Supplementary material to

Improvement of low-temperature characteristics of biodiesel by additivation

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Hem. Ind. **73 (2)** 103–114 (2019)

Table S-1. Values of CP, CFPP and PP with additive supplementations at different concentrations for "aged" biodiesel with palm oil (sample 1)

			Temperature of CP, °C		
Concentration of additives	N_1	N_2	N_3	CF	LM
0	9	9	9	9	9
100 ppm	9	9	9	9	9
300 ppm	9	9	9	9	9
500 ppm	8	9	9	9	9
700 ppm	8	9	9	9	9
900 ppm	7	8	9	9	9
1100 ppm	7	8	8	9	9
2000 ppm	7	7	7	9	9
5000 ppm	6	7	7	8	9
			Temperature of CFPP, °C		
Concentration of additives	N_1	N_2	N_3	CF	LM
0	6	6	6	6	6
100 ppm	6	6	6	6	6
300 ppm	6	6	6	6	6
500 ppm	4	6	6	6	6
700 ppm	4	5	5	6	6
900 ppm	3	4	5	6	6
1100 ppm	3	4	4	5	6
2000 ppm	3	3	3	5	6
5000 ppm	2	3	3	4	6
			Temperature of PP, °C		
Concentration of additives	N_1	N_2	N_3	CF	LM
0	3	3	3	3	3
100 ppm	2	3	3	3	3
300 ppm	2	3	3	3	3
500 ppm	2	3	3	3	3
700 ppm	2	2	3	3	3
900 ppm	2	2	3	2	3
1100 ppm	2	1	2	1	3
2000 ppm	1	1	2	1	2
5000 ppm	1	1	1	1	1

Table S-2. Values of CP, CFPP and PP with additive supplementations at different concentrations for fresh rapeseed biodiesel (sample 2).

repseed		Biodiesel with 1000 ppm of additives (first series)				
Properties	Pure biodisel	N_1	N_2	N_3	CF	LM
Temperature of CFPP, °C	-9	-13	-12	-11	-10	-12
Temperature of PP, °C	-11	-18	-15	-12	-18	-15
repseed		Biodiesel with with 1000 ppm of additives (second series)				
Properties	Pure biodisel	C_1	C_2	C_3	C_4	
Temperature of CFPP, °C	-9	-11	-12	-9	-12	
Temperature of PP, °C	-11	-15	-16	-11	-16	
repseed		Biodiesel with with 1000 ppm of additives (third series)				
Properties	Pure biodisel	H_1	PL_1	V_1	V_2	
Temperature of CFPP, °C	-9	-12	-12	-13	-18	
Temperature of PP, °C	-11	-17	-15	-24	-36	

Table S-3. Values of CP, CFPP and PP with additive supplementations at different concentrationS, concentration for the mixture of the rapeseed biodiesel and fossil diesel (5:95) (sample 3)

biodiesel – diesel mixture		Biodiesel mixture with 1000 ppm of additives (first series)				
properties	BD-100+ED (5:95)	N_1	N_2	N_3	CF	LM
Temperature of CFPP, °C	-12	-23	-15	-21	-12	-12
Temperature of PP, °C	-14	-31	-27	-30	-18	-14
repseed + EURODIESEL		Biodiesel mixture with 1000ppm additives (second series)				
Properties	BD-100+ED (5:95)	C_1	C_2	C_3	C_4	
Temperature of CFPP, °C	-12	-12	-12	-12	-12	
Temperature of PP, °C	-14	-24	-14	-15	-14	
repseed + EURODIESEL		Biodiesel mixture with 1000ppm additives (third series)				
Properties	BD-100+ED (5:95)	H_1	PL_1	V_1	V_2	
Temperature of CFPP, °C	-12	-12	-12	-13	-16	
Temperature of PP, °C	-14	-14	-14	-15	-27	

Table S-4. ULSD properties, according to EN SRPS 590

Property	**Value**	**Method**	**Property**	**Value**	**Method**
Density at 15 °C, kg m^{-3}	838.3	SRPS ISO 12185	Distillation at 250 °C, vv^{-1}	45.2	SRPS EN ISO 3405
IBP, °C	171.5	SRPS EN ISO 3405	Distillation at 350 °C, vv^{-1}	95.9	
10 % point, °C	202.9		Viscosity, $mm^2 s^{-1}$	3.01	SRPS ISO3104
20 % point, °C	216.5		Temperature of flash point, °C	65	SRPS EN ISO 2719
30 % point, °C	229.7		Temperature of blur point, °C	-5	SRPS ISO 3015
40 % point, °C	243.5		Temperature of CFPP, °C	-19	EN 116
50 % point, °C	255.7		Sulfur content, mg kg^{-1}	8.2	ASTM D 5453
60 % point, °C	269.2		Water content, mg kg^{-1}	60	SRPS ISO 12937
70 % point, °C	284.1		Cetane index	49.7	SRPS ISO 4264
80 % point, °C	301.8		Copper band corrosion, 3 h at 50 °C	1a	SRPS ISO 2160
90 % point, °C	326.1		Appearance	Clear	Visual
95 % point, °C	345.5		Color	0.5	SRPS ISO 2049
FBP, °C	362.7		Polycyclic aromatic hydrocarbons, % (m/m)	6.6	FOX (MIDAC)
Rest, %v/v	0.8		High heating value, MJ kg^{-1}	46.291	ASTM D5865-07
Loss, %vv	0.9				

Table S-5. Fatty acid composition obtained by a GC analysis

Acid name	Formula	MW_i	Factor F	*C* / mas%	*F c* / mas%	c / mas%	*F c* / mas%	Repseed (sample 2)		Rep+Palm (sample 1)	
				Repseed (sample 2)		Rep+Palm (sample 1)		g_i/M_i	g_i / ($\sum g_i/M_i$)	g_i/M_i	g_i / ($\sum g_i/M_i$)
Palmitic $C_{16:0}$	$C_{16}H_{32}O_2$	256.430	0.000	4.55	0.00	22.081	0.00	1.78	13.00	8.61	61.79
Stearic $C_{18:0}$	$C_{18}H_{36}O_2$	284.430	0.000	1.65	0.00	5.736	0.00	0.58	4.71	2.02	16.05
Oleic $C_{18:1}$	$C_{18}H_{34}O_2$	282.470	0.860	66.19	56.92	37.37	32.14	23.43	189.04	13.23	104.58
Linoleic $C_{18:2}$	$C_{18}H_{32}O_2$	280.450	1.732	17.82	30.86	32.405	56.13	6.35	50.89	11.55	90.69
Linolenic $C_{18:3}$	$C_{18}H_{30}O_2$	278.430	2.616	6.91	18.06	0.399	1.04	2.48	19.72	0.14	1.12
Arachidic $C_{20:0}$	$C_{20}H_{40}O_2$	312.536	0.000	0.52	0.00	0.069	0.00	0.17	1.50	0.02	0.19
Eicosenoic $C_{20:1}$	$C_{20}H_{38}O_2$	310.500	0.785	0.70	0.55	0.436	0.34	0.23	2.00	0.14	1.22
Behenic $C_{22:0}$	$C_{22}H_{44}O_2$	340.590	0.000	0.00	0.00	0.018	0.00	0.00	0.00	0.01	0.05
Lignoceric $C_{24:0}$	$C_{24}H_{48}O_2$	368.640	0.000	0.00	0.00	0.036	0.00	0.00	0.00	0.01	0.10
	$MW_{ester}=\sum (x_i M_i)+M_{methanol}-MW_{H_2O}$			IN = sum (*Fc* / mas%) =106.40		IN = sum (*Fc* / mas%) = 89.65		MW_{ester}=294.878 g/mol		MW_{ester}=289.822 g/mol	
	$MW_{oil}=M_{glic}+3(\sum(x_i MW_i)-MW_{H_2O})$							MW_{oil}=880.610 g/mol		MW_{oil}=865.440 g/mol	