical balance, then filled with 200ml hexane solvent. The extraction flask and cooler were connected and the soxhlet was placed on top of the heating mantle at a temperature of 70^0C. Then it was extracted for 5-6 hours. The oil mixture with hexane in the extraction flask was vacuum-distilled until no hexane evaporates. The oil-filled flask was inserted into the oven at a temperature of 103 ± 20°C to evaporate un-distilled hexane. The extraction flask was removed from the oven and cooled for 15 minutes inside a desiccator. The extraction flask was removed from the desiccator and weighed until a constant weight was obtained. Then the level of oil was determined with the following formula:

$$\text{Oil Content} = \frac{\text{Oil Weight}}{\text{Sample Weight}} \text{ X } 100\%$$

EFBS and OPMF Oil Quality Parameters

Determination of carotenoid levels (PORIM 1995)

The oil was heated at 60^0C- 70^0C temperatures and shaken until homogeneous. Then the oil was weighed ± 0.1 g and was inserted into a 10 mL measuring flask. Then, the iso-octane or N-hexane was added until it reached the line mark. The absorbance was measured at λ = 446 nm.

Determination of the Deterioration of bleachability index (DOBI) (Naibaho, 1998)

The oil sample was heated at a temperature of 50^0C on a hotplate until all layers of oil melted and then it was stirred using stirring rod until evenly distributed. Then the oil sample was weighed 4g at a 25 ml measuring flask. The iso-octane solvent was added to the flask neck until it reached 25 ml mark. It was shaken by flipping the measuring flask until homogeneous. The spectrophotometer was perfectly calibrated according to the measurement /reading. Two spectrophotometer cuvettes were provided. One of them was filled with iso-octane and the other was filled with samples dissolved with iso-octane. The spectrophotometer was set at a wavelength of 446 nm. Then the cuvette containing iso-octane was inserted into spectrophotometer and was set at 0,00 A (blank). The cuvette containing iso-octane was removed and replaced with a cuvette containing the oil sample. The spectrophotometer was set at a wavelength of 269 nm. Then, the cuvette containing iso-octane was inserted into the spectrophotometer and was set at 0.00 A (blank). The cuvette containing iso-octane was removed and replaced with the cuvette containing the sample.

$$\text{DOBI Value} = \frac{\text{Absorbance at 446 nm}}{\text{Absorbance at 446 nm}}$$

Determination of free fatty acid (FFA) (AOCS method Ca 5a1, 1987).

The oil was weighed at 5 ± 0.01g in an empty erlenmeyer. Then, 50 ml of neutralized alcohol was added. Next, it was heated at a temperature of 50^0C until all oil soluble. Afterwards, 2-3 drops of 1%

phenolphthaline indicator was added. It was titrated with 0.1N KOH standard solution until the color changes from yellow to stable reddish yellow.

$$\text{FFA content (\%)} = \frac{((\text{ml x N KOH}) \text{ x } 256)}{((\text{gram sampel}) \text{ x } 1000)} \text{ X } 100$$

OPMF Oil Characteristics

Fatty acid composition (AOCS Method Ce 1b-89, 1987)

The OPMF oil sample was weighed at ± 0.025 g, and then was inserted into a vial flask. Then, 0.5 mL of Na-methilate 5N was added. Then it was vortexed for 2 minutes. It was then left for 10 minutes and after that 1 mL of iso-octane was added. It was vortexed back for 1 minute, and then centrifuged for 10 minutes. Afterwards, the 1 µL sample was injected into gas chromatography.

Antioxidant activity by DPPH method (Rubalya and Neelamegan, 2012).

The OPMF oil sample was diluted with hexane solvent: chloroform 2:3 at carotene concentration of 0.5 ppm, 2 ppm, 4 ppm, 8 ppm, 10 ppm, 12 ppm and 15 ppm. The diluted oil sample was piped in 1 mL, and inserted into a test tube. The test tube containing the sample was added 4 mL 0.5 mM DPPH dissolved in ethanol and left for 60 minutes. Then, its absorbance was measured by using a UV-visible spectrophotometer at 516 nm wavelength. DPPH radical damping activity was expressed as a damping percentage to DPPH radicals as calculated by the following formula:

$$\% \text{ Damping} = [(A0\text{-}As) / A0] \text{ x}100$$

Where A0 = absorbance without sample addition (blanko absorbance). Each time fiber absorbance measurement is performed, then the blanko absorbance measurement is performed as well. The percentage of DPPH radical absorption and carotene concentration in fiber oil were plotted on Y and X axis respectively. Then a linear regression equation was calculated with the equation form of Y = a + bX. The value of IC_{50} (inhibition concentration 50%) was obtained by substituting Y with 50% so that X ppm value was obtained. This ppm X value was IC_{50} OPMF oil.

The Effect of GHG reduction after OPMF oil maceration

The effect of GHG reduction after maceration was calculated under the assumption that OPMF oil is similar to CPO since the type of dominant fatty acid in OPMF oil is similar to that of the dominant fatty acid in CPO. Therefore, the energy of CPO heat of 9113,3 kkal/kg, (Mahmud et al., 2010) can be used as an energy of OPMF oil calor. Liquid organic fuels with 1 TJ calorific energy value will produce GHG emissions of 79.996 kgCO2 (e) (IPCC, 2006). The number of OPMF used in determining the effect of GHG emission reduction is 496 kg (according to the number of OPMF samples used). At first, the amount of oil contained in the OPMF (eg a kg) was calculated, then the amount of calorific energy from the oil weighing a kg was calculated. Then the amount of GHG emissions from the amount of calorific energy (for example the result of the amount of GHG emission b kgCO2 (e) was calculated. The amount of this GHG is the amount of GHG emissions before maceration. After maceration, the amount of oil left in the fiber as calculated, for example c kg. Then the amount of calorific energy of the oil weighing c kg was calculated. Then, GHG emissions from the energy of calorific oil weighing c kg (for example d kgCO2 (e) was calculated. The effect of GHG emission reduction was determined by the following formula: Reduction of GHG emissions (%) = b kgCO2 (e) - d kgC02 (e) / b kgCO2 (e) x 100%

Results and Discussion

The quantity and quality of oil isolated from EFBS and OPMF can be seen as in Table 2 below.

Table – 2: Quantity and quality of EFBs and OPMF oil

Parameter	EFBs	OPMF
Oil quantity:		
Residual Oil Content (%)	2.86±0.55	3.91±1.00
Oil Yield (%)	2.26±0.34	3.47±0.98
Oil Quality:		
Carotenoid content (ppm)	915.25±300.28	2305±645.75
DOBI value	1.14±0.15	3.49±1.61
FFA content (%)	21.58±3.79	9.68±0.78

Remark: Average Results of EFBs 4 OPM with two repetitions

Table 2 above shows that the oil content of OPMF residues was higher (3.91%) as compared to EFBS oil

content (2.86%). This is due to the fact that oil palm mesocarp contains much oil as compared to palm bunches. According to Yunos et. al. (2015), based on the sudan staining test, the oil contained in EFBS are located on the fiber surface through the process of oil adsorption with EFBS fibers. Therefore, the oil contained in the EFBS comes from mesocarp oil as TBS slammed into palm fruits extraction station. The yield of OPMF maseration was higher (3.47%) as compared to EFBS yield (2.26%). This is due to the maceration process where oil was diffused from residue into hexane solution until the amount of oil on the residue equals the amount of oil in the hexane solvent (Bernasconi et al 1995). Since the OPMF oil content was higher than EFBS oil content, then the amount of oil diffused in the OPMF oil maceration was higher. Carotenoid content and OPMF oil DOBI were higher as compared to carotenoid content of EFBS which was at 2305 ppm and DOBI of 3,49 with 915,25 ppm and DOBI of 1,14 respectively. Based on carotenoids content and DOBI values, the quality of OPMF oil is better than the quality of EFBS oil even with the quality of CPO. The CPO carotenoid content was of 500-700 ppm with a minimum DOBI of 2.3 (Subramanian et al, 2013). The low levels of carotenoids content and DOBI value of EFBS oil are due to the fact that EFBS oil was located on the surface of EFB leading to the susceptibility of free oxygen oxidation and subjected to isomerization due to its direct contact with light. Meanwhile, OPMF oil is inside the fiber matrix making it protected from external factors such as oxygen and light. Low DOBI value (1.14) and high FFA in EFBS (21.58%) showed that carotenoids and EFBS oil had been damaged by isomeric reactions and oxidation reaction. Carotenoid damage through isomerization, oxidation, and molecular fragmentation resulted in decreased performance of pro vitamin A and decreased DOBI values (Levin and Mokaday, 1994). Oxidation and isomerization of carotenoids not only decreased the DOBI but also decreased the functional nature of carotenoids as antioxidants and the color faded away. Nurcahyono and Zubaidah (2015) puts forward that carotene iosmerization from the trans form into the cis form causes a decrease in the intensity of the color so that it cannot be used as a dye. Carotenoid content and high DOBI value of OPMF oil indicated that the oil is a potential raw material for natural food coloring industry and as nutraceutical as compared to EFBS oil. Currently, global industries are facing problems in fulfilling the needs of natural and environmentally friendly carotenoids (Kupan et al., 2015). The use of OPMF oil as a dye and as a raw material of nutraceutical products brings more benefits, for: its naturalness, the raw material of OPMF residue is cheap and abundant so that the raw materials continuity can be guaranteed, and are environmentally friendly. In Indonesia, carotenoid products are still imported with their relatively high price, therefore, oil palm diversification as a natural source of carotenoids and nutraceutical raw materials can improve CPO competitiveness (Wulandari, 2007). As for EFBs oil, although the level of FFA is considerably high (21.58%), it can still be used as raw material for biodiesel production, as Putri et al. (2015) mentioned that 96.29% of FFA oil off grade (FFA content of 16.18%) can turn into methyl esters or biodiesel.

Fatty acid composition of OPMF Waste Oil

Fatty acid compositions with percentage of above 1% of targeted POM OPMF oil are presented in the following Table 3.

Table – 3: OPMF oil acid composition

Fat Type Acid	Total of carbon atom	OPMF oil (%) fatty acid				
		OPM A	OPM B	OPM C	Average	CPO[a]
Lauric acid	C12:0	22.0	2.65	21.34	15.33± 10.33	0.2
Miristic acid	C14:0	7.8	1.78	8.57	6.05± 3.71	1.1
Palmitic acid	C16:0	25.17	41.26	24.74	30.39 ±9.41	44.0
Stearic acid	C18:0	3.07	3.51	3.31	3.29± 0.22	4.5
Oleic acid	C18:1	30.31	38.70	30.64	33.21± 4.75	39.2
Linoleic acid	C18:2	7.36	10.74	7.59	8.56 ±1.88	10.1

Remark: Profile of OPMF fatty acid of OPM D oil waste was not analyzed. [a]Haryadi (2010)

Table 3 shows that the dominant fatty acid type in OPMF oil is similar to the dominant fatty acids of CPO, namely C16:0 Palmitic acid and C18:1 oleic acid with respective average of 30.39% (CPO 44.0%), and 33.21% (at CPO of 39.2%). This is because CPO and OPMF oil are both derived from Palm Fruit Bunches mesocarp. However, there is a difference in terms of the amount of lauric fatty acids. Oil produced by OPMF at the three POMs respectively contained 22.0%, 2.65% and 21.34% lauric acid, while the lauric acid in CPO oil was only 0.2%. The results of this study were consistent with that of Majid et al (2012) and Neoh et al (2011) who reported the dominant fatty acids of OPMF oil were palmitic acid (31.9%), oleic acid (24.8%), and lauric acid (22.0%). Lauric acid in the OPMF oil originated from crushed palm kernel during pressing. Crushed palm kernel was blended and mixed with OPMF, so that as OPMF was macerated, the oil in the Crushed palm kernel was extracted. Based on the fatty acid composition of OPMF oil which is of no difference with that of fatty acid composition of CPO as shown in Table 3, it can be inferred that oil maceration from OPMF allows CPO to increase and decreases the value of oil loses in POM and can be used as a substitute of CPO as a raw material in food industry.

Antioxidation Power (IC50) of OPMF Oil with DPPH Method

The result of observation of OPMF oil antioxidation power using DPPH method can be seen in Table 4 below.

Table – 4: Correlation of OPMF oil concentration with damping percentage

Consentration (ppm)	% Damping
DPPH (blanko)	0
0,5 ppm	7.75
2 ppm	16.17
4 ppm	36.16
8 ppm	57.1
10 ppm	60.36
12 ppm	65.67
15 ppm	70.68

Table 4 shows that the higher carotenoid concentration in the OPMF oil, the more the number of dumped DPPH increased from 0% at 0 ppm oil concentration to 70.68% at 15 ppm oil concentration. The increase of DPPH damping percentage is due to the increasing number of carotenoid as electron giver to DPPH. By giving electrons of hydrogen atoms from carotenoids to DPPH as free radicals, the electrons in DPPH formed a pair. Consequently, paired electrons lost their nature as free radicals. The state of losing free radicals is called the damping process (Gurav et al., 2007). The carotenoid-free radical damping mechanism was performed by binding the singlet oxygen and converting it into a triplet oxygen. The excited carotenoid releases heat and then returns to a stable caretonoid (Gordon, 1990).

$$^1O^2 + \text{carotenoid} \longrightarrow 3O2 + *\text{carotenoid}$$
$$*\text{carotenoid} \longrightarrow \text{Carotenoid} + \text{heat energy}$$

The correlation of OPMF oil concentration with the amount of dumped DPPH (%) was calculated using linear regression of $Y = 4.458\ X + 12.11$ with $R^2 = 0.927$. The value of IC_{50} (concentration of test sample capable of trapping free radicals by 50%) was used as a parameter to determine antioxidant activity of the test sample (Prakash, 2001). By substituting Y with a value of 50% on the regression equation of $Y = 4.458\ X + 12.11$, then the X value obtained 8.499 ppm. As a result, IC_{50} OPMF oil of 8.49 ppm was obtained. The antioxidant activity of oil palm mesocarp extract was classified in the very strong category with an IC_{50} value of 8.49 ppm, much stronger than pure carotene beta having IC_{50} of 551 ppm (Kurniawati, et al., 2007). The compounds classified as extremely strong antioxidant if the IC_{50} value is less than 50 ppm, strong antioxidant if $IC_{50}$is 50 to 100 ppm, moderate antioxidant if IC_{50} is 100-150 ppm and weak antioxidant if IC_{50} is 151 - 200 ppm (Mardawati, et al. 2008). The antioxidant activity of OPMF oil is extremely strong due to the amount of carotene and other minor compounds such as Vitamin E in the OPMF waste oil higher than that of other oils (Choo et al, 1989). Manasika and Widjarnarko (2015) stated that the more the amount of carotene in the material, then the more powerful the antioxidant power gets, leading to IC50 getting smaller. The extremely low IC_{50} (8.49ppm) indicated that OPMF oil can be potentially used as a functional food antioxidant and natural antioxidant substituting artificial antioxidants

such as BHA (Butyl Hidroxy Anisol) and BHT (Butyl Hidroksi Toluene).

The effect of GHG reduction after oil maceration

The effect of GHG CO2 reduction (eq) after maceration was calculated by the following measures. OPMF oil content was 3.91% and the OPMF weighing at 496 kg, resulting in the amount of oil contained in OPMF before maceration weighing at 19.35 kg. The amount of calorific heat burning before maceration was 176,342.35 Kkal (19.35kgx9113.3Kkal / kg) or 0,000737 TJ. Liquid organic fuel with a 1 TJ calorific value will produce GHG emission of 79.996 kg CO2 (eq) (IPCC 2006) leading to the organic fuel with a 0.000737 TJ caloric value produces 58.95 KgCO2 (e). Macerated OPMF content was 3.47%, leading to the OPMF oil content after maceration became 0.44% (3.91-3.47%). The amount of oil left in the OPMF after maceration was 2.17 kg. The amount of GHG resulted from the burning of 2.17 kg of oil was 6.62 KgCO2 (e). The effect of GHG reduction after maceration = $\frac{(58{,}95-6{,}62)\ \mathbf{kgCO2\ (e)}}{58{,}95\ \mathbf{kgCo2\ (e)}}$ x 100%= 88.77%. The summary of the effect of GHG reduction after OPMF maceration is presented in the following table.

Table – 5: Effect of GHG reduction CO2(e) after OPMF waste maceration

Parameter	Before maceration	After maceration
Oil Content (%)	3.91	0.44
Total Oil (kg)	19.35	2.17
Total GHG (CO2.eq)	58.95	6.62
Effect of GHG reduction (CO2.eq) after maceration	88.77%	

Conclusion

The findings above lead to the following conclusions: The quantity and quality of oil isolated from OPMF residue is higher than oil isolated from EFBS for the following reasons: oil content higher by 3.91% (2.86% in EFBS), oil yield by 3.47% (2.26% in EFBS), carotenoid levels were higher at 2305 ppm (915.25 ppm in EFBS), DOBI higher by 3.49 (1.14 in EFBS), and FFA lower by 9.68% (21.58% in EFBS). The OPMF oil fatty acid composition is generally similar to that of CPO fatty acid composition of which is dominated by C16:0 palmitic acid and C18:1 oleic acid, at an average of 30.31% (at 44.0% CPO) and 33.22 % (at 39.2% CPO) respectively. Antioxidant activity (IC50) of OPMF Oil was at 8.49 ppm (extremely strong antioxidation power category).. The effect of GHG emission reduction after OPMF oil maceration can potentially reach 88.77% of the amount of GHG emissions before maceration.

Acknowledgement

The author would like to express his gratitude to the Head of Agricultural Research and Development Board for providing research funds through the scheme of Partnership Cooperation of National Agricultural Research and Development and the Director of Indonesian Oil Palm Research Institute (IOPRI) for allowing the Author to harness research facilities at the Laboratory of Analysis of Postharvest Board and Oleo Food and Quality Laboratory of IOPRI, Medan

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