

## Room temperature esterification of high-free fatty acid feedstock into biodiesel

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**Table 1.** ANOVA and Tukey post hoc test for biodiesel conversion of the homogenizer-intensified the esterification of oleic acid to biodiesel.

### Effect of ratio molar

Effect	Univariate Tests of Significance for Conversion (Spreadsheet2) Sigma-restricted parameterization Effective hypothesis decomposition				
	SS	Degr. of Freedom	MS	F	p
Intercept	197705.2	1	197705.2	234963.7	0.000000
Ratio Molar	2435.5	2	1217.8	1447.3	0.000000
Reaction Time	5068.8	6	844.8	1004.0	0.000000
Ratio Molar*Reaction Time	115.3	12	9.6	11.4	0.000001
Error	17.7	21	0.8		

Tukey HSD test: variable Conversion (Spreadsheet2)																									
Approximate Probabilities for Post Hoc Tests																									
Error: Between MS = .84143, df = 21.000																									
Cell No.	Ratio Molar	Reaction Time	{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}	{9}	{10}	{11}	{12}	{13}	{14}	{15}	{16}	{17}	{18}	{19}	{20}	{21}		
1	1:6	5		0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190		
2	1:6	15	0.000190		0.000198	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	
3	1:6	30	0.000190	0.000198		0.000194	0.000190	0.000190	0.000190	0.000190	1.000000	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	
4	1:6	45	0.000190	0.000190	0.000194		0.385158	0.016731	0.033132	0.000190	0.000197	0.001009	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	
5	1:6	60	0.000190	0.000190	0.000190	0.385158		0.968350	0.968350	0.996441	0.000190	0.000190	0.303706	0.000195	0.000190	0.000190	0.000190	0.000190	0.000214	1.000000	0.000190	0.000190	0.000190	0.000190	
6	1:6	75	0.000190	0.000190	0.000190	0.016731	0.968350		1.000000	0.000190	0.000190	0.996441	0.000529	0.000190	0.000190	0.000190	0.000190	0.000191	0.896965	0.000190	0.000190	0.000190	0.000190	0.000190	
7	1:6	90	0.000190	0.000190	0.000190	0.033132	0.996441	1.000000		0.000190	0.000190	0.968350	0.000349	0.000190	0.000190	0.000190	0.000191	0.976469	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	
8	1:9	5	0.000190	0.001907	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190		0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	
9	1:9	15	0.000190	0.000195	1.000000	0.000197	0.000190	0.000190	0.000190	0.000190	0.000190		0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	
10	1:9	30	0.000190	0.000190	0.000190	0.001009	0.303706	0.996441	0.968350	0.000190	0.000190		0.007445	0.000197	0.000190	0.000190	0.000190	0.000190	0.195468	0.000191	0.000190	0.000190	0.000190	0.000190	
11	1:9	45	0.000190	0.000190	0.000190	0.000190	0.000195	0.000529	0.000349	0.000190	0.000190	0.007445		0.356697	0.003325	0.029601	0.000190	0.000193	0.108654	0.000489	0.000190	0.000190	0.000190	0.000190	
12	1:9	60	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000197	0.356697		0.676935	0.996441	0.000190	0.000190	1.000000	0.161766	0.000237	0.000190	0.000190	0.000197	
13	1:9	75	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.003325	0.676935		0.999898	0.000190	0.000190	0.968350	0.999898	0.011834	0.000202	0.002373	0.002373	
14	1:9	90	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.029601	0.996441	0.999898		0.000190	0.000190	1.000000	0.852747	0.001374	0.000191	0.000395	0.000395	
15	1:12	5	0.000190	0.000190	0.132935	0.018767	0.000214	0.000191	0.000191	0.000190	0.177971	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000237	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190
16	1:12	15	0.000190	0.000190	0.000190	0.543286	1.000000	0.896965	0.976469	0.000190	0.000190	0.195468	0.000193	0.000190	0.000190	0.000190	0.000190	0.000237		0.000190	0.000190	0.000190	0.000190	0.000190	0.000190
17	1:12	30	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000191	0.108654	1.000000	0.968350	1.000000	0.000190	0.000190		0.477422	0.000454	0.000190	0.000231	0.000231	
18	1:12	45	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000489	0.161766	0.999898	0.852747	0.000190	0.000190	0.477422		0.098040	0.000349	0.356697	0.999999	
19	1:12	60	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000237	0.011834	0.001374	0.000190	0.000190	0.000190	0.000454	0.098040		0.356697	0.999999	0.999999	
20	1:12	75	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000202	0.000191	0.000190	0.000190	0.000190	0.000190	0.000349	0.356697		0.800270	0.800270	
21	1:12	90	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000197	0.002373	0.000395	0.000190	0.000190	0.000231	0.021045	0.999999	0.800270		0.800270	

### Effect of catalyst concentration

Effect	Univariate Tests of Significance for Conversion (%) (Spreadsheet8)				
	SS	Degr. of Freedom	MS	F	p
Intercept	444136.4	1	444136.4	229986.3	0.000000
Catalyst Concentration	6514.7	4	1628.7	843.4	0.000000
Reaction Time	7427.8	6	1238.0	641.1	0.000000
Catalyst Concentration*Reaction Time	334.8	24	14.0	7.2	0.000000
Error	67.6	35	1.9		

Tukey HSD test; variable Conversion (%) (Spreadsheet)			Approximate Probabilities for Post Hoc Tests Error: Between MS = 1.0311, df = 35.000																																			
Cell No.	Catalyst Concentration	Reaction Time	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	
			37.700	50.800	62.900	70.150	74.250	76.400	75.350	60.800	69.300	78.300	80.800	85.350	87.150	87.400	51.600	68.100	77.100	81.900	84.500	86.850	85.300	71.000	80.350	88.100	91.600	94.350	95.400	96.550	73.350	85.950	91.350	94.700	96.850	97.950	98.300	
1	0.1	5	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167

# Effect of rotational speed

Effect	Univariate Tests of Significance for Conversion (%) (Spreadsheet11) Sigma-restricted parameterization Effective hypothesis decomposition				
	SS	Degr. of Freedom	MS	F	p
Intercept	336681.1	1	336681.1	217080.3	0.00000
Rotational Speed	154.5	2	77.2	49.8	0.00000
Reaction Time	3724.3	6	620.7	400.2	0.00000
Rotational Speed*Reaction Time	63.7	12	5.3	3.4	0.00667
Error	32.6	21	1.6		

Tukey HSD test: variable Conversion (%) (Spreadsheet11)																							
Approximate Probabilities for Post Hoc Tests																							
Error: Between MS = 1.5510, df = 21.000																							
Cell No.	Rotational Speed	Reaction Time	{1} 64.000	{2} 77.800	{3} 86.850	{4} 91.850	{5} 94.550	{6} 95.850	{7} 96.850	{8} 73.350	{9} 83.900	{10} 91.350	{11} 94.700	{12} 96.950	{13} 97.950	{14} 98.300	{15} 73.550	{16} 83.350	{17} 91.150	{18} 95.000	{19} 96.850	{20} 97.750	{21} 98.300
1	3000	5		0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000209	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000202	0.000190	0.000190	0.000190	0.000190	0.000190	
2	3000	15	0.000190		0.000224	0.000190	0.000190	0.000190	0.000190	0.125783	0.008494	0.000190	0.000190	0.000190	0.000190	0.000190	0.167971	0.021634	0.000190	0.000190	0.000190	0.000190	
3	3000	30	0.000190	0.000224		0.053659	0.000663	0.000228	0.000195	0.000190	0.694671	0.116786	0.000545	0.000194	0.000191	0.000190	0.428413	0.156406	0.000393	0.000195	0.000191	0.000190	
4	3000	45	0.000190	0.000190	0.053659		0.806563	0.236097	0.053659	0.000190	0.000485	1.000000	0.741494	0.045645	0.008494	0.004675	0.000190	0.000296	1.000000	0.596744	0.053659	0.011952	
5	3000	60	0.000190	0.000190	0.000663	0.806563		0.999886	0.933939	0.000190	0.000191	0.572014	1.000000	0.909310	0.474655	0.323148	0.000190	0.000191	0.474655	1.000000	0.933939	0.572014	
6	3000	75	0.000190	0.000190	0.000228	0.236097	0.999886		0.999998	0.000190	0.000190	0.116786	0.999981	0.968927	0.895136	0.000190	0.000190	0.086191	1.000000	0.999998	0.987972	0.895136	
7	3000	90	0.000190	0.000190	0.000195	0.053659	0.933939	0.999998		0.000190	0.000190	0.023531	0.961855	1.000000	0.999991	0.999492	0.000190	0.000190	0.016793	0.990855	1.000000	0.999492	
8	4000	5	0.000209	0.125783	0.000190	0.000190	0.000190	0.000190	0.000190		0.000192	0.000190	0.000190	0.000190	0.000190	0.000190	1.000000	0.000195	0.000190	0.000190	0.000190	0.000190	
9	4000	15	0.000190	0.008494	0.694671	0.000485	0.000191	0.000190	0.000190	0.000192		0.000937	0.000191	0.000190	0.000190	0.000190	0.000192	1.000000	0.001262	0.000191	0.000190	0.000190	
10	4000	30	0.000190	0.000190	0.116786	1.000000	0.572014	0.116786	0.023531	0.000190	0.000937		0.498471	0.019886	0.003632	0.002039	0.000190	0.000459	1.000000	0.363158	0.023531	0.005088	
11	4000	45	0.000190	0.000190	0.000545	0.741494	1.000000	0.999981	0.961855	0.000190	0.000191	0.498471		0.944412	0.547395	0.384214	0.000190	0.000191	0.406114	1.000000	0.961855	0.646124	
12	4000	60	0.000190	0.000190	0.000194	0.045645	0.909310	0.999991	1.000000	0.000190	0.000190	0.019886	0.944412		0.999998	0.999807	0.000190	0.000190	0.014171	0.984432	1.000000	0.999807	
13	4000	75	0.000190	0.000190	0.000191	0.008494	0.474655	0.968927	0.999991	0.000190	0.000190	0.003632	0.547395	0.999998		1.000000	0.000190	0.000190	0.002602	0.694671	0.999991	1.000000	
14	4000	90	0.000190	0.000190	0.000190	0.004675	0.323148	0.895136	0.999492	0.000190	0.000190	0.002039	0.384214	0.999807	1.000000		0.000190	0.000190	0.001479	0.522654	0.999492	1.000000	
15	5000	5	0.000202	0.167971	0.000190	0.000190	0.000190	0.000190	0.000190	1.000000	0.000192	0.000190	0.000190	0.000190	0.000190	0.000190	0.000190	0.000197	0.000190	0.000190	0.000190	0.000190	
16	5000	15	0.000190	0.021634	0.428413	0.000296	0.000191	0.000190	0.000190	0.000195	1.000000	0.000459	0.000191	0.000190	0.000190	0.000190	0.000197		0.000580	0.000190	0.000190	0.000190	
17	5000	30	0.000190	0.000190	0.156406	1.000000	0.474655	0.086191	0.016793	0.000190	0.001262	1.000000	0.406114	0.014171	0.002602	0.001479	0.000190	0.000580		0.286094	0.016793	0.003632	
18	5000	45	0.000190	0.000190	0.000393	0.596744	1.000000	1.000000	0.990855	0.000190	0.000191	0.363158	1.000000	0.984432	0.694671	0.522654	0.000190	0.000190	0.286094		0.990855	0.522654	
19	5000	60	0.000190	0.000190	0.000195	0.053659	0.933939	0.999998	1.000000	0.000190	0.000190	0.023531	0.961855	1.000000	0.999991	0.999492	0.000190	0.000190	0.016793	0.990855		0.999492	
20	5000	75	0.000190	0.000190	0.000191	0.011952	0.572014	0.987972	1.000000	0.000190	0.000190	0.005088	0.646124	1.000000	1.000000	1.000000	0.000190	0.000190	0.003632	0.785699	1.000000	1.000000	
21	5000	90	0.000190	0.000190	0.000190	0.004675	0.323148	0.895136	0.999492	0.000190	0.000190	0.002039	0.384214	0.999807	1.000000	1.000000	0.000190	0.000190	0.001479	0.522654	0.999492	1.000000	