

Article

Economic Analysis of Thermal–Catalytic Process of Palm Oil (*Elaeis guineensis*, Jacq) and Soap Phase Residue from Neutralization Process of Palm Oil (*Elaeis guineensis*, Jacq)

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Supplementary Tables

Table S1. Yields of thermal catalytic cracking of crude palm oil (*Elaeis guineensis*, Jacq) at 450 °C, 1.0 atmosphere, and 10% (wt.) Na₂CO₃ as catalyst, and distillation of organic liquid products (OLP) [26–31].

Process	Yield [wt.%]
Thermal catalytic cracking	75.00
Organic Liquid Products	63.60
Solids	8.00
Gas	28.40
Distillation of OLP	60.00

Table S2. Physicochemical properties of crude palm oil used as raw by thermal catalytic cracking at 450 °C, 1.0 atmosphere, and 10% (wt.) Na₂CO₃ as catalyst [26–31].

Properties	CPO Na ₂ CO ₃ 10% (wt.)
Density [g/cm ³]	0.95
Kinematic viscosity [cSt]	2.90
Acidity index [mg KOH/g]	8.98
Saponification index [mg KOH/g]	9.19
Ester index [mg KOH/g]	0.21
Free fatty acids – AFF [%]	4.51
Refractive index	1.45
Melting point [°C]	19.10
Corrosiveness	1A
Water and Sediment [%]	*
Carbon residue [%]	0.73

Table S3. Chemical compositional of distillation fraction within the temperature range 40 °C - 175 °C (biogasoline), described in terms of oxygenated and hydrocarbons, of OLP obtained by thermal catalytic cracking at 450 °C, 1.0 atmosphere, and 10% (wt.) Na₂CO₃ as catalyst [26–31].

Compounds	Content [area.%]
Hydrocarbons	52.76
Normal paraffins	15.78
Branched paraffins	0
Naphthenico	3.50
Aromatics	1.94
Olefins	31.54
Oxygenated compounds	47.24
Others	47.24

Table S4. Chemical compositional of distillation fraction within the temperature range 175 °C – 235 °C (biokerosene), described in terms of oxygenated and hydrocarbons, of OLP obtained by thermal catalytic cracking soap crude palm oil at 450 °C, 1.0 atmosphere, and 10% (wt.) Na₂CO₃ as catalyst [26–31].

Compounds	Content [area.%]
Hydrocarbons	86.37
Normal paraffins	19.48
Branched paraffins	0
Naphthenico	19.63
Aromatics	7.04
Olefins	40.22
Oxygenated compounds	13.63
Others	13.63

Table S5. Chemical compositional of distillation fraction within the temperature range 235 °C – 305 °C (light green diesel), described in terms of oxygenated and hydrocarbons, of OLP obtained by thermal catalytic cracking of at 450 °C, 1.0 atmosphere, and 10% (wt.) Na₂CO₃ as catalyst [26–31].

Compounds	Content [area.%]
Hydrocarbons	91.38
Normal paraffins	31.27
Branched paraffins	0
Naphthenico	5.67
Aromatics	0
Olefins	54.44
Oxygenated compounds	8.62
Others	8.62

Table S6. Chemical compositional of distillation fraction within the temperature range 305 °C – 400 °C (heavy green diesel), described in terms of oxygenated and hydrocarbons, of OLP obtained by thermal catalytic cracking of at 450 °C, 1.0 atmosphere, and 10% (wt.) Na₂CO₃ as catalyst [26–31].

Compounds	Content [area.%]
Hydrocarbons	70.78
Normal paraffins	25.30
Branched paraffins	0
Naphthenico	9.64
Aromatics	0
Olefins	35.84
Oxygenated compounds	29.22
Others	29.22

Table S7. Yields of thermal catalytic cracking of palm oil neutralizing sludge (*Elaeis guineensis*, Jacq) at 450 °C, 1.0 atmosphere, and 15% (wt.) Na₂CO₃ as catalyst, and distillation of organic liquid products (OLP) [34,35].

Process	Yield [wt.%]
Thermal catalytic cracking	56.25
Organic Liquid Product	71.37
Solids	23.55
Gas	0.48
Distillation of OLP	60.00

Table S8. Physicochemical properties of organic liquid product (bio-oil), of experiment 5, thermal catalytic cracking of palm oil neutralizing sludge (*Elaeis guineensis*, Jacq) at 450 °C, 1.0 atmosphere, and 15% (wt.) Na₂CO₃ as catalyst [34,35].

Physicochemical properties	Exp. 5	Diesel S10 (ANP N° 65)
Acidity index [mg KOH / g]	1.07	Note
Refractive index	1.45	-
Saponification index [mg KOH / g]	27.52	-
Kinematic viscosity [cSt]	1.90	2.0 – 4.5
Density [g/ mL]	0.8	0.82 – 0.85
Corrosiveness	1	1
Melting point [°C]	>71	38 minimum
Carbon residue [%]	0.466	0.25 (máximo)
Yield of bio-oil* (%)	71.37	-
Sulphur content	24	10 ppm (max)
Color	4	3 (max)
Aspect	Approved	Not approved**

* Yield obtained in dry basis (without the water mass generated in the process).

** Clear and free from impurities.

Table S9. Chemical composition of organic liquid product (experiment 5), described in terms of oxygenated and hydrocarbons, obtained by thermal catalytic cracking of palm oil neutralizing sludge (*Elaeis guineensis*, Jacq) at 450 °C, 1.0 atmosphere, and 15% (wt.) Na₂CO₃ as catalyst [34,35].

Chemical functions	Composition [area.%]
Hydrocarbons	91.22
Paraffins	30.75
Olefíns	53.72
Naphthenicos	4.5
Aromatics	2.25
Oxygenated compounds	8.78
Alcohols	2.27
Ketones	5.34
Ether	1.17

Table S10. The physicochemical properties of distillation fractions of biogasoline (40 °C – 175 °C) and biokerosene (175 °C – 235 °C), of OLP (experiment 5) obtained by thermal catalytic cracking of palm oil neutralizing sludge (*Elaeis guineensis*, Jacq) at 450 °C, 1.0 atmosphere, and 15% (wt.) Na₂CO₃ as catalyst [34,35].

Characteristics	Light fractions		Residue	Diesel S10 (ANP N° 65)
	(40 – 175 °C)	(175 °C – 235 °C)	-	Note
Acidity Index [mg KOH / g]	3.489	4.046	5.52	2.0 – 4.5
Viscosity [cSt]	0.14	0.17	5.52	2.0 – 4.5
Density [g/ mL]	0.74	0.76	0.85	0.82 – 0.85
Corrosiveness	1	1	1	1
Flash point [°C]	37	22	81	38 minimum
Sulphur content [ppm]	16			10 [max]
Color	1	-	-	3 [max]
Aspect	Approved			Approved*
Carbon residue**	1.3	-	-	0.25 [max]

* Clear and free from impurities.

** Obtained with 10 % ends of the curve of distillation.

Table S11. Chemical compositional of distillation fraction within the temperature range 175 °C – 235 °C (heavy green diesel), described in terms of oxygenated and hydrocarbons, of OLP obtained by thermal catalytic cracking of palm oil neutralizing sludge (*Elaeis guineensis*, Jacq) at 450 °C, 1.0 atmosphere, and 15% (wt.) Na₂CO₃ as catalyst [34,35].

Compounds	Composition [%]
Paraffins	30.55
Olefins	49.76
Aromatics	6.92
Naphthenicos	9.27
Total of Hydrocarbons	96.5
Others	3.5

Table S12. Chemical compositional of distillation fraction within the temperature range 305 °C – 400 °C (heavy green diesel), described in terms of oxygenated and hydrocarbons, of OLP obtained by thermal catalytic cracking of palm oil neutralizing sludge (*Elaeis guineensis*, Jacq) at 450 °C, 1.0 atmosphere, and 15% (wt.) Na₂CO₃ as catalyst [34,35].

Compounds	Composition [area.%]
Paraffins	29.27
Olefins	56.98
Aromatics	3.41
Naphthenicos	3.55
Total of Hydrocarbons	93.21
Ketones	2.88
Alcohols	3.91
Total oxygenated	6.79

Table S13. Chemical compositional of distillation fraction within the temperature range 235 °C – 305 °C (light green diesel), described in terms of oxygenated and hydrocarbons, of OLP obtained by thermal catalytic cracking of palm oil neutralizing sludge (*Elaeis guineensis*, Jacq) at 450 °C, 1.0 atmosphere, and 15% (wt.) Na₂CO₃ as catalyst [34,35].

Compounds	Composition [area.%]
Paraffins	33.55
Olefíns	54.90
Aromatics	1.52
Naphthenicos	8.79
Total of Hydrocarbons	98.76
Others	1.24

Table S14. Chemical compositional of distillation fraction within the temperature range 40 °C – 175 °C (biogasoline), described in terms of oxygenated and hydrocarbons, of OLP obtained by thermal catalytic cracking of palm oil neutralizing sludge (*Elaeis guineensis*, Jacq) at 450 °C, 1.0 atmosphere, and 15% (wt.) Na₂CO₃ as catalyst [34,35].

Compounds	Composition [area.%]
Paraffins	34.64
Olefíns	51.09
Aromatics	5.85
Naphthenicos	8.42
Total of Hydrocarbons	100