

**APPENDIX-D**  
**EXPERIMENTAL DATA AND RESULT**

**Table D1: Effect of mixing time on the yield of biodiesel production at the reactor**

<b>RPM</b>	<b>Reaction Time</b>	<b>Soybean Oil (Yield %)</b>	<b>Waste Soybean Oil (Yield %)</b>	<b>Mustard Oil (Yield %)</b>	<b>Palm Oil (Yield %)</b>
450	20	75.98	75.46	71.81	73.21
	30	80.65	81.54	76.23	75.67
	40	79.95	80.12	75.46	75.17
	50	78.23	77.53	74.98	75.08
	60	78.11	80.87	74.56	74.96
500	20	83.78	82.52	75.56	83.23
	30	86.67	86.16	78.26	86.65
	40	87.56	86.37	77.56	85.96
	50	86.45	84.23	77.89	84.56
	60	86.35	88.16	77.45	84.81
550	20	93.94	89.78	85.56	89.25
	30	97.46	92.57	88.96	89.93
	40	96.94	92.83	87.54	88.26
	50	95.86	90.56	87.23	88.93
	60	95.97	92.45	87.11	89.06
600	20	90.56	90.45	93.45	94.76
	30	92.93	93.47	95.65	96.95
	40	92.46	94.47	95.11	95.51
	50	91.93	91.34	94.96	94.66
	60	91.23	90.78	94.57	94.51
650	20	82.46	86.89	87.24	90.96
	30	86.13	87.52	90.96	91.96
	40	85.56	89.32	89.53	90.13
	50	84.45	88.26	89.89	89.63
	60	84.76	87.12	88.98	89.28

**Table D2: Effect of stirring velocity on the yield biodiesel production at the reactor**

<b>Reaction Time</b>	<b>RPM</b>	<b>Soybean Oil (Yield %)</b>	<b>Waste Soybean Oil (Yield %)</b>	<b>Mustard Oil (Yield %)</b>	<b>Palm Oil (Yield %)</b>
20	450	75.98	75.46	71.81	73.21
	500	83.78	82.52	75.56	83.23
	550	93.94	89.78	85.56	89.25
	600	90.56	90.45	93.45	94.76
	650	82.46	86.89	87.24	90.96
30	450	80.65	81.54	76.23	75.67
	500	86.67	86.16	78.26	86.65
	550	97.46	92.57	88.96	89.93
	600	92.93	93.47	95.65	96.95
	650	86.13	87.52	90.96	91.96
40	450	79.95	80.12	75.46	75.17
	500	87.56	86.37	77.56	85.96
	550	96.94	92.83	87.54	88.26
	600	92.46	94.47	95.11	95.51
	650	85.56	89.32	89.53	90.13
50	450	78.23	77.53	74.98	75.08
	500	86.45	84.23	77.89	84.56
	550	95.86	90.56	87.23	88.93
	600	91.93	91.34	94.96	94.66
	650	84.45	88.26	89.89	89.63
60	450	78.11	80.87	74.56	74.96
	500	86.35	88.16	77.45	84.81
	550	95.97	92.45	87.11	89.06
	600	91.23	90.78	94.57	94.51
	650	84.76	87.12	88.98	89.28

**Table D3: Oil property data for pure diesel**

Temperature ( °C )	Kinematic Viscosity (mm <sup>2</sup> /sec)	Density (Kg/ m <sup>3</sup> )	Flash point ( °C )	Calorific value (MJ/kg)
30	3.32	832.80	65	46.8
40	3.02	811.78		
50	2.73	792.42		
60	2.41	771.60		

**Table D4: Oil property data for biodiesel made from soybean oil**

Blend	Temperature ( °C )	Kinematic Viscosity (mm <sup>2</sup> /sec)	Density (Kg/ m <sup>3</sup> )	Flash point (°C)	Calorific value (MJ/kg)
S100	30	6.51	871.32	92	39.93
	40	6.17	846.38		
	50	5.83	824.24		
	60	5.38	804.18		
S80	30	6.11	863.46	82	41.09
	40	5.84	838.60		
	50	5.46	814.65		
	60	5.02	788.34		
S60	30	5.43	855.60	81	42.24
	40	5.11	824.40		
	50	4.85	794.98		
	60	4.55	775.43		
S40	30	4.88	847.45	78	43.2
	40	4.57	823.38		
	50	4.14	791.42		
	60	3.86	770.60		
S20	30	4.23	839.80	73	44.5
	40	3.97	819.78		
	50	3.68	795.42		
	60	3.13	767.60		

**Table D5: Oil property data for biodiesel made from waste soybean oil**

<b>Blend</b>	<b>Temperature ( °C)</b>	<b>Kinematic Viscosity (mm<sup>2</sup>/sec)</b>	<b>Density (Kg/ m<sup>3</sup>)</b>	<b>Flash point (°C)</b>	<b>Calorific value (MJ/kg)</b>
B100	30	6.71	905.40	113	39.43
	40	6.34	871.11		
	50	5.83	833.24		
	60	5.45	809.18		
B80	30	6.23	873.49	103	40.27
	40	5.84	844.62		
	50	5.46	813.24		
	60	5.04	792.29		
B60	30	5.77	859.65	95	41.36
	40	5.47	837.69		
	50	4.89	801.45		
	60	4.20	781.49		
B40	30	5.25	853.45	84	42.89
	40	4.97	829.38		
	50	4.34	799.42		
	60	3.96	784.60		
B20	30	4.62	841.91	77	43.56
	40	4.11	826.14		
	50	3.77	805.42		
	60	3.25	787.60		

**Table D6: Oil property data for biodiesel made from palm oil**

<b>Blend</b>	<b>Temperature ( ° C )</b>	<b>Kinematic Viscosity (mm<sup>2</sup>/sec)</b>	<b>Density (Kg/ m<sup>3</sup> )</b>	<b>Flash point ( °C)</b>	<b>Calorific value (MJ/kg)</b>
P100	30	4.87	901.63	262	39.81
	40	4.53	881.06		
	50	4.46	867.45		
	60	4.33	839.86		
P80	30	4.42	893.06	213	40.23
	40	4.22	869.71		
	50	4.16	842.47		
	60	4.02	814.32		
P60	30	4.12	887.30	183	41.59
	40	3.97	855.87		
	50	3.84	828.57		
	60	3.69	803.37		
P40	30	3.85	878.87	162	42.05
	40	3.67	846.35		
	50	3.38	817.28		
	60	3.11	793.11		
P20	30	3.54	859.00	123	43.46
	40	3.32	832.34		
	50	3.03	805.44		
	60	2.91	786.37		

**Table D7: Oil property data for biodiesel made from mustard oil**

Blend	Temperature (°C)	Kinematic Viscosity (mm <sup>2</sup> /sec)	Density (Kg/ m <sup>3</sup> )	Flash point (°C)	Calorific value (MJ/kg)
M100	30	6.57	924.83	122	33.53
	40	5.90	912.56		
	50	5.11	894.45		
	60	4.25	872.89		
M80	30	6.17	900.56	113	35.4
	40	5.56	876.38		
	50	4.92	854.24		
	60	4.11	832.18		
M60	30	5.96	883.84	105	37.5
	40	5.36	848.40		
	50	4.77	814.98		
	60	4.20	785.43		
M40	30	5.11	866.14	92	39.3
	40	4.69	837.24		
	50	4.21	809.46		
	60	3.95	777.12		
M20	30	4.65	851.34	85	41.2
	40	4.12	821.67		
	50	3.69	803.23		
	60	3.37	775.42		

**Table D8: Engine performance data for pure diesel**

Fuel type: Diesel					
Engine speed, (rpm)	BHP (kW)	HP	bsfc (g/kwhr)	Thermal Efficiency (%)	Exhaust Gas Temperature (°C)
1800	0.82	1.10	347.08	33.56	111
2000	0.94	1.27	349.76	34.55	124
2200	1.05	1.41	350.67	34.46	140
2400	1.19	1.59	336.57	35.91	156
2600	1.36	1.83	327.14	36.94	171

**Table D9: Engine performance data for biodiesel made from soybean oil**

<b>Fuel type: Soybean oil</b>						
<b>Blend</b>	<b>Engine speed, (rpm)</b>	<b>BHP (kW)</b>	<b>HP</b>	<b>bsfc (g/ kwhr)</b>	<b>Thermal Efficiency (%)</b>	<b>Exhaust Gas Temperature ( °C )</b>
S100	1800	0.61	0.82	424.21	25.28	116
	2000	0.69	0.92	395.42	27.12	132
	2200	0.80	1.07	359.12	29.71	145
	2400	0.93	1.25	328.38	32.66	155
	2600	1.00	1.34	327.89	32.71	172
S80	1800	0.66	0.89	390.27	28.28	110
	2000	0.73	0.97	384.85	28.67	129
	2200	0.87	1.16	338.05	32.64	137
	2400	0.99	1.33	311.06	35.48	155
	2600	1.06	1.42	306.07	36.05	170
S60	1800	0.69	0.92	366.65	30.94	109
	2000	0.84	1.12	324.81	34.93	127
	2200	0.94	1.26	327.63	34.62	146
	2400	1.15	1.54	310.52	35.93	161
	2600	1.23	1.66	310.57	35.57	167
S40	1800	0.75	1.00	363.65	31.36	115
	2000	0.89	1.15	345.81	31.51	122
	2200	0.99	1.30	338.63	33.14	130
	2400	1.16	1.59	330.52	35.78	146
	2600	1.25	1.67	331.57	35.16	163
S20	1800	0.86	1.05	334.23	32.25	117
	2000	0.93	1.23	343.37	33.57	125
	2200	1.03	1.36	358.67	34.46	145
	2400	1.21	1.69	343.97	35.24	161
	2600	1.29	1.76	335.89	36.11	173

**Table D10: Engine performance data for biodiesel made from waste soybean oil**

<b>Fuel type: Waste Soybean Oil</b>						
<b>Blend</b>	<b>Engine speed, (rpm)</b>	<b>BHP (kW)</b>	<b>HP</b>	<b>bsfc (g/kwhr)</b>	<b>Thermal Efficiency (%)</b>	<b>Exhaust Gas Temperature ( °C )</b>
B100	1800	0.64	0.78	400.25	25.47	118
	2000	0.76	0.89	367.48	26.19	133
	2200	0.87	1.01	346.80	28.35	147
	2400	0.94	1.28	321.83	31.04	156
	2600	1.12	1.35	315.13	32.78	174
B80	1800	0.67	0.83	381.07	28.01	113
	2000	0.76	0.94	372.26	28.82	131
	2200	0.89	1.13	345.06	31.39	138
	2400	1.02	1.09	324.25	33.96	158
	2600	1.14	1.20	307.09	34.52	173
B60	1800	0.75	0.85	366.65	29.94	112
	2000	0.89	1.07	354.81	31.86	129
	2200	0.99	1.17	327.63	32.14	148
	2400	1.15	1.46	317.51	34.33	164
	2600	1.21	1.61	310.57	35.16	170
B40	1800	0.79	1.14	355.52	30.21	115
	2000	0.93	1.19	341.85	31.86	126
	2200	1.07	1.38	332.43	32.84	135
	2400	1.19	1.46	324.52	33.98	153
	2600	1.29	1.55	317.49	35.49	169
B20	1800	0.77	1.15	344.31	31.55	123
	2000	0.91	1.33	333.35	32.53	129
	2200	1.10	1.46	328.70	34.26	147
	2400	1.24	1.69	313.76	35.07	167
	2600	1.35	1.79	305.29	35.99	175



**Table D11: Engine performance data for biodiesel made from palm oil**

<b>Fuel type: Palm oil</b>						
<b>Blend</b>	<b>Engine speed (rpm)</b>	<b>BHP (kW)</b>	<b>HP</b>	<b>bsfc (g/kwhr)</b>	<b>Thermal Efficiency (%)</b>	<b>Exhaust Gas Temperature ( °C )</b>
P100	1800	0.60	0.81	435.18	25.49	107
	2000	0.70	0.93	389.77	28.46	116
	2200	0.88	1.18	336.89	32.92	125
	2400	1.03	1.38	315.74	35.13	139
	2600	1.12	1.51	322.51	34.39	150
P80	1800	0.63	0.85	407.49	27.98	105
	2000	0.70	0.93	393.63	32.53	119
	2200	0.92	1.23	357.93	35.87	129
	2400	1.08	1.44	333.94	35.15	141
	2600	1.16	1.56	325.98	34.98	157
P60	1800	0.67	0.90	388.86	30.05	105
	2000	0.76	1.01	359.00	32.55	117
	2200	0.95	1.28	321.05	36.40	128
	2400	1.11	1.49	327.87	35.64	132
	2600	1.20	1.61	322.51	36.23	156
P40	1800	0.81	0.97	355.56	32.98	110
	2000	0.92	1.08	341.85	33.35	119
	2200	1.09	1.33	333.36	35.25	139
	2400	1.19	1.46	325.89	35.94	153
	2600	1.27	1.51	318.92	35.88	164
P20	1800	0.72	1.06	359.34	34.56	121
	2000	0.84	1.17	351.45	34.98	126
	2200	1.05	1.30	344.12	35.67	132
	2400	1.29	1.49	330.67	36.26	147
	2600	1.35	1.58	322.36	36.12	159

**Table D12: Engine performance data for biodiesel made from mustard oil**

<b>Fuel type: Mustard Oil</b>						
<b>Blend</b>	<b>Engine speed, N (rpm)</b>	<b>BHP (kW)</b>	<b>HP</b>	<b>bsfc (g/kwhr)</b>	<b>Thermal efficiency (%)</b>	<b>Exhaust Gas Temperature ( °C)</b>
M100	1800	0.66	0.89	394.34	29.63	125
	2000	0.74	0.99	368.70	31.69	132
	2200	0.89	1.19	338.78	34.48	135
	2400	1.05	1.41	321.22	36.37	146
	2600	1.21	1.62	323.62	36.10	161
M80	1800	0.71	0.95	375.99	32.10	119
	2000	0.83	1.11	354.76	34.02	125
	2200	0.96	1.29	345.24	34.96	135
	2400	1.14	1.53	339.78	35.52	152
	2600	1.26	1.69	338.48	35.66	168
M60	1800	0.74	0.99	358.06	33.29	119
	2000	0.86	1.16	332.24	35.88	127
	2200	1.01	1.35	324.90	36.69	134
	2400	1.24	1.66	328.35	36.30	141
	2600	1.35	1.81	334.46	35.64	163
M40	1800	0.71	0.93	335.1303	32.96	109
	2000	0.85	1.01	341.8835	33.89	118
	2200	1.09	1.20	344.6677	34.52	133
	2400	1.23	1.43	347.5723	35.07	147
	2600	1.32	1.57	347.1371	36.23	161
M20	1800	0.77	0.97	338.178	33.56	115
	2000	0.89	1.14	343.3579	34.59	130
	2200	1.12	1.36	350.6677	34.97	144
	2400	1.32	1.63	344.5723	35.89	157
	2600	1.42	1.83	337.1371	36.23	166

**Table D13: Engine emission data for pure diesel**

<b>Fuel type: Diesel</b>						
<b>Speed (rpm)</b>	<b>CO (ppm)</b>	<b>CO<sub>2</sub> (%)</b>	<b>O<sub>2</sub> (%)</b>	<b>NO<sub>x</sub> (ppm)</b>	<b>SO<sub>2</sub> (ppm)</b>	<b>HC (ppm)</b>
1800	420	4.94	18.21	57	12.69	71
2000	425	5.27	19.63	72	12.55	65
2200	417	5.35	20.16	91	12.44	57
2400	420	5.56	20.94	105	12.39	49
2600	423	5.83	21.58	114	12.35	41

**Table D14: Engine emission data for biodiesel made from soybean oil**

<b>Fuel type: Soybean Oil</b>							
<b>Blend</b>	<b>Speed (rpm)</b>	<b>CO (ppm)</b>	<b>CO<sub>2</sub> (%)</b>	<b>O<sub>2</sub> (%)</b>	<b>NO<sub>x</sub> (ppm)</b>	<b>SO<sub>2</sub> (ppm)</b>	<b>HC (ppm)</b>
S100	1800	391	5.27	19.23	37	12.01	65
	2000	386	5.54	20.68	42	11.92	53
	2200	392	5.71	21.52	45	11.86	47
	2400	394	5.92	22.21	49	11.79	43
	2600	397	6.11	22.96	52	11.74	35
S80	1800	395	5.13	20.43	40	11.89	63
	2000	383	5.32	20.85	46	11.93	55
	2200	386	5.59	21.56	51	11.99	44
	2400	390	5.73	22.49	54	12.06	40
	2600	388	5.95	22.02	57	12.13	33
S60	1800	397	4.91	19.56	49	12.01	69
	2000	402	5.14	19.84	56	12.17	59
	2200	404	5.39	20.53	62	12.21	53
	2400	400	5.52	21.34	59	12.23	47
	2600	402	5.78	21.87	61	12.27	41
S40	1800	411	4.83	18.54	47	12.46	73
	2000	402	4.96	19.42	62	12.33	61
	2200	395	5.06	20.78	73	12.26	55
	2400	398	5.25	21.46	77	12.15	46
	2600	400	5.33	21.99	84	12.13	44
S20	1800	403	4.89	18.08	54	12.51	76
	2000	397	5.07	19.32	65	12.46	64
	2200	401	5.26	19.95	86	12.37	57
	2400	405	5.39	20.34	98	12.34	52
	2600	407	5.56	21.06	111	12.29	49

**Table D15: Engine emission data for biodiesel made from waste soybean oil**

<b>Fuel type: Waste Soybean Oil</b>							
<b>Blend</b>	<b>Speed (rpm)</b>	<b>CO (ppm)</b>	<b>CO<sub>2</sub> (%)</b>	<b>O<sub>2</sub> (%)</b>	<b>NO<sub>x</sub> (ppm)</b>	<b>SO<sub>2</sub> (ppm)</b>	<b>HC (ppm)</b>
B100	1800	409	5.34	20.12	40	12.06	67
	2000	401	5.59	20.46	44	11.99	57
	2200	396	5.77	20.97	47	11.88	45
	2400	391	6.01	21.34	50	11.91	39
	2600	394	6.13	21.98	53	11.95	32
B80	1800	401	5.18	20.23	42	11.93	67
	2000	396	5.36	20.67	44	11.88	61
	2200	390	5.68	21.11	49	11.92	51
	2400	386	5.77	21.67	52	12.01	42
	2600	391	6.01	21.98	58	12.11	36
B60	1800	408	5.03	19.95	50	12.19	65
	2000	407	5.2	19.98	53	12.13	60
	2200	400	5.45	20.41	56	12.21	53
	2400	401	5.57	20.59	63	12.24	50
	2600	400	5.83	21.11	71	12.31	48
B40	1800	423	4.92	19.13	56	12.53	71
	2000	414	5.06	19.32	59	12.41	62
	2200	411	5.16	20.23	74	12.34	54
	2400	408	5.34	20.76	83	12.21	49
	2600	405	5.40	21.14	98	12.11	41
B20	1800	414	5.01	19.34	58	12.59	69
	2000	409	5.17	19.68	69	12.42	63
	2200	407	5.29	20.33	89	12.31	58
	2400	408	5.49	20.78	100	12.27	51
	2600	407	5.61	21.23	113	12.19	44

**Table D16: Engine emission data for biodiesel made from palm oil**

<b>Fuel type: Palm Oil</b>							
<b>Blend</b>	<b>Speed (rpm)</b>	<b>CO (ppm)</b>	<b>CO<sub>2</sub> (%)</b>	<b>O<sub>2</sub> (%)</b>	<b>NO<sub>x</sub> (ppm)</b>	<b>SO<sub>2</sub> (ppm)</b>	<b>HC (ppm)</b>
P100	1800	404	5.27	19.56	49	11.83	64
	2000	398	5.33	19.94	56	11.79	56
	2200	391	5.41	20.26	69	11.73	41
	2400	389	5.49	20.53	73	11.64	35
	2600	385	5.57	20.81	81	11.69	26
P80	1800	394	4.87	19.27	47	11.74	59
	2000	390	5.01	19.38	58	11.61	54
	2200	387	5.21	19.56	69	11.69	46
	2400	386	5.36	19.73	78	11.75	34
	2600	392	5.43	19.92	89	11.79	27
P60	1800	406	4.89	18.52	53	12.35	57
	2000	401	4.83	18.91	59	12.24	50
	2200	403	4.99	19.28	64	12.09	44
	2400	400	5.08	19.57	71	12.01	36
	2600	397	5.17	19.75	77	11.97	33
P40	1800	409	4.72	18.76	60	12.41	72
	2000	413	4.85	18.99	65	12.34	64
	2200	415	4.91	19.23	69	12.21	57
	2400	416	4.97	19.49	79	12.17	48
	2600	419	5.06	19.98	87	12.1	39
P20	1800	412	5.06	19.13	68	12.59	68
	2000	417	5.13	19.46	75	12.47	60
	2200	419	5.18	19.73	83	12.41	53
	2400	421	5.28	20.11	91	12.33	47
	2600	420	5.37	20.35	101	12.29	41

**Table D17: Engine emission data for biodiesel made from mustard oil**

<b>Fuel type: Mustard Oil</b>							
<b>Blend</b>	<b>Speed (rpm)</b>	<b>CO (ppm)</b>	<b>CO<sub>2</sub> (%)</b>	<b>O<sub>2</sub> (%)</b>	<b>NO<sub>x</sub> (ppm)</b>	<b>SO<sub>2</sub> (ppm)</b>	<b>HC (ppm)</b>
M100	1800	403	5.19	22.94	46	12.05	67
	2000	408	5.33	23.92	49	11.91	51
	2200	407	5.48	24.12	58	11.83	40
	2400	404	5.75	25.16	66	11.72	33
	2600	405	6.16	25.64	68	11.65	27
M80	1800	412	5.05	20.13	45	12.11	69
	2000	410	5.38	20.56	56	12.03	57
	2200	409	5.56	21.91	60	11.91	44
	2400	412	5.79	22.49	63	11.75	38
	2600	413	5.96	23.63	66	11.65	33
M60	1800	416	4.75	21.26	45	12.47	73
	2000	417	4.83	22.05	52	12.35	66
	2200	414	4.99	22.45	59	12.26	50
	2400	415	5.16	22.93	71	12.13	44
	2600	415	5.29	23.04	76	11.91	35
M40	1800	413	4.71	19.56	48	12.52	75
	2000	418	4.92	20.77	59	12.49	63
	2200	419	5.17	22.59	68	12.34	48
	2400	420	5.33	24.23	77	12.26	41
	2600	418	5.49	24.74	86	12.29	37
M20	1800	417	4.87	18.96	47	12.37	79
	2000	421	5.14	19.22	61	12.19	67
	2200	418	5.28	19.83	73	12.12	53
	2400	416	5.46	21.27	95	12.05	48
	2600	420	5.75	22.05	99	12.11	40