
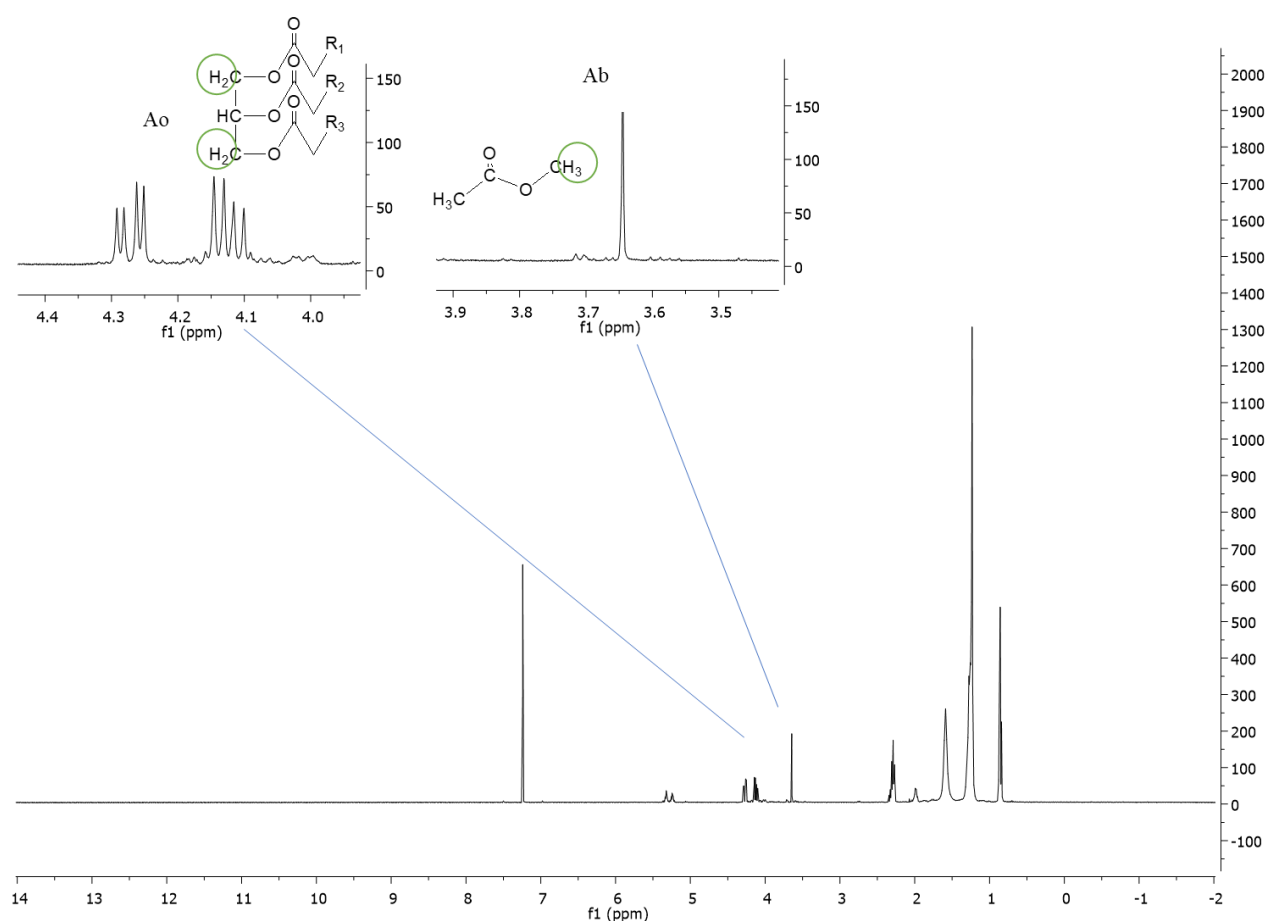


**Methyl Esters Production by Heterogeneous Catalyst Mixtures of CaO/Nb<sub>2</sub>O<sub>5</sub> with Simulation of Analysis of Environmental Impacts**

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**Figure S1.** <sup>1</sup>H NMR spectrum (400 MHz, CDCl<sub>3</sub>) of biodiesel samples. (Ao) represents the area value of the integration signal absorbed by the triglyceride hydrogens, (Ab) represents the area value of the integration signal absorbed by the methoxy hydrogens.

**Table S1.** Physicochemical characterization of macauba oil and biodiesel

	Oil	Biodiesel	ANP Res 45 2014 for biodiesel
Acid index / (mgKOH g <sup>-1</sup> )	12.1	0.49	max 0.50
Specific mass / (kg.m <sup>-3</sup> )	920	892	850 to 900
Kinematic viscosity / (mm <sup>2</sup> s <sup>-1</sup> )	30.61	5.91	3.0 to 6.0
Fatty acids composition / wt.%			
Palmitic acid (C16:0)	21.20	21.61	
Palmitoleic acid (C16:1)	4.81	4.54	
Stearic acid (C18:0)	1.09	1.61	
Oleic acid (C18:1n-9)	46.85	46.35	
Linoleic acid (C18:2n-6)	24.28	29.89	
Linolenic acid (C18:3)	1.57	1.49	

**Table S2.** Summary of unit operating conditions for each process

	Homogeneous	Heterogeneous
Transesterification		
Catalyst	NaOH	CaO/Nb <sub>2</sub> O <sub>5</sub>
Reactor type	CSTR	CSTR
Temperature / °C	75	75
Pressure / kPa	101.325	101.325
Oil-to-alcohol ratio	1:36	1:36
Residence time / h	2	2
Conversion / %	95	90
Methanol recovery		
Recovery / %	98.9	99.1
Distillate flowrate / (kg h <sup>-1</sup> )	32.79	29.24
Distillate purity / %	99.9	99.9
Catalyst removal	glycerol wash	–
Neutralizing agent	nitric acid	–
Glycerol separation		
Water flowrate / (kg h <sup>-1</sup> )	406.8	0
Biodiesel recovery		
Recovery / %	99	99
Final purity	99.8	97.6

CSTR: continuous stirred-tank reactor.

**Table S3.** Inlet and outlet material streams of the processes simulation

	Homogeneous catalyst process								Heterogeneous catalyst process			
	Water	Oil	Methanol	Cat	Acid	Waste	MS-14	Biodiesel	Oil	Methanol	Waste	Biodiesel
Mass flow / (kg h <sup>-1</sup> )	406.8	360	38.07	3.6	5.671	439.3	40.28	334.6	360	38.07	70.85	327.1
Mass fraction												
Water	1.000	0.000	0.000	0.000	0.000	0.833	0.999	0.001	0.000	0.000	0.000	0.000
Glycerol	0.000	0.000	0.000	0.000	0.000	0.083	0.000	0.000	0.000	0.000	0.497	0.001
NaOH	0.000	0.000	0.000	1.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.000
Methanol	0.000	0.000	1.000	0.000	0.000	0.001	0.000	0.000	0.000	1.000	0.004	0.000
Triolein	0.000	1.000	0.000	0.000	0.000	0.023	0.001	0.003	1.000	0.000	0.257	0.006
Methyl oleate	0.000	0.000	0.000	0.000	0.000	0.040	0.000	0.995	0.000	0.000	0.241	0.993
Nitric acid	0.000	0.000	0.000	0.000	1.000	0.013	0.001	0.001	0.000	0.000	0.000	0.000