Supporting information for

Cold flow properties of biodiesel and the improvement methods: a review

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Table S1 Improvement effect of different modifying structure methods on cold flow properties of biodiesel.

Biodiesel	Methods	Cold flow properties of the modified biodiesel		
		CP/℃	PP/℃	Refs.
Soybean oil biodiesel	/	0	-2	1
	Partially hydrogenated	3	0	1
Jatropha oil methyl esters	/		3	2
	Partially hydrogenated			
	Hydro-processed			3
Poultry fat biodiesel	Distilled biodiesel	2	-3	4
Step 1	Catalytic hydrogenation	15	18	
Step 2	Epoxidation	2	-3	
Step 3	Hydroxylation	3	-3	
Canola oil methyl ester		-2		5
	Epoxidation-Alkoxylation	4		
Canola oil ethyl ester		-3		
	Epoxidation Alkoxylation	0		
Canola oil butyl ester		-3		
	Epoxidation Alkoxylation	-4		
High oleic methyl ester biodiesel	Epoxidation Alkoxylation	2	0	6
Methoxy		3	-1	
Ethoxy		-2	-4	
n-propoxy		-3	-6	
Isopropoxy		-3	-10	
n-butoxy		-4	-6	
Isobutoxy		-4	-8	
n-hexoxy		-7	-10	
n-octoxy		-7	-10	
n-decoxy		-11	-14	
Palmitic acid methyl ester		30		7
	Hydro-isomerization, Beta zeolite CP814E, 285 ℃, 4.0 MPa	20		
Hexanoic acid				7
Stearic acid	0.4% w/w Pt doped zeolite catalyst, 340 ℃ and 689 kPa H_2 for 6 h			8
Soybean oil methyl esters	Isomerization, $SO4^{2-}$-ZrO2/ H-mordenite	-2		9
Desoxygenated palm oil (HDO)			17	10
	Hydro-isomerization (i-HDO)		<−13	
	distilled (i-HDOd)		−5	
	71% i-HDOd and 29% HDO		2.8	
Soybean methyl esters	Cis-trans isomerization			11
	Partial hydrogenation			
Palm biodiesel fuel	unstable components→ cis-mono-unsaturated FAME			12
	hydro-processing			3

CP: cloud point; PP: pour point; FAME: fatty acid methyl ester.

Table S2 Effects of blend ratio on cold flow properties of biodiesel.

Components	Blending ratio	CP/°C	PP/°C	CFPP/°C	Refs
Biodiesel/Biodiesel					
Jatropha oil methyl esters /Castor oil methyl esters	100/0			1	13
	0/100			-7	
	75/25			-6	
	50/50			-12	
	25/75			-12	
Palm oil methyl esters/Castor oil methyl esters	100/0			14	13
	0/100			-7	
	75/25			8	
	50/50			4	
	25/75			1	
Palm oil methyl esters /Sacha inchi oil methyl esters	100/0			14	13
	0/100			-10	
	75/25			8	
	50/50			3	
	25/75			-5	
Camelus dromedaries (Hachi) fat methyl esters/Citrullus colocynthis methyl esters	100/0	10	4	19	14
	0/100	0	-7	4	
	80/20	8	2	13	
	60/40	7	0	11	
	40/60	5	-2	9	
	20/80	3	-4	7	
Camelina oil methyl esters /Field pennycress oil methyl esters	100/0	4.1	0	0	15
	75/25	1.7	-6.7	-4	
	65/35	0.6	-9	-6	
	50/50	-1.4	-14.3	-10.3	
	35/65	-2.2	-19	-12	
	25/75	-2.8	-21	-13.3	
	0/100	-6.5	-24.3	-18.7	
Cottonseed oil methyl esters /Field pennycress oil methyl esters	100/0	5.6	5	6.3	15
	75/25	1.4	2.7	2.3	
	65/35	-0.4	-1.7	1.3	
	50/50	-0.9	-5	-1.7	
	35/65	-6.9	-9.3	-6	
	25/75	-8.5	-12.3	-9	
	0/100	-6.5	-24.3	-18.7	
Palm oil methyl esters /Field pennycress oil methyl esters	100/0	15.3	14	12.3	15
	75/25	9.1	10.3	9	
	65/35	7.2	8	7.7	
	50/50	2.9	4	4.3	
	35/65	2.2	-0.7	2.7	
	25/75	0.5	-6.3	-2.7	
	0/100	-6.5	-24.3	-18.7	
Soybean methyl esters /Field pennycress oil methyl esters	100/0	0	-1	-3	15

Components	Blending ratio	CP/°C	PP/°C	CFPP/°C	Refs
Biodiesel/Biodiesel					
	75/25	-2.4	-4.3	-6	
	65/35	-3.6	-6	-7	
	50/50	-5.4	-9	-10	
	35/65	-6	-13.7	-14	
	25/75	-5.9	-17.3	-17	
	0/100	-6.5	-24.3	-18.7	
Camelina oil methyl esters /Meadowfoam oil methyl esters	100/0	4.1	0	0	15
	75/25	1.5	-6.3	-4	
	65/35	0.4	-5	-3.7	
	50/50	-1.6	-7.7	-5.7	
	35/65	-4.1	-8.7	-6.7	
	25/75	-5.4	-9	-7.7	
	0/100	-6.6	-10	-10	
Cottonseed oil methyl esters /Meadowfoam oil methyl esters	100/0	5.6	5	6.3	15
	75/25	1.3	-1	2	
	65/35	-0.1	-2	-0.7	
	50/50	-2.4	-5	-6	
	35/65	-4.1	-8.7	-6.7	
	25/75	-5	-13	-8	
	0/100	-6.6	-10	-10	
Palm oil methyl esters /Meadowfoam oil methyl esters	100/0	15.3	14	12.3	15
	75/25	9.2	9.3	8.7	
	65/35	7.3	7.7	6.3	
	50/50	3.7	2.3	2	
	35/65	0.6	-2	-3.3	
	25/75	-1.1	-6.3	-4.7	
	0/100	-6.6	-10	-10	
Soybean oil methyl esters /Meadowfoam oil methyl esters	100/0	0.4	-1	-3	15
	75/25	-2.1	-4	-5.7	
	65/35	-3.4	-5	-6.7	
	50/50	-5.2	-5.7	-9.7	
	35/65	-6.9	-6.3	-9	
	25/75	-7.2	-8.7	-10	
	0/100	-6.6	-10	-10	
Other type					
Mahua methyl ester/Ethanol	100/0	17.7	7		16
	0/100				
	95/5	14.9	2.4		
	90/10	14.3	-1.2		
	85/15	12.1	-3.5		
	80/20	8.3	-4		
(80%Soybean/20%Palm oil methyl esters)/N-butanol	100/0	2.1	0	-1	17
	0/100	<-115.5	<-120.7	<-51	
	97.5/2.5	1.7	-1	-2	
	95/5	1	-1	-2	
	90/10	0.4	-2	-3	

Components	Blending ratio	CP/°C	PP/°C	CFPP/°C	Refs
	80/20	-0.7	-2	-4	
	60/40	-2.8	-4	-5	
	40/60	/	-7	/	
	25/75	-7.4	-62	-9	
	10/90	/	/	-18	
	5/95	-21.6	-97	-24	
(80%soybean/20%palm oil methyl esters)/Ethanol	100/0	2.1	0	-1	[17]
	0/100	<-120.7	<-120.7	<-51	
	97.5/2.5	1.8	-1	-2	
	95/5	1.3	-1	-2	
	90/10	0.8	-2	-3	
	80/20	0.2	-2	-4	
	60/40	-0.4	-3	-5	
	40/60	/	/	/	
	25/75	-2.2	-7	-6	
	10/90	/	/	-12	
	5/95	-13.5	-72	-18	
Biodiesel/petro-diesel					
Meadowfoam seed oil methyl esters/Ultra low sulfur diesel	100/0	-6	-10	-9	[18]
	0/100	-18	-23	-17	
	2/98	-18	-23	-17	
	5/95	-17	-22	-16	
	10/90	-16	-22	-17	
	20/80	-16	-22	-17	
Safflower oil methyl ester /Euro diesel	100/0	-5	-14	-9	[19]
	0/100	-10	-32	-17	
	90/10	-6	-15	-10	
	80/20	-6	-17	-10	
	70/30	-7	-19	-11	
	60/40	-7	-20	-12	
	50/50	-8	-22	-12	
	40/60	-8	-24	-13	
	30/70	-9	-26	-14	
	20/80	-9	-28	-15	
	10/90	-10	-30	-16	
Tallow methyl esters /Petroleum diesel	100/0			10	[20]
	0/100			-5	
	20/80			-10	
Lard methyl esters/Petroleum diesel	100/0			5	
	0/100			-5	
	20/80			-6	
Poultry fat methyl esters /Petroleum diesel	100/0			3	
	0/100			-5	
	20/80			-8	
Hazelnut oil methyl esters/Ultra-low-sulfur diesel	100/0	-9.3	-13.0	-12.7	[21]
	0/100	-14.9	-24.3	-19.7	
	20/80	-13.4	-21.7	-16.7	

Components	Blending ratio	CP/°C	PP/°C	CFPP/°C	Refs
	10/90	-13.8	-23.3	-17	
	5/95	-14.2	-24.3	-17.3	
	2/98	-14.6	-24.3	-18	
Peanut oil methyl esters/Ultra-low-sulfur diesel	100/0	17.8	15.0	16.0	
	0/100	-14.9	-24.3	-19.7	
	20/80	-2.3	-17	-3	
	10/90	-7.4	-19	-9.7	
	5/95	-11.2	-21.3	-13.7	
	2/98	-14.4	-22.7	-16	
Walnut oil methyl esters/Ultra-low-sulfur diesel	100/0	-6.1	-10.0	-9.0	
	0/100	-14.9	-24.3	-19.7	
	20/80	-13.5	-21	-16.3	
	10/90	-14.3	-22.7	-16.7	
	5/95	-14.3	-24	-17.3	
	2/98	-14.6	-24	-19	
Mahua oil methyl esters /Mineral diesel	100/0	12	6	-8	22
	0/100	1	-8	-5	
	90/10	12	5	7	
	80/20	11	3	5	
	70/30	9	2	4	
	60/40	8	0	3	
	50/50	7	-1	2	
	40/60	6	-2	1	
	30/70	5	-4	-3	
	20/80	3	-5	-4	
	10/90	2	-7	-5	
Dairy washed milk-scum biodiesel/Ethyl acetoacetate	100/0	17	10	17	23
	95/5	14	8	14	
	90/10	13	7	12	
	85/15	9	6	7	
	80/20	8	6	7	
Dairy washed milk-scum biodiesel/ Ethyl Levulinate	100/0	17	10	17	23
	95/5	14	9	13	
	90/10	13	7	13	
	85/15	10	6	9	
	80/20	8	4	7	

CP: cloud point; PP: pour point; CFPP: cold filter plugging point.

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