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APPENDIX A

DENSITIES AND VISCOSITIES

Table A.1 Density and viscosity of reagents

Reagent	Temperature (degree Celsius)	Density (kg/m^3)	Viscosity (cSt)
MCPO	60	887	19.15
De-acidified MCPO	60	865	8.315
1st-stage waste	60	1029	1.708
Crude biodiesel	60	847	2.535
Glycerol	60	964	5.323

APPENDIX B

PROPERTIES OF SOLUTION IN ESTERIFICATION AND TRANSESTERIFICATION

Mass fraction

Esterification

MCPO = 0.896

Methanol = 0.097

Sulfuric acid = 0.007

Transesterification (without NaOH)

De-acidified MCPO = 0.826

Methanol = 0.174

Transesterification (include)

De-acidified MCPO = 0.818

Methanol = 0.172

NaOH = 0.010

Density

Esterification

$$\text{Average density} = (887 \times 0.896) + (791.8 \times 0.097) + (1840 \times 0.007)$$
$$= 884.44 \text{ kg/m}^3$$

Transesterification

$$\text{Average density} = (865 \times 0.818) + (791.8 \times 0.172) + (2100 \times 0.010)$$
$$= 864 \text{ kg/m}^3$$

Viscosity

Esterification

$$\text{Average viscosity} = (0.0216 \times 0.896) + (0.0059 \times 0.097) + (0.0267 \times 0.007)$$
$$= 0.0253 \ \text{Pa} \cdot \text{s}$$

Transesterification

$$\text{Average viscosity} = (0.0096 \times 0.826) + (0.0059 \times 0.174)$$
$$= 0.00896 \ \text{Pa} \cdot \text{s}$$

Specific heat at constant pressure (Cp)

Esterification

Cp_{MCPO} = $1.959 \ \text{KJ/kg} \cdot ^{\circ}\text{C}$ (CHEMPRO, 2008)

$Cp_{methanol}$ = $2.480 \ \text{KJ/kg} \cdot ^{\circ}\text{C}$ (Wikipedia, 2008b)

$Cp_{sulfuric\ acid}$ = $0.028 \ \text{KJ/kg} \cdot ^{\circ}\text{C}$ (Stetina, 2008))

$$\text{Average } C_p = (1.959 \times 0.896) + (2.480 \times 0.097) + (0.028 \times 0.007)$$
$$= 1.996 \ \text{KJ/kg} \cdot ^{\circ}\text{C}$$

Transesterification

$Cp_{de\text{-}acidified\ MCPO}$ = $1.959 \ \text{KJ/kg} \cdot ^{\circ}\text{C}$

$Cp_{methanol}$ = $2.480 \ \text{KJ/kg} \cdot ^{\circ}\text{C}$

$$\text{Average } C_p = (1.959 \times 0.826) + (2.480 \times 0.174)$$
$$= 2.050 \ \text{KJ/kg} \cdot ^{\circ}\text{C}$$

Thermal conductivity (k)

Esterification

k_{MCPO} $= 0.1691\ \text{W/m}\cdot^{\circ}\text{C}$ (CHEMPRO, 2008)

$k_{methanol}$ $= 0.2100\ \text{W/m}\cdot^{\circ}\text{C}$ (Wikipedia, 2008c)

$k_{sulfuric\ acid}$ $= 0.2600\ \text{W/m}\cdot^{\circ}\text{C}$ (Stetina, 2008))

Average k = $(0.1691 \times 0.896) + (0.2100 \times 0.097) + (0.2600 \times 0.007)$

$= 0.174\ \text{KJ/kg}\cdot^{\circ}\text{C}$

Transesterification

k_{MCPO} $= 0.1691\ \text{W/m}\cdot^{\circ}\text{C}$

$k_{methanol}$ $= 0.2100\ \text{W/m}\cdot^{\circ}\text{C}$

Average k = $(0.1691 \times 0.826) + (0.2100 \times 0.174)$

$= 0.176\ \text{KJ/kg}\cdot^{\circ}\text{C}$

Mass flow rate ($\dot{m}$)

Esterification

$\dot{m}_{MCPO}$ = 0.0213 kg/s

$\dot{m}_{methanol}$ = 0.0013 kg/s

$\dot{m}_{sulfuric\ acid}$ = 0.0001 kg/s

Average $\dot{m}$ = $(0.0213 \times 0.896) + (0.0013 \times 0.097) + (0.0001 \times 0.007)$

= 0.0123 kg/s

Transesterification

$\dot{m}_{\text{de-acidified MCPO}} = 0.120$ kg/s

$\dot{m}_{\text{methanol}} = 0.0025$ kg/s

$$\text{Average } \dot{m} = (0.120 \times 0.826) + (0.0025 \times 0.174)$$
$$= 0.096 \text{ kg/s}$$

APPENDIX C

VISCOSITY ESTIMATION OF BLENDS OF LIQUIDS (SAMPLE)

The viscosity blending number (V_{BN}) of Esterification could be calculated by using Equation C.1 (Wikipedia, 2008d)

$$V_{BN} = 14.534 \times \ln[\ln(\mu + 0.8)] + 10.9175 \qquad (C.1)$$

Where

$\mu_{\text{de-acidified MCPO}} = 8.315 \text{ cSt} = 7.192 \text{ cP}$

$\mu_{\text{waste}} = 1.708 \text{ cSt} = 1.758 \text{ cP}$

The results indicated that V_{BN} of de-acidified MCPO ($V_{BN,\,A}$) and of the 1st-stage waste was 21.608 and 10.064 cP, respectively. After that, the average viscosity blending number could be calculated by using Equation C.2. In addition, the mass fraction of de-acidified MCPO (X_A) and of 1st-stage waste (X_B) at 0.9 and 0.1, respectively, were also used.

$$V_{BN,\,aver} = (V_{BN,\,A} \times X_A) + (V_{BN,\,B} \times X_B) \qquad (C.2)$$

Finally, the average viscosity blending number at 4.136 cP was used to estimate the average viscosity with Equation C.3 (Wikipedia, 2008d). It was found that the average viscosity of blending was 6.019 cP.

$$\mu_{aver} = e^{e^{\frac{V_{BN,\,aver} - 10.975}{14.534}}} \qquad (C.3)$$

APPENDIX D

ELEMENTS AND DRAWINGS OF CONTINUOUS REACTOR

Detail of the two-stage process continuous system components

The first stage process (Esterification)

1. MCPO storage tank

Two 200-liter plastic tanks consisted of heaters and temperature controllers were used as a container for storing and preparing MCPO before feeding it into system as shown in Figure D.1. Both tanks were connected to two pumps. First one was used to circulate MCPO during heating it up. Other one (metering pump) was used to feed warmed MCPO into esterification reactor.

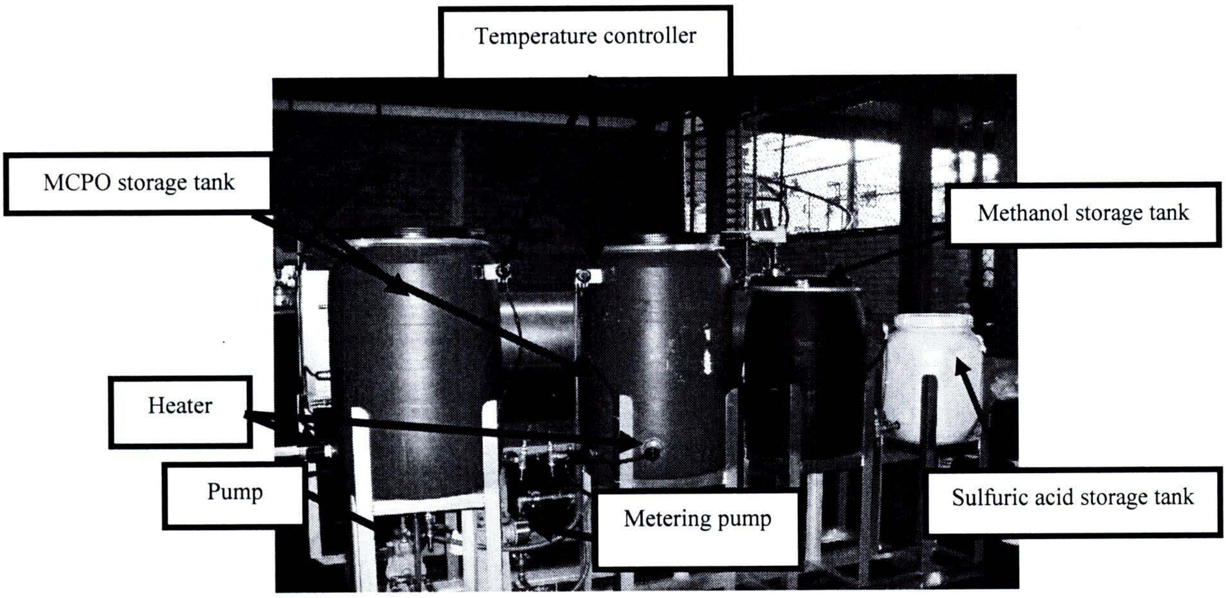

Figure D.1 Back side of the first stage system

2. Methanol storage tank

A 120-liter plastic tank was used as a container for storing methanol. It was connected to metering pump for feeding it into esterification reactor as shown in Figure D.1.

3. Sulfuric acid storage tank

Like methanol storage tank, a 50-liter plastic tank connected to metering pump was used to store sulfuric acid which was used as a catalyst in esterification process as shown in Figure D.1.

4. Esterification reactor

Esterification reactor as shown the detail in Figure D.2 was fabricated by using 1.5 mm thick stainless #304 for reactor body and 4 mm thick jacket # 304 stainless for flange sheets, cover sheet and bottom sheet.

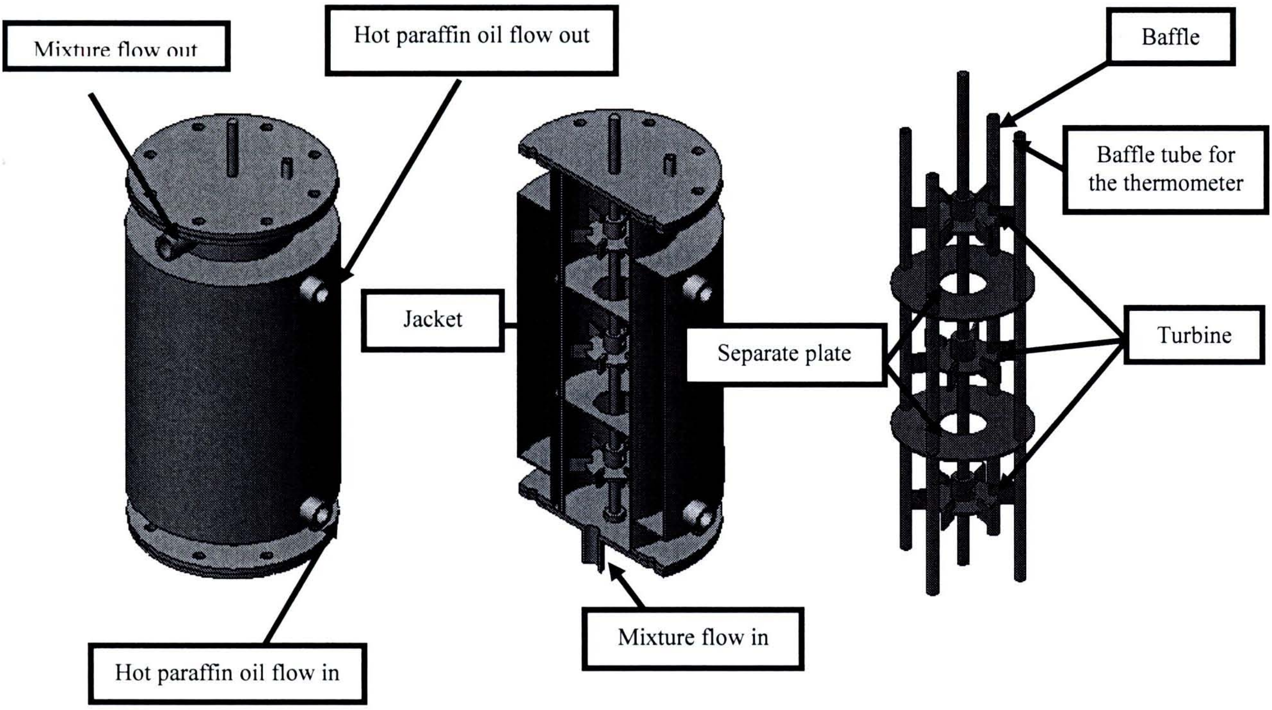

Figure D.2 Esterification reactor

5. Hot paraffin oil tank

A 1.5-liter hot paraffin oil tank installing with heater was fabricated from #304 stainless sizing 250 mm diameter and 300 mm high.

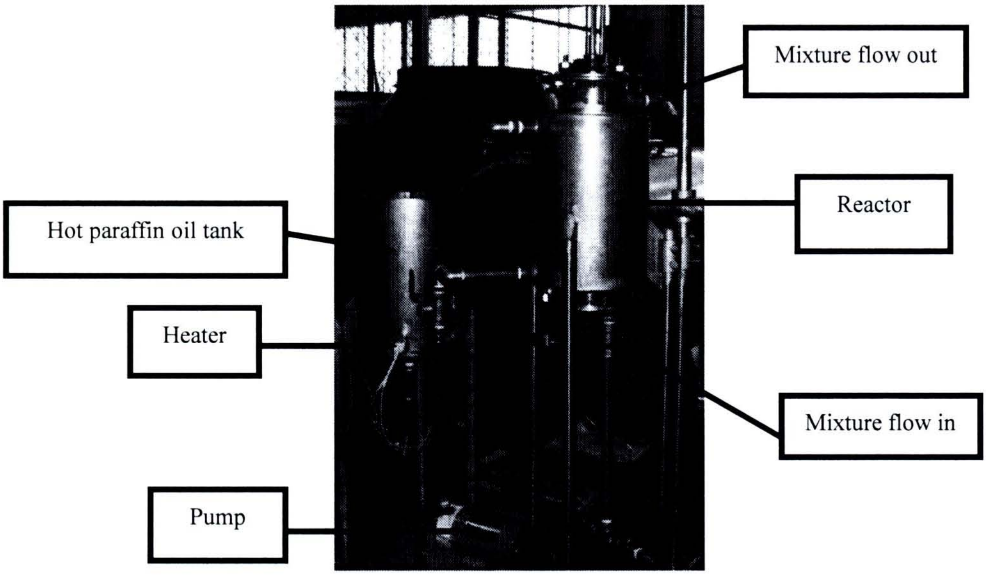

Figure D.3 Hot paraffin oil tank and reactor

6. Separate tank

A separate tank installing with heater was fabricated from #304 stainless sizing 300 mm diameter and 1,500 mm long.

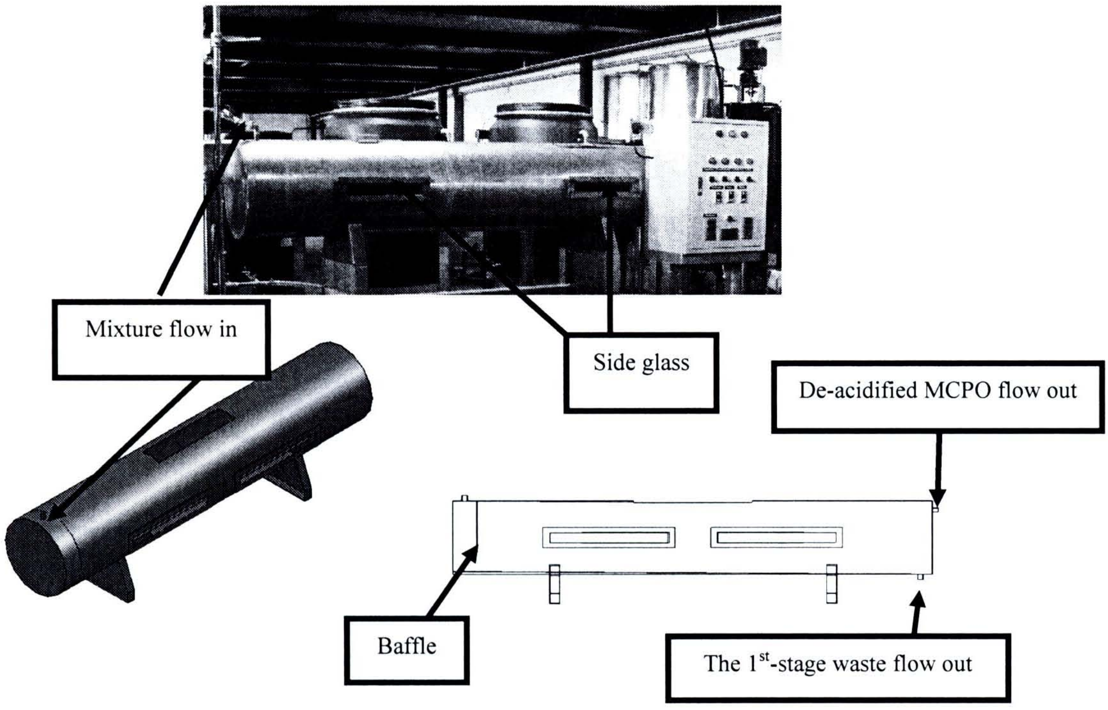

Figure D.4 The 1st-stage separate tank

7. Controller box of the 1st-stage process

Controller box of the 1st-stage process as shown in Figure D.5 consisted of heater lamp, heater switch, pump switch, temperature controller.

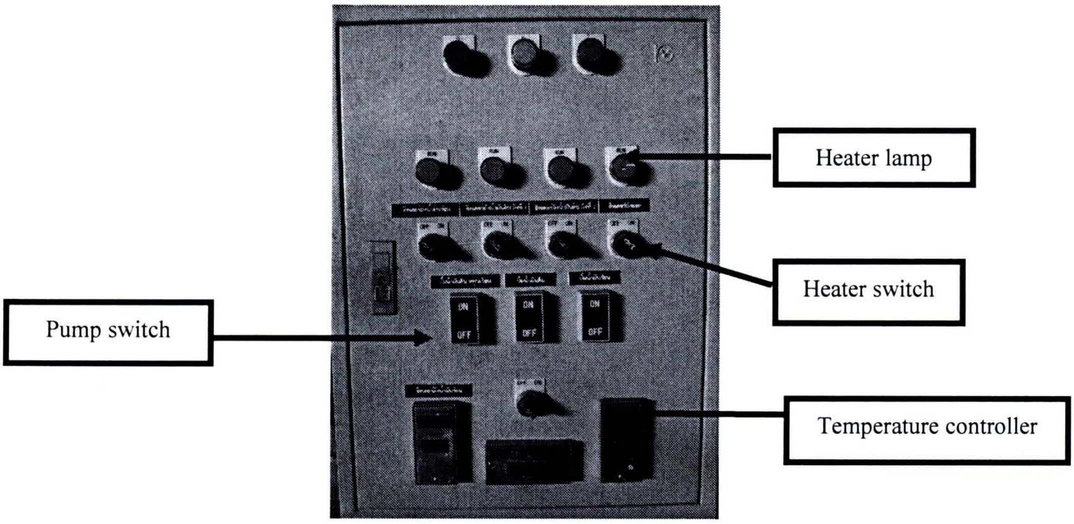

Figure D.5 Controller box of the 1st-stage process

The second process (Transesterification)

1. De-acidified MCPO storage tank

A 200-liter plastic tank consisted of heaters and temperature controllers was used as a container for storing and warming de-acidified MCPO before feeding it into system as shown in Figure D.6. It was connected to metering pump for feeding warmed de-acidified MCPO into transesterification reactor.

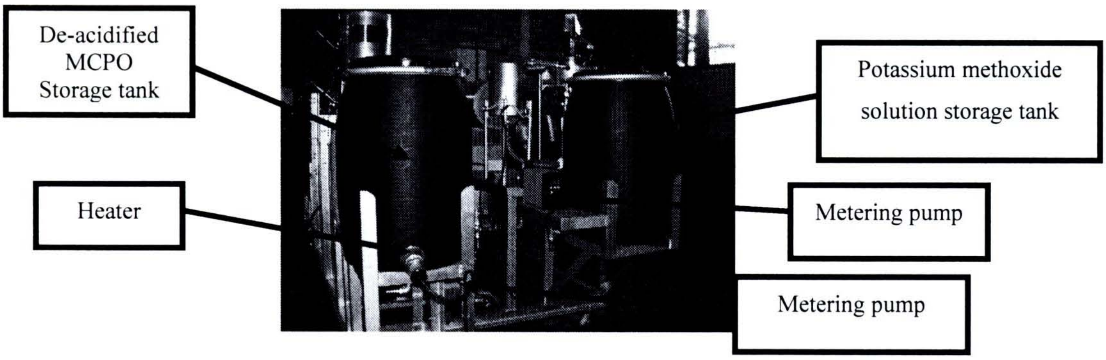

Figure D.6 Left side of the second stage

2. The first stage waste solution storage tank

A 120-liter plastic tank connected to pump for feeding waste solution into distillation tower was used as a container for storing the first stage waste solution as shown in Figure D.7.

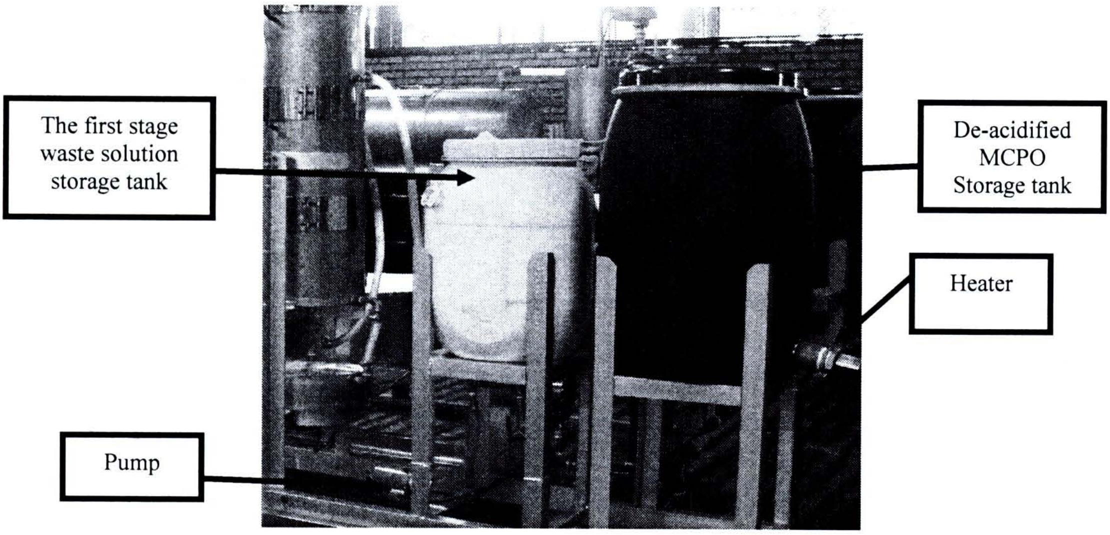

Figure D.7 The first stage waste solution storage tank

3. Potassium methoxide solution storage tank

A 120-liter plastic tank connected to metering pump for feeding potassium methoxide solution into reactor was used as a container for storing potassium methoxide solution as shown in Figure D.6.

4. Transesterification reactor

Similar to esterification reactor, transesterification reactor as shown the detail in Figure D.8 and D.9 was fabricated by using 1.5 mm thick #304 stainless for reactor body and 4 mm thick jacket # 304 stainless for flange sheets, cover sheet and bottom sheet.

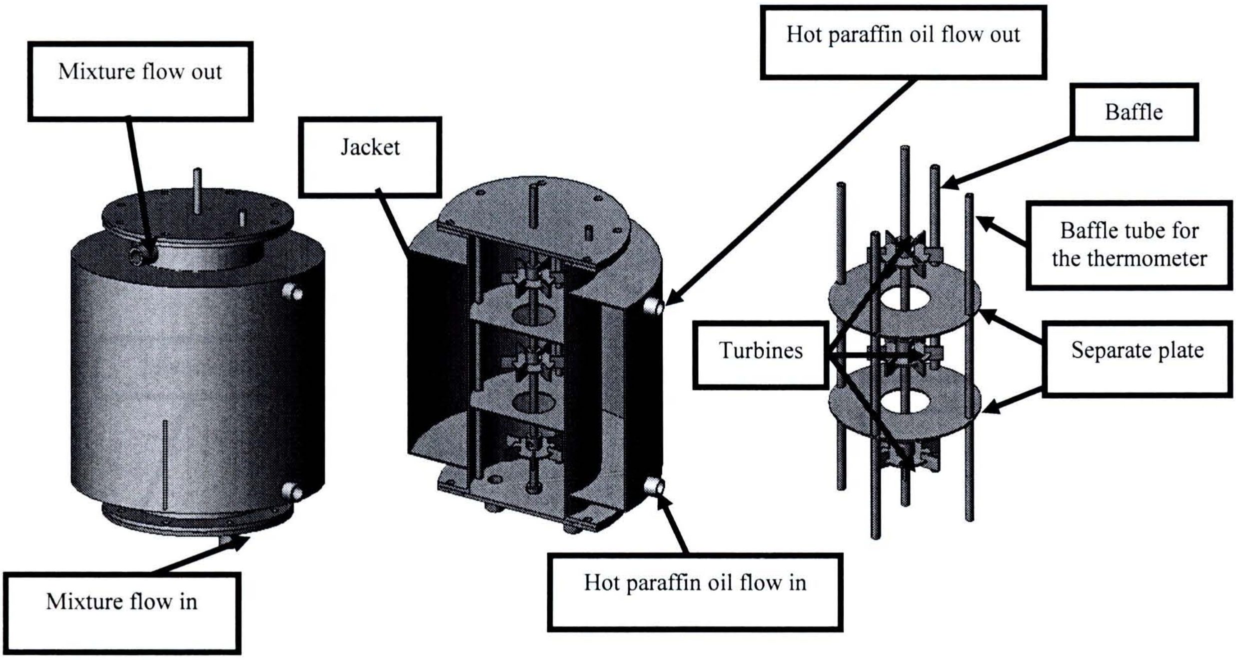

Figure D.8 Details of transesterification reactor

5. Hot paraffin oil tank

A 1.5-liter hot paraffin oil tank installing with heater was fabricated from stainless #304 sizing 250 mm diameter and 300 mm high which was similar to hot paraffin oil tank used for warming mixture in esterification reactor.

6. Separate tank

A separate tank installing with heater was fabricated from #304 stainless sizing 250 mm diameter and 300 mm long as shown in Figure 9.

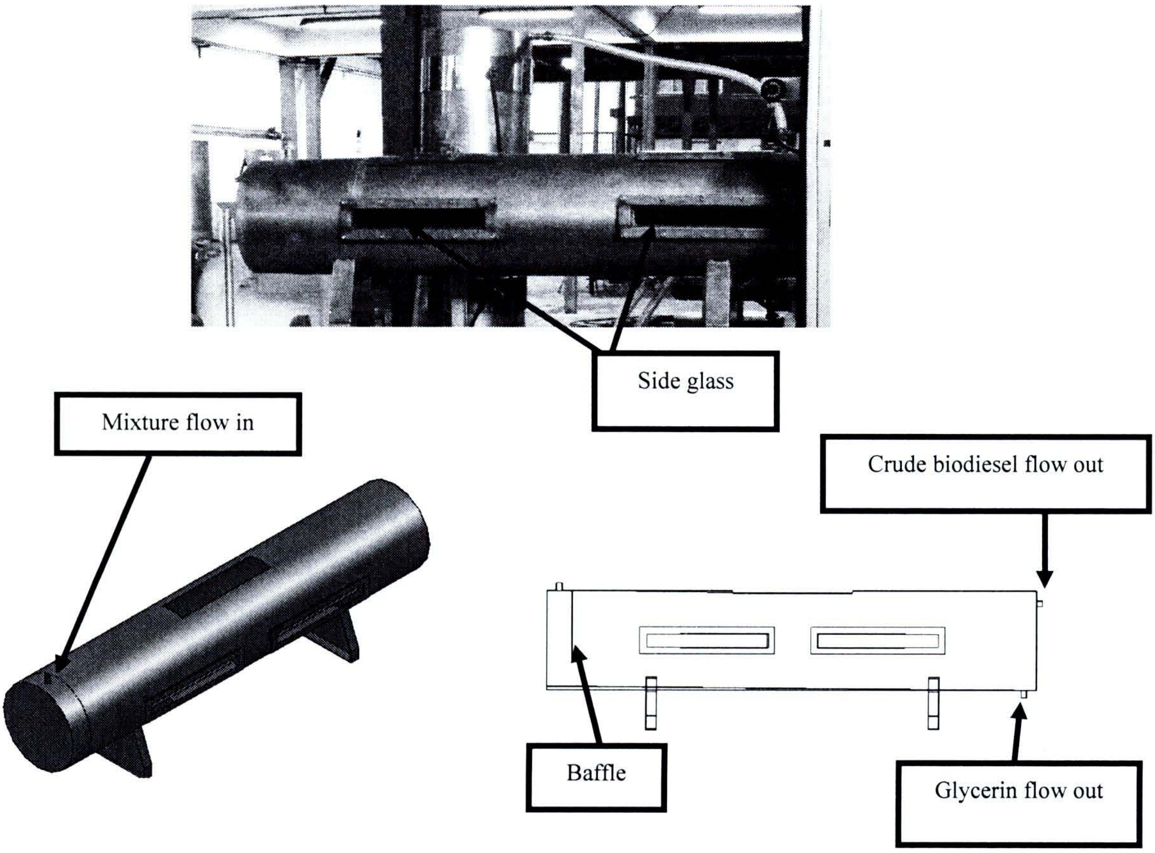

Figure D.9 The 2nd-stage separate tank

7. Crude biodiesel storage tank

A 200-liter plastic tank connected to pump for feeding crude biodiesel storage tank into distillation tower was used as a container for storing crude biodiesel storage tank as shown in Figure D.10.

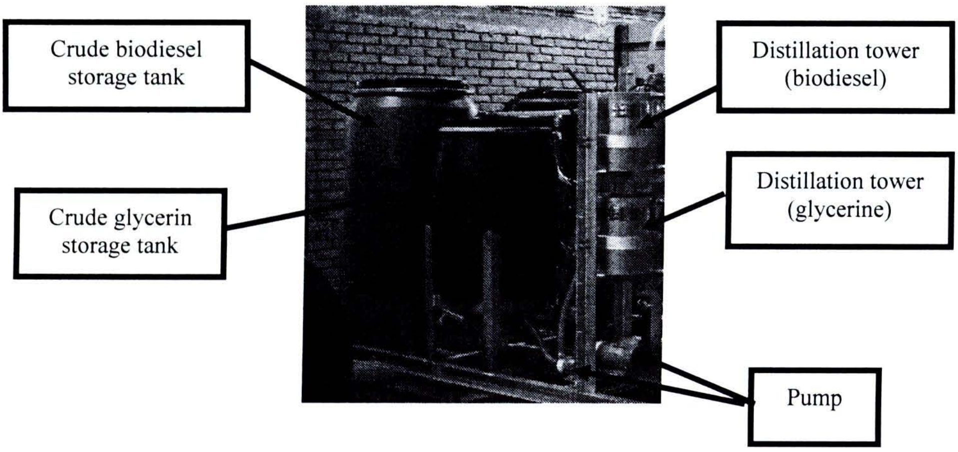

Figure D.10 Crude biodiesel and crude glycerin storage tank

8. Crude glycerin storage tank

A 160-liter plastic tank connected to pump for feeding crude biodiesel storage tank into distillation tower was used as a container for storing crude biodiesel storage tank as shown in Figure D.10.

9. Distillation tower

There were 3 distillation towers used to recovery methanol from crude biodiesel, crude glycerin and the 1st-stage waste solution. All of them were fabricated from #304 stainless and installed with band heater as shown in Figure D.11-13.

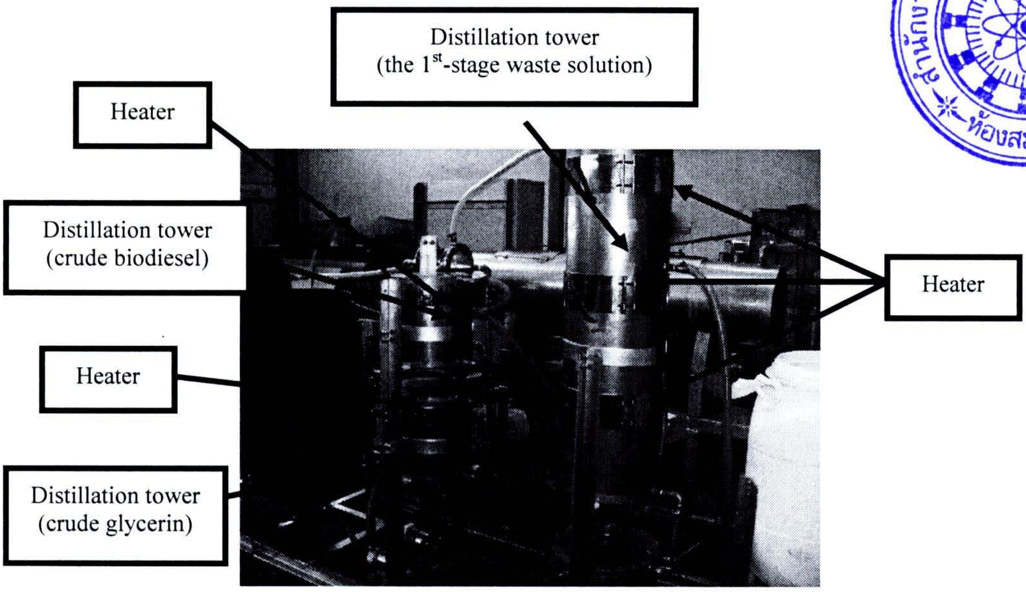

Figure D.11 Distillation tower

10. Re-boiler

There were 3 re-boilers used to evaporate remained methanol that contained in crude biodiesel, crude glycerin and the 1st-stage waste solution. Re-boilers were fabricated from #304 stainless and installed with heater as shown in Figure D.14.

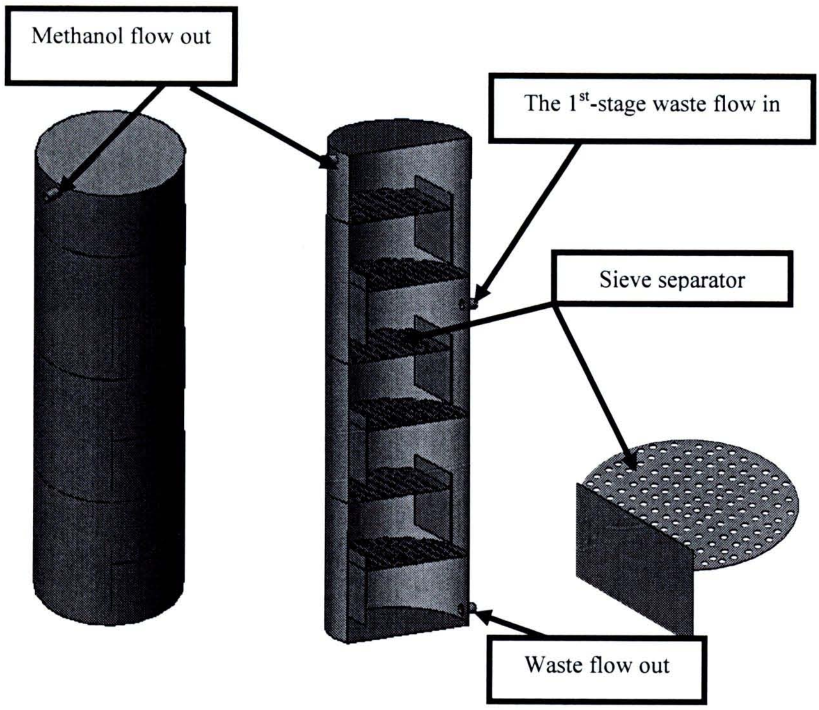

Figure D.12 Detail of the 1^{st}-stage waste distillation tower

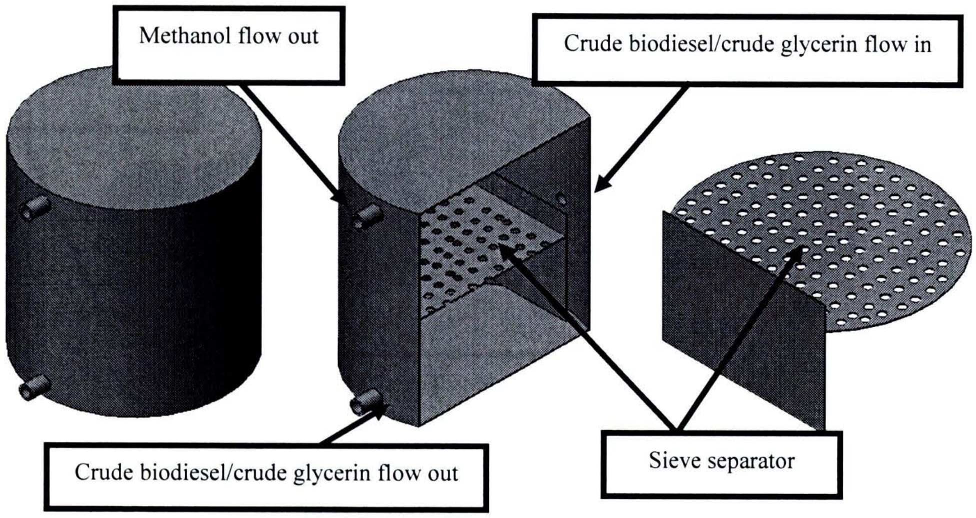

Figure D.13 Detail of crude biodiesel/crude glycerin distillation tower

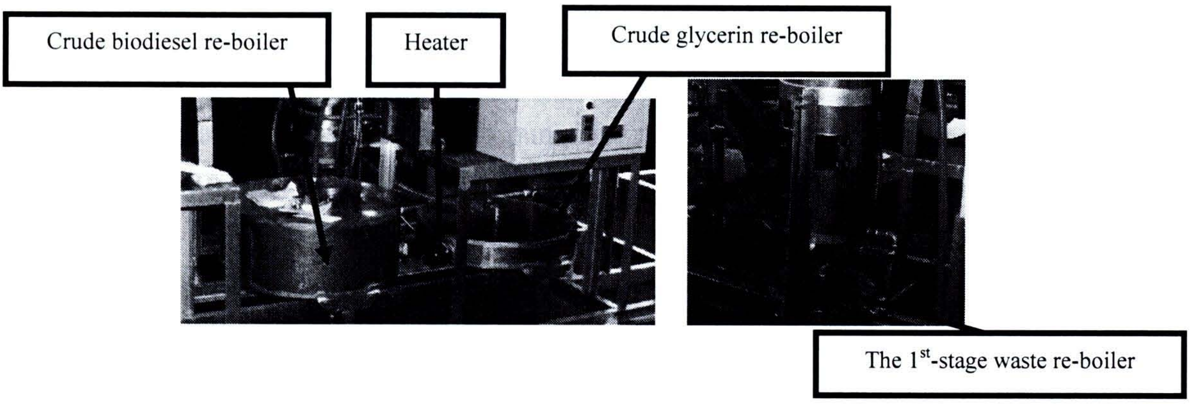

Figure D.14 Re-boilers

11. Condenser

Condenser as shown the detail in Figure D.15 was fabricated by using 1.5 mm thick #304 stainless for body of condenser and baffles, and 4 mm thick jacket # 304 stainless for flange sheets. Moreover, 10 mm long stainless tubes were used as cooling water tubes.

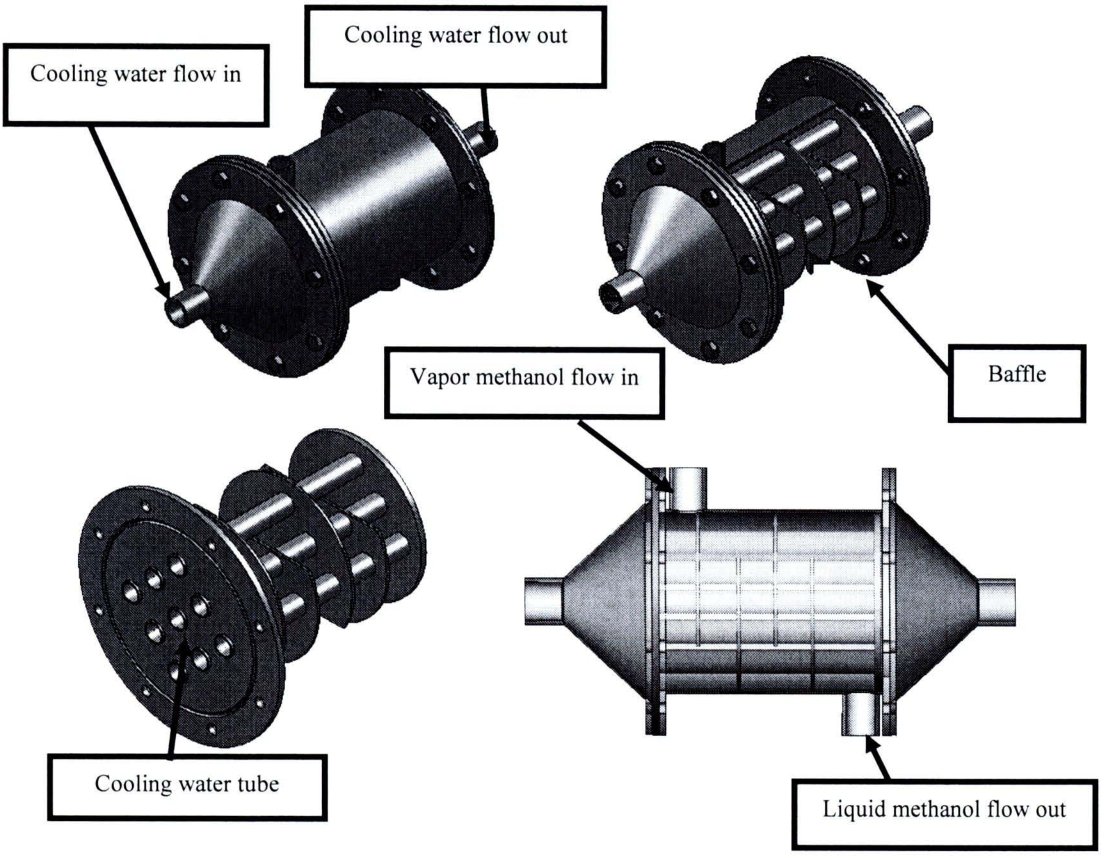

Figure D.15 Condenser

12. Cooling water tank

A 160-liter plastic tank connected to pump for feeding cooling water into condensers was used as a container for storing cooling water as shown in Figure D.16.

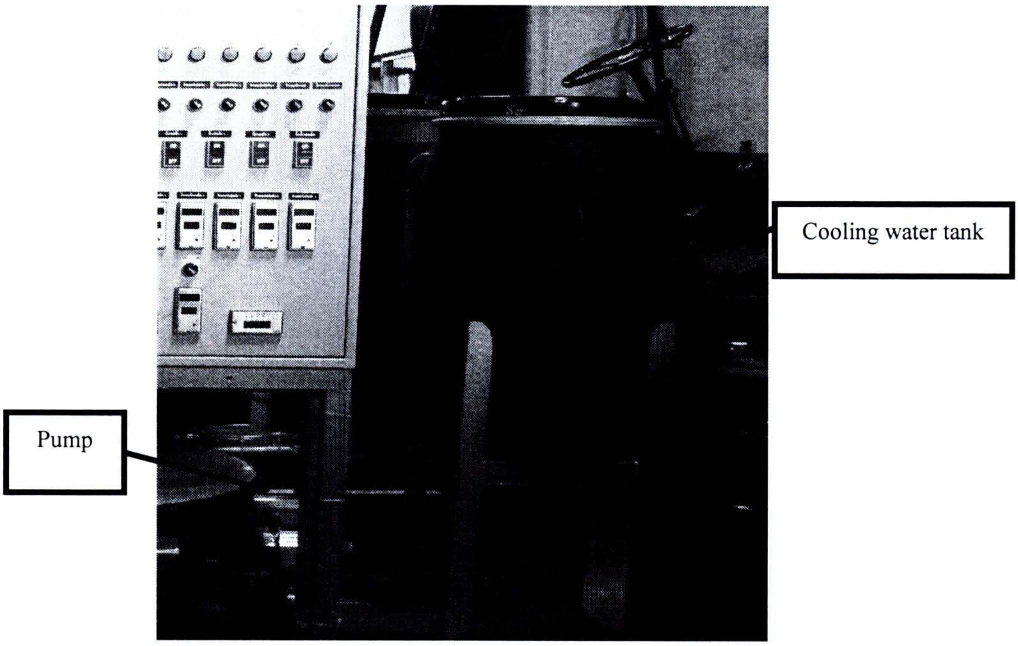

Figure D.16 Cooling water tank

13. Controller box of the 2nd-stage process

Similar to the 1st-stage process, controller box of the 2nd-stage process as shown in Figure D.17 consisted of heater lamp, heater switch, pump switch, temperature controller.

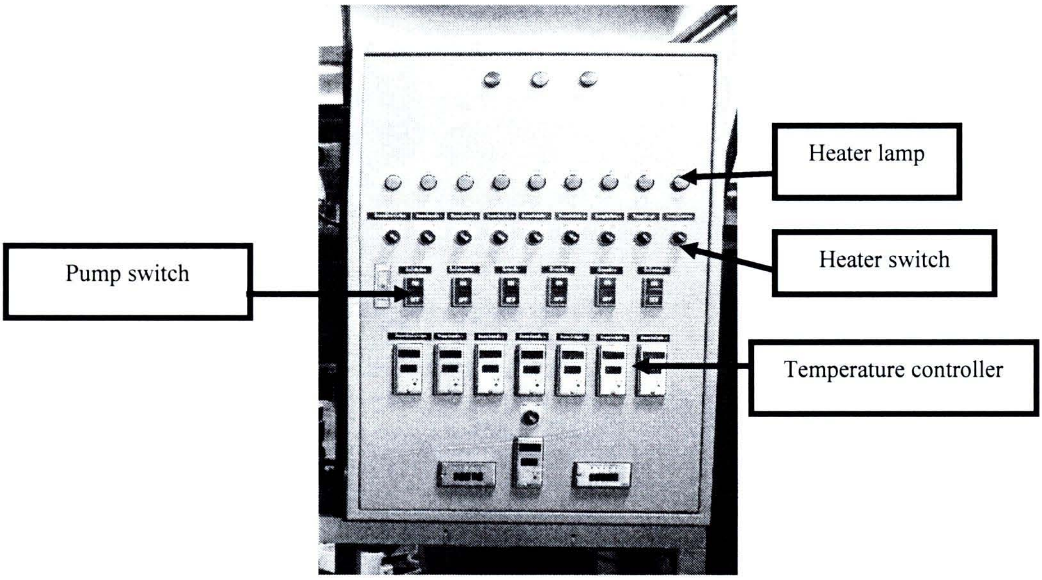

Figure D.17 Controller box of the 2nd-stage process

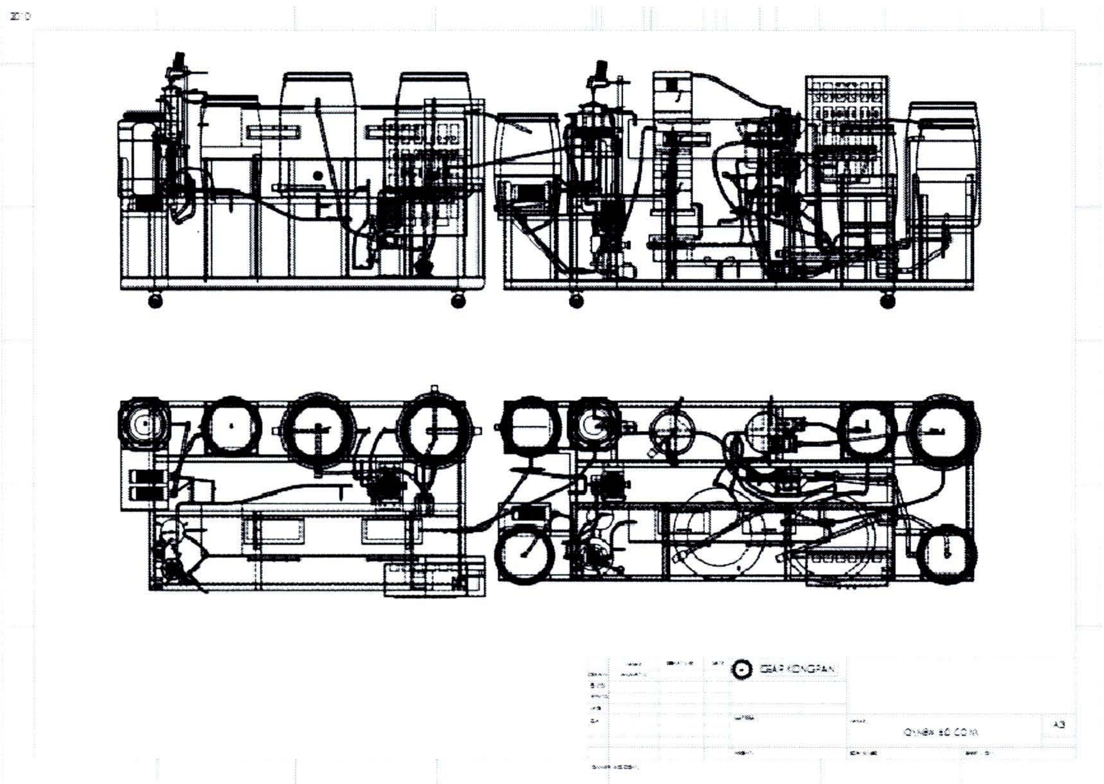

Figure D.18 Full view

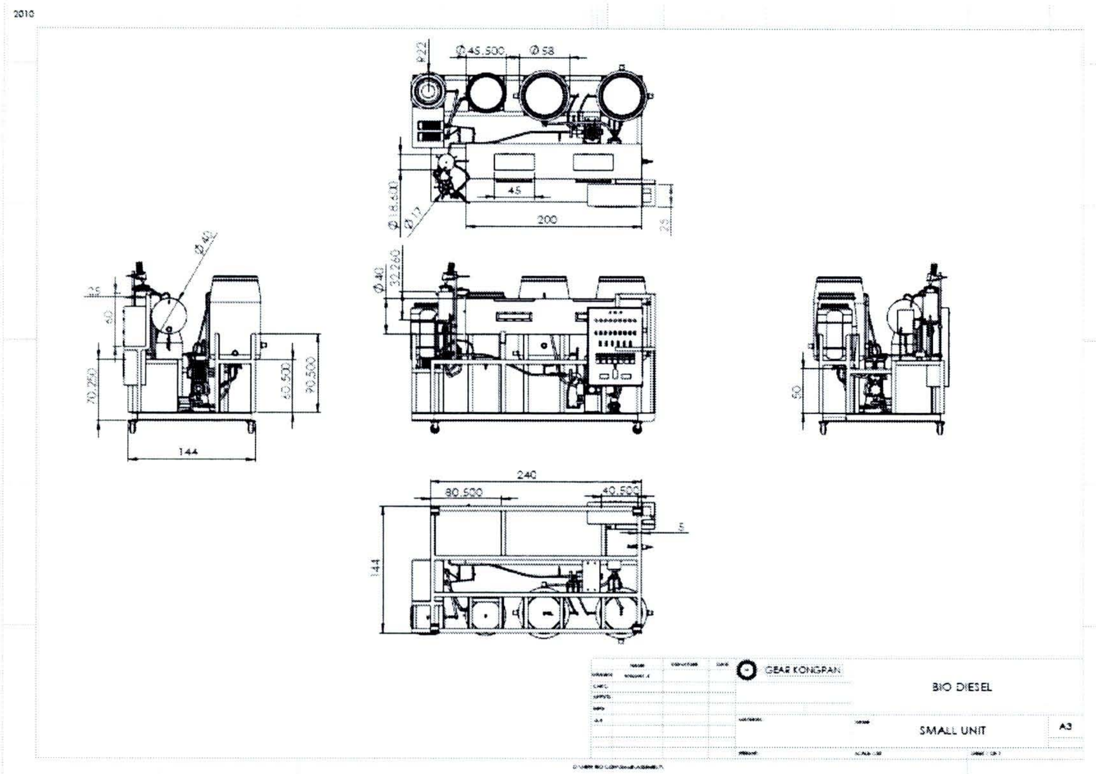

Figure D.19 Full view of esterification part

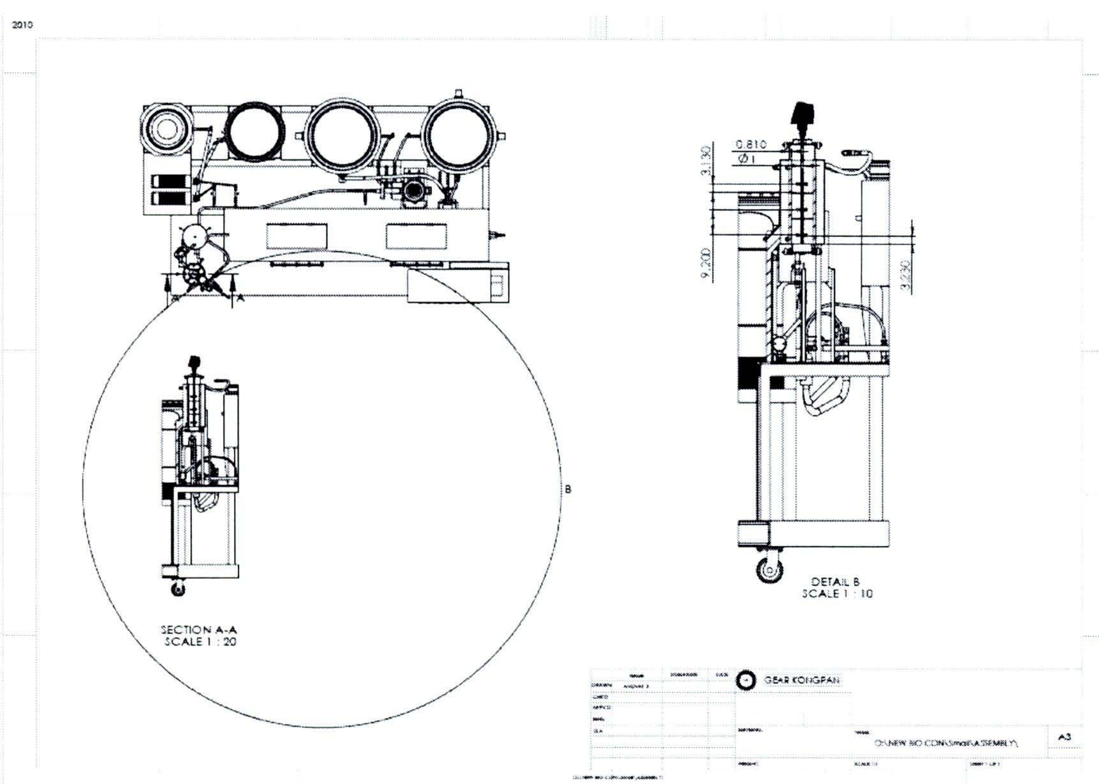

Figure D.20 Section view of reactor in esterification part

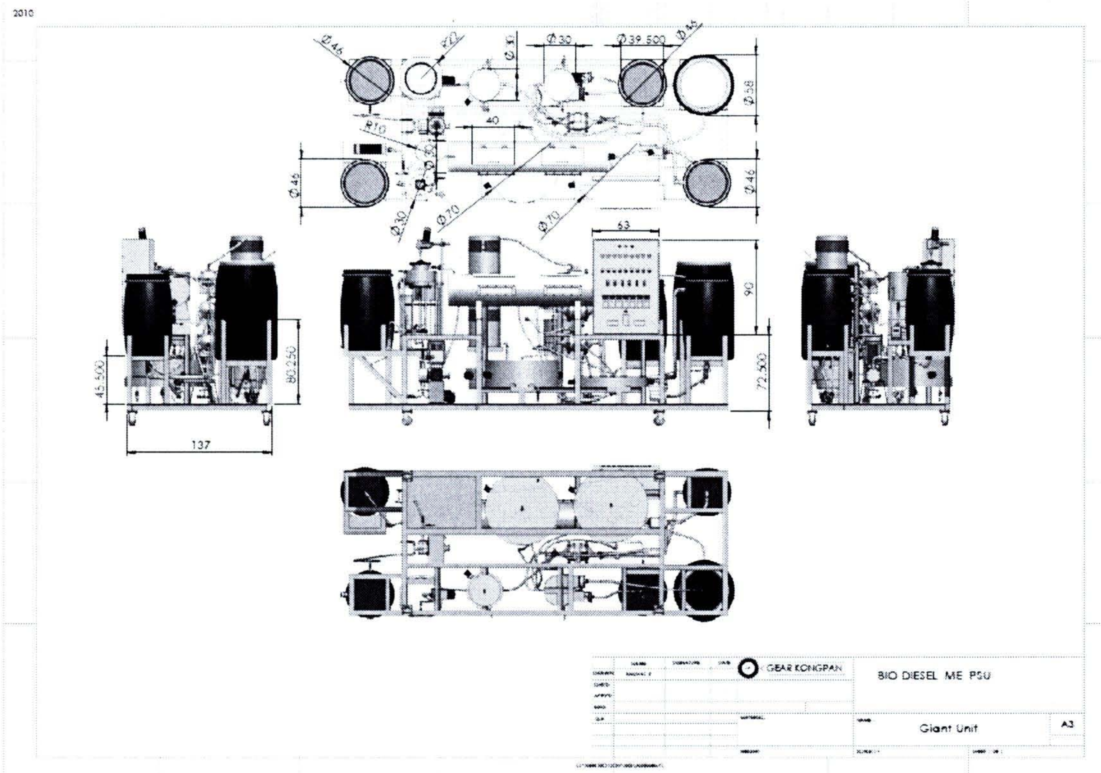

Figure D.21 Full view of transesterification part

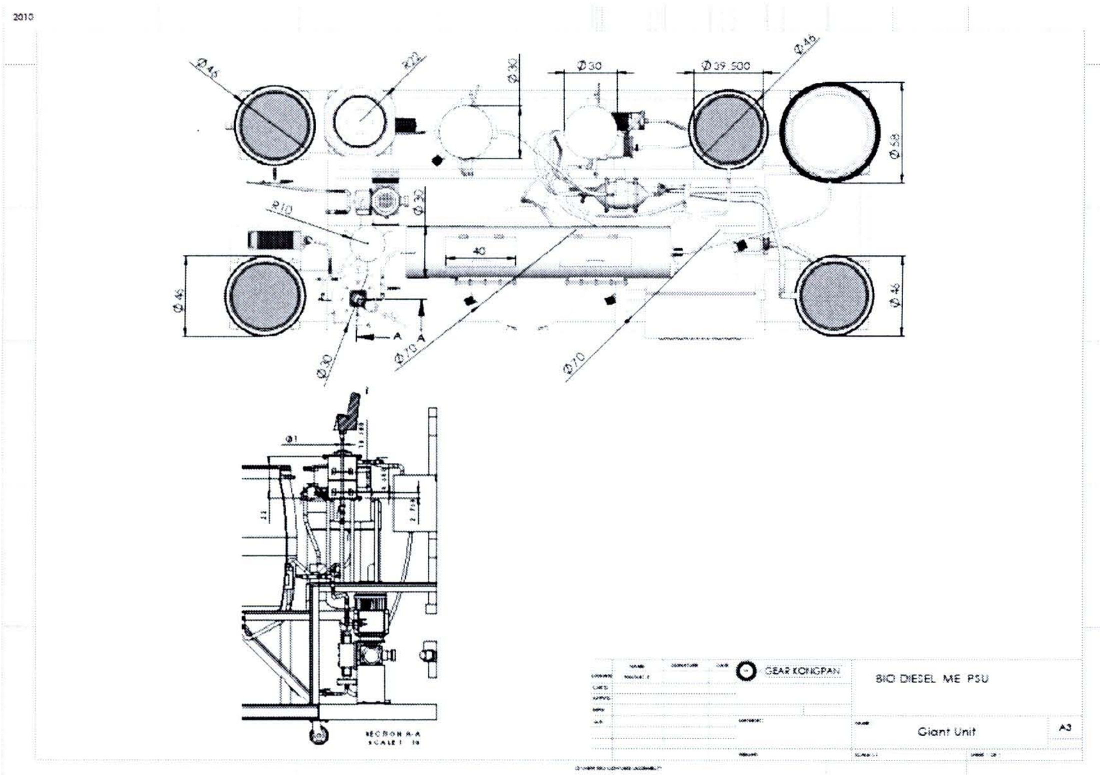

Figure D.22 Section view of reactor in transesterification part

E

METHANOL CONTENT

Table E.1 Methanol content (old condition)

Samples	Methanol Content (wt%)
Methanol content in crude biodiesel	6.31
Methanol content in 1^{st}-waste	8.76
Methanol content in glycerol	3.24

APPENDIX F

MULTIPLE REGRESSION ANALYSIS

Multiple regression model before considering the significance of each factor was shown in equation B.1 and in table as followed

$$FFA = \beta_0 + \beta_1(M) + \beta_2(S) + \beta_3(T) + \beta_4(P) + \beta_5(M^2) + \beta_6(S^2) + \beta_7(T^2) + \beta_8(P^2) + \beta_9(MS) + \beta_{10}(MT) + \beta_{11}(MP) + \beta_{12}(ST) + \beta_{13}(SP) + \beta_{14}(TP) \quad (B.1)$$

Summary	
|R|	0.993
R^2	0.986
R^2 adjusted	0.971
Standard Error	5.498×10^{-2}
# Points	28
PRESS	0.23
R^2 for Prediction	0.919
Durbin-Watson d	2.027
First Order Autocorrelation	-0.032
Collinearity	0.000
Coefficient of Variation	4.554

ANOVA

Source	*SS*	*SS%*	*MS*	*F*	*F Signif*	*df*
Regression	2.768	99	0.198	65.41	1.050×10^{-9}	14
Residual	3.929×10^{-2}	1	3.020×10^{-3}			13
Total	2.807	100				27

Terms	**Regression coefficients**	**P value**	**Std Error**	**-95%**	**95%**	**t Stat**	**VIF**
β_0	15.190	9.406×10^{-8}	1.437	12.080	18.290	10.570	-
β_1	-0.436	1.071×10^{-8}	3.437×10^{-2}	-0.510	-0.362	-12.690	234.50
β_2	-2.757	2.171×10^{-6}	0.344	-3.499	-2.014	-8.022	234.50
β_3	-4.827	1.220×10^{-4}	0.894	-6.759	-2.895	-5.397	397.00
β_4	-2.85×10^{-3}	5.540×10^{-3}	8.590×10^{-4}	-4.710×10^{-3}	-9.960×10^{-4}	-3.319	234.50
β_5	7.600×10^{-3}	3.081×10^{-10}	4.490×10^{-4}	6.630×10^{-3}	8.570×10^{-3}	16.930	65.14
β_6	0.340	4.093×10^{-6}	4.489×10^{-2}	0.243	0.437	7.566	65.14
β_7	0.867	3.290×10^{-4}	0.180	0.479	1.255	4.830	325.14
β_8	1.594×10^{-6}	7.513×10^{-5}	2.806×10^{-7}	9.881×10^{-7}	2.200×10^{-6}	5.682	65.14
β_9	4.250×10^{-2}	3.247×10^{-6}	5.500×10^{-3}	3.062×10^{-2}	5.438×10^{-2}	7.731	49.00
β_{10}	4.110×10^{-3}	0.714	1.100×10^{-2}	-1.964×10^{-2}	2.787×10^{-2}	0.374	146.50
β_{11}	-1.452×10^{-5}	0.310	1.374×10^{-5}	-4.421×10^{-5}	1.517×10^{-5}	-1.057	49.00
β_{12}	0.246	4.333×10^{-2}	0.110	8.580×10^{-3}	0.484	2.238	146.50
β_{13}	-2.240×10^{-4}	0.127	1.370×10^{-4}	-5.210×10^{-4}	7.308×10^{-5}	-1.629	49.00
β_{14}	4.710×10^{-4}	0.110	2.750×10^{-4}	-1.220×10^{-4}	1.070×10^{-3}	1.715	146.50

Multiple regression model after considering the significance of each factor was shown in equation B.2 and in table as followed

$$FFA = \beta_0 + \beta_1(M) + \beta_2(S) + \beta_3(T) + \beta_4(P) + \beta_5(M^2) + \beta_6(S^2) + \beta_7(T^2) + \beta_8(P^2) + \beta_9(MS) + \beta_{10}(MT) \quad \text{(B.2)}$$

Summary	
|R|	0.989
R^2	0.979
R^2 adjusted	0.966
Standard Error	5.941×10^{-2}
# Points	28
PRESS	0.16
R^2 for Prediction	0.943
Durbin-Watson d	2.044
First Order Autocorrelation	-0.034
Collinearity	0.000
Coefficient of Variation	4.921

ANOVA						
Source	*SS*	*SS%*	*MS*	*F*	*F Signif*	*df*
Regression	2.747	98	0.275	77.84	3.520×10^{-12}	10
Residual	0.060	2	3.530×10^{-3}			17
Total	2.807	100				27

Terms	Regression coefficients	P value	Std Error	-95%	95%	t Stat	VIF
β_0	14.740	2.775×10^{-9}	1.314	11.970	17.520	11.220	-
β_1	-0.438	6.037×10^{-13}	2.288×10^{-2}	-0.487	-0.390	-19.160	89.00
β_2	-2.936	2.048×10^{-7}	0.352	-3.678	-2.194	-8.344	210.50
β_3	-4.368	1.600×10^{-4}	0.906	-6.280	-2.456	-4.820	349.00
β_4	-2.530×10^{-3}	7.622×10^{-5}	4.890×10^{-4}	-3.560×10^{-3}	-1.50×10^{-3}	-5.174	65.00
β_5	7.600×10^{-3}	1.553×10^{-11}	4.850×10^{-4}	6.570×10^{-3}	8.62×10^{-3}	15.660	65.14
β_6	0.340	2.130×10^{-6}	4.851×10^{-2}	0.237	0.442	7.002	65.14
β_7	0.867	3.370×10^{-4}	0.194	0.458	1.277	4.470	325.14
β_8	1.594×10^{-6}	6.405×10^{-5}	3.032×10^{-7}	9.545×10^{-7}	2.234×10^{-6}	5.258	65.14
B_9	4.250×10^{-2}	1.615×10^{-6}	5.940×10^{-3}	2.997×10^{-2}	5.503×10^{-2}	7.154	49.00
β_{10}	0.246	5.385×10^{-2}	0.119	-4.560×10^{-3}	0.497	2.071	146.50

APPENDIX G

F-TEST

Table G.1 F-test (Kleinbaum, *et al.*, 1988)

DEGREES OF FREEDOM FOR DENOMINATOR	DEGREES OF FREEDOM FOR NUMERATOR																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	40	50	100	150	200
1	161	200	216	225	230	234	237	239	241	242	243	244	245	245	246	246	247	247	248	248	249	250	251	252	253	253	254
2	18.5	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.5	19.5	19.5	19.5	19.5	19.5	19.5
3	10.1	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.76	8.74	8.73	8.71	8.70	8.69	8.68	8.67	8.67	8.66	8.63	8.62	8.59	8.58	8.55	8.54	8.54
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.94	5.91	5.89	5.87	5.86	5.84	5.83	5.82	5.81	5.80	5.77	5.75	5.72	5.70	5.66	5.65	5.65
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.70	4.68	4.66	4.64	4.62	4.60	4.59	4.58	4.57	4.56	4.52	4.50	4.46	4.44	4.41	4.39	4.39
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.03	4.00	3.98	3.96	3.94	3.92	3.91	3.90	3.88	3.87	3.83	3.81	3.77	3.75	3.71	3.70	3.69
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.60	3.57	3.55	3.53	3.51	3.49	3.48	3.47	3.46	3.44	3.40	3.38	3.34	3.32	3.27	3.26	3.25
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.31	3.28	3.26	3.24	3.22	3.20	3.19	3.17	3.16	3.15	3.11	3.08	3.04	3.02	2.97	2.96	2.95
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.10	3.07	3.05	3.03	3.01	2.99	2.97	2.96	2.95	2.94	2.89	2.86	2.83	2.80	2.76	2.74	2.73
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.94	2.91	2.89	2.86	2.85	2.83	2.81	2.80	2.79	2.77	2.73	2.70	2.66	2.64	2.59	2.57	2.56
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.82	2.79	2.76	2.74	2.72	2.70	2.69	2.67	2.66	2.65	2.60	2.57	2.53	2.51	2.46	2.44	2.43
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.72	2.69	2.66	2.64	2.62	2.60	2.58	2.57	2.56	2.54	2.50	2.47	2.43	2.40	2.35	2.33	2.32
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.63	2.60	2.58	2.55	2.53	2.51	2.50	2.48	2.47	2.46	2.41	2.38	2.34	2.31	2.26	2.24	2.23
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.57	2.53	2.51	2.48	2.46	2.44	2.43	2.41	2.40	2.39	2.34	2.31	2.27	2.24	2.19	2.17	2.16
15	4.54	3.68	3.29	3.05	2.90	2.79	2.71	2.64	2.59	2.54	2.51	2.48	2.45	2.42	2.40	2.38	2.37	2.35	2.34	2.33	2.28	2.25	2.20	2.18	2.12	2.10	2.10
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.46	2.42	2.40	2.37	2.35	2.33	2.32	2.30	2.29	2.28	2.23	2.19	2.15	2.12	2.07	2.05	2.04
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.41	2.38	2.35	2.33	2.31	2.29	2.27	2.26	2.24	2.23	2.18	2.15	2.10	2.08	2.02	2.00	1.99
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.37	2.34	2.31	2.29	2.27	2.25	2.23	2.22	2.20	2.19	2.14	2.11	2.06	2.04	1.98	1.96	1.95
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.34	2.31	2.28	2.25	2.23	2.21	2.20	2.18	2.17	2.16	2.11	2.07	2.03	2.00	1.94	1.92	1.91
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.31	2.28	2.25	2.22	2.20	2.18	2.17	2.15	2.14	2.12	2.07	2.04	1.99	1.97	1.91	1.89	1.88
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.28	2.25	2.22	2.20	2.18	2.16	2.14	2.12	2.11	2.10	2.05	2.01	1.96	1.94	1.88	1.86	1.84
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.26	2.23	2.20	2.17	2.15	2.13	2.11	2.10	2.08	2.07	2.02	1.98	1.94	1.91	1.86	1.83	1.82
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.24	2.20	2.18	2.15	2.13	2.11	2.09	2.08	2.06	2.05	2.00	1.96	1.91	1.88	1.82	1.80	1.79
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.22	2.18	2.15	2.13	2.11	2.09	2.07	2.05	2.04	2.03	1.97	1.94	1.89	1.86	1.80	1.78	1.77
25	4.24	3.39	2.99	2.75	2.60	2.49	2.40	2.34	2.28	2.24	2.20	2.16	2.14	2.11	2.09	2.07	2.06	2.04	2.02	2.01	1.96	1.92	1.87	1.84	1.78	1.76	1.75
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.18	2.15	2.12	2.09	2.07	2.05	2.03	2.02	2.00	1.99	1.94	1.90	1.85	1.82	1.76	1.74	1.73
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20	2.17	2.13	2.10	2.08	2.06	2.04	2.02	2.00	1.99	1.97	1.92	1.88	1.84	1.81	1.74	1.72	1.71
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19	2.15	2.12	2.09	2.06	2.04	2.02	2.00	1.99	1.97	1.96	1.91	1.87	1.82	1.79	1.73	1.70	1.69
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18	2.14	2.10	2.08	2.05	2.03	2.01	1.99	1.97	1.96	1.94	1.89	1.85	1.81	1.77	1.71	1.69	1.67
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.13	2.09	2.06	2.04	2.01	1.99	1.98	1.96	1.95	1.93	1.88	1.84	1.79	1.76	1.70	1.67	1.66
32	4.15	3.29	2.90	2.67	2.51	2.40	2.31	2.24	2.19	2.14	2.10	2.07	2.04	2.01	1.99	1.97	1.96	1.94	1.92	1.91	1.85	1.82	1.77	1.74	1.67	1.64	1.63
34	4.13	3.28	2.88	2.65	2.49	2.38	2.29	2.23	2.17	2.12	2.08	2.05	2.02	1.99	1.97	1.95	1.93	1.92	1.90	1.89	1.83	1.80	1.75	1.71	1.65	1.62	1.61
36	4.11	3.26	2.87	2.63	2.48	2.36	2.28	2.21	2.15	2.11	2.07	2.03	2.00	1.98	1.95	1.93	1.92	1.90	1.88	1.87	1.81	1.78	1.73	1.69	1.62	1.60	1.59
38	4.10	3.24	2.85	2.62	2.46	2.35	2.26	2.19	2.14	2.09	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.87	1.85	1.80	1.76	1.71	1.68	1.61	1.58	1.57
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.04	2.00	1.97	1.95	1.92	1.90	1.89	1.87	1.85	1.84	1.78	1.74	1.69	1.66	1.59	1.56	1.55
42	4.07	3.22	2.83	2.59	2.44	2.32	2.24	2.17	2.11	2.06	2.03	1.99	1.96	1.94	1.91	1.89	1.87	1.86	1.84	1.83	1.77	1.73	1.68	1.65	1.57	1.55	1.53
44	4.06	3.21	2.82	2.58	2.43	2.31	2.23	2.16	2.10	2.05	2.01	1.98	1.95	1.92	1.90	1.88	1.86	1.84	1.83	1.81	1.76	1.72	1.67	1.63	1.56	1.53	1.52
46	4.05	3.20	2.81	2.57	2.42	2.30	2.22	2.15	2.09	2.04	2.00	1.97	1.94	1.91	1.89	1.87	1.85	1.83	1.82	1.80	1.75	1.71	1.65	1.62	1.55	1.52	1.51
48	4.04	3.19	2.80	2.57	2.41	2.29	2.21	2.14	2.08	2.03	1.99	1.96	1.93	1.90	1.88	1.86	1.84	1.82	1.81	1.79	1.74	1.70	1.64	1.61	1.54	1.51	1.49
50	4.03	3.18	2.79	2.56	2.40	2.29	2.20	2.13	2.07	2.03	1.99	1.96	1.92	1.89	1.87	1.85	1.83	1.81	1.80	1.78	1.73	1.69	1.63	1.60	1.52	1.50	1.48
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.95	1.92	1.89	1.86	1.84	1.82	1.80	1.78	1.76	1.75	1.69	1.65	1.59	1.56	1.48	1.45	1.44
70	3.98	3.13	2.74	2.50	2.35	2.23	2.14	2.07	2.02	1.97	1.93	1.89	1.86	1.84	1.81	1.79	1.77	1.75	1.74	1.72	1.66	1.62	1.57	1.53	1.45	1.42	1.40
80	3.96	3.11	2.72	2.49	2.33	2.21	2.13	2.06	2.00	1.95	1.91	1.88	1.84	1.82	1.79	1.77	1.75	1.73	1.72	1.70	1.64	1.60	1.54	1.51	1.43	1.39	1.38
90	3.95	3.10	2.71	2.47	2.32	2.20	2.11	2.04	1.99	1.94	1.90	1.86	1.83	1.80	1.78	1.76	1.74	1.72	1.70	1.69	1.63	1.59	1.53	1.49	1.41	1.38	1.36
100	3.94	3.09	2.70	2.45	2.31	2.19	2.10	2.03	1.97	1.93	1.89	1.85	1.82	1.79	1.77	1.75	1.73	1.71	1.69	1.68	1.62	1.57	1.52	1.48	1.39	1.36	1.34
125	3.92	3.07	2.68	2.44	2.29	2.17	2.08	2.01	1.96	1.91	1.87	1.83	1.80	1.77	1.75	1.73	1.71	1.69	1.67	1.66	1.59	1.55	1.49	1.45	1.36	1.33	1.31
150	3.90	3.06	2.66	2.43	2.27	2.16	2.07	2.00	1.94	1.89	1.85	1.82	1.79	1.76	1.73	1.71	1.69	1.67	1.66	1.64	1.58	1.54	1.48	1.44	1.34	1.31	1.29
200	3.89	3.04	2.65	2.42	2.26	2.14	2.06	1.98	1.93	1.88	1.84	1.80	1.77	1.74	1.72	1.69	1.67	1.66	1.64	1.62	1.56	1.52	1.46	1.41	1.32	1.28	1.26
300	3.87	3.03	2.63	2.40	2.24	2.13	2.04	1.97	1.91	1.86	1.82	1.78	1.75	1.72	1.70	1.68	1.66	1.64	1.62	1.61	1.54	1.50	1.43	1.39	1.30	1.26	1.23
500	3.86	3.01	2.62	2.39	2.23	2.12	2.03	1.96	1.90	1.85	1.81	1.77	1.74	1.71	1.69	1.66	1.64	1.62	1.61	1.59	1.53	1.48	1.42	1.38	1.28	1.23	1.21
1000	3.85	3.00	2.61	2.38	2.22	2.11	2.02	1.95	1.89	1.84	1.80	1.76	1.73	1.70	1.68	1.65	1.63	1.61	1.60	1.58	1.52	1.47	1.41	1.36	1.26	1.22	1.19

APPENDIX H
RAW DATA

Table H.1 Raw data of esterification under the condition of 20 v% of methanol, 1 v% of sulfuric acid, retention time of 2.25 min and stirrer speed at 800 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.892	0.367
2.25	1.122	1.447
4.50	1.113	1.430
6.75	1.249	1.257
9.00	1.042	1.440
11.25	1.038	1.237
13.50	1.231	1.297
15.75	1.669	1.173
18.00	1.320	1.253
20.25	1.613	1.227
22.50	1.235	1.193
Average (6 to 10 times of retention time)	1.413	1.229

Table H.2 Raw data under of esterification the condition of 20 v% of methanol, 2 v% of sulfuric acid, retention time of 1.75 min and stirrer speed at 800 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.425	0.435
1.75	0.967	1.470
3.50	0.998	1.490
5.25	1.026	1.330
7.00	1.172	1.257
8.75	1.046	1.467
10.50	1.091	1.427
12.25	1.070	1.157
14.00	1.021	1.310
15.75	1.094	1.293
17.50	1.096	1.447
Average (6 to 10 times of retention time)	1.074	1.327

Table H.3 Raw data of esterification under the condition of 25 v% of methanol, 1.5 v% of sulfuric acid, retention time of 2 min and stirrer speed at 600 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.529	0.511
2.00	0.923	1.500
4.00	0.825	1.457
6.00	1.071	1.360
8.00	1.080	1.377
10.00	0.988	1.390
12.00	1.091	1.437
14.00	0.998	1.370
16.00	0.849	1.530
18.00	1.017	1.410
20.00	0.890	1.333
Average (6 to 10 times of retention time)	0.969	1.416

Table H.4 Raw data of esterification under the condition of 15 v% of methanol, 2.5 v% of sulfuric acid, retention time of 2.5 min and stirrer speed at 600 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	13.871	0.326
2.50	1.623	0.723
5.00	1.234	1.037
7.50	1.405	0.863
10.00	1.306	0.877
12.50	1.079	1.097
15.00	1.447	0.817
17.50	1.310	0.920
20.00	1.315	1.170
22.50	1.263	1.017
25.00	1.409	0.823
Average (6 to 10 times of retention time)	1.349	0.949

Table H.5 Raw data of esterification under the condition of 25 v% of methanol, 2.5 v% of sulfuric acid, retention time of 2.5 min and stirrer speed at 600 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.057	0.592
2.50	1.725	2.160
5.00	1.193	1.990
7.50	1.532	1.863
10.00	1.427	1.463
12.50	1.082	1.547
15.00	1.004	1.373
17.50	1.022	1.667
20.00	1.041	1.390
22.50	1.052	1.383
25.00	1.044	1.543
Average (6 to 10 times of retention time)	1.032	1.471

Table H.6 Raw data of esterification under the condition of 20 v% of methanol, 2 v% of sulfuric acid, retention time of 2.25 min and stirrer speed at 800 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	13.663	0.510
2.25	1.083	1.083
4.50	0.976	1.133
6.75	1.086	1.240
9.00	1.443	1.163
11.25	0.935	1.157
13.50	0.894	1.100
15.75	0.877	1.220
18.00	0.865	1.343
20.25	0.854	1.997
22.50	0.861	1.167
Average (6 to 10 times of retention time)	0.870	1.365

Table H.7 Raw data of esterification under the condition of 20 v% of methanol, 2 v% of sulfuric acid, retention time of 2.25 min and stirrer speed at 400 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.842	0.524
2.25	1.161	1.227
4.50	1.385	1.297
6.75	1.151	1.330
9.00	1.047	1.513
11.25	1.318	1.410
13.50	1.047	1.347
15.75	1.126	1.317
18.00	1.270	1.550
20.25	1.294	1.340
22.50	1.031	1.577
Average (6 to 10 times of retention time)	1.154	1.426

Table H.8 Raw data of esterification under the condition of 30 v% of methanol, 2 v% of sulfuric acid, retention time of 2.25 min and stirrer speed at 800 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.017	0.244
2.25	0.792	1.227
4.50	1.269	1.233
6.75	0.847	1.233
9.00	0.986	1.457
11.25	0.906	1.210
13.50	1.140	1.123
15.75	1.147	1.063
18.00	1.147	1.107
20.25	1.187	1.057
22.50	1.154	1.163
Average (6 to 10 times of retention time)	1.155	1.103

Table H.9 Raw data of esterification under the condition of 20 v% of methanol, 2 v% of sulfuric acid, retention time of 2.75 min and stirrer speed at 800 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.308	0.533
2.75	0.799	1.147
5.50	0.817	1.573
8.25	0.983	1.270
11.00	1.310	1.503
13.75	1.232	1.297
16.50	1.194	1.283
19.25	1.123	1.357
22.00	1.123	1.387
24.75	1.142	1.607
27.50	1.186	1.350
Average (6 to 10 times of retention time)	1.154	1.397

Table H.10 Raw data of esterification under the condition of 25 v% of methanol, 1.5 v% of sulfuric acid, retention time of 2 min and stirrer speed at 1000 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	15.288	0.408
2.00	0.863	1.360
4.00	0.882	1.377
6.00	0.950	1.490
8.00	1.127	1.447
10.00	0.967	1.437
12.00	1.165	1.470
14.00	0.949	1.307
16.00	0.987	1.417
18.00	1.057	1.280
20.00	0.980	1.443
Average (6 to 10 times of retention time)	1.028	1.383

Table H.11 Raw data of esterification under the condition of 15 v% of methanol, 1.5 v% of sulfuric acid, retention time of 2 min and stirrer speed at 600 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	13.791	0.652
2.00	1.108	1.063
4.00	1.108	1.253
6.00	1.749	1.397
8.00	1.710	1.460
10.00	1.789	1.350
12.00	1.746	1.403
14.00	1.750	1.433
16.00	1.753	1.450
18.00	1.763	1.407
20.00	1.794	1.407
Average (6 to 10 times of retention time)	1.761	1.420

Table H.12 Raw data of esterification under the condition of 15 v% of methanol, 1.5 v% of sulfuric acid, retention time of 2.5 min and stirrer speed at 1000 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.673	0.624
2.50	1.774	1.397
5.00	1.755	1.437
7.50	1.064	1.407
10.00	1.391	1.363
12.50	1.591	1.377
15.00	1.772	1.407
17.50	1.747	1.617
20.00	1.795	1.443
22.50	1.797	1.430
25.00	1.755	1.480
Average (6 to 10 times of retention time)	1.773	1.475

Table H.13 Raw data under of esterification the condition of 25 v% of methanol, 1.5 v% of sulfuric acid, retention time of 2.5 min and stirrer speed at 600 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.538	0.677
2.50	0.894	1.720
5.00	0.829	1.397
7.50	0.909	1.563
10.00	0.681	1.400
12.50	0.608	1.377
15.00	0.992	1.637
17.50	1.003	1.440
20.00	0.941	1.513
22.50	0.921	1.597
25.00	1.096	1.527
Average (6 to 10 times of retention time)	0.991	1.543

Table H.14 Raw data under of esterification the condition of 15 v% of methanol, 1.5 v% of sulfuric acid, retention time of 2.5 min and stirrer speed at 600 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	13.485	0.868
2.50	2.194	1.633
5.00	2.670	1.507
7.50	2.055	1.510
10.00	1.634	1.527
12.50	1.538	1.613
15.00	1.565	1.680
17.50	1.457	1.730
20.00	1.473	1.633
22.50	1.563	1.667
25.00	1.477	1.657
Average (6 to 10 times of retention time)	1.507	1.673

Table H.15 Raw data of esterification under the condition of 20 v% of methanol, 2 v% of sulfuric acid, retention time of 2.25 min and stirrer speed at 1200 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.946	0.596
2.25	0.865	1.173
4.50	0.921	1.483
6.75	0.942	1.690
9.00	0.968	1.383
11.25	1.127	1.470
13.50	1.136	1.693
15.75	1.183	1.367
18.00	1.139	1.400
20.25	1.132	1.397
22.50	1.162	1.553
Average (6 to 10 times of retention time)	1.151	1.482

Table H.16 Raw data of esterification under the condition of 25 v% of methanol, 2.5 v% of sulfuric acid, retention time of 2.5 min and stirrer speed at 1000 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.805	0.474
2.50	1.026	1.583
5.00	0.891	1.507
7.50	1.198	1.337
10.00	1.198	1.313
12.50	1.046	1.457
15.00	1.057	1.363
17.50	1.076	1.300
20.00	1.088	1.317
22.50	1.065	1.357
25.00	1.044	1.507
Average (6 to 10 times of retention time)	1.066	1.369

Table H.17 Raw data of esterification under the condition of 25 v% of methanol, 2.5 v% of sulfuric acid, retention time of 2 min and stirrer speed at 600 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.948	0.385
2.00	1.052	1.733
4.00	1.234	2.043
6.00	1.194	1.570
8.00	1.013	1.773
10.00	1.417	1.647
12.00	1.028	1.377
14.00	1.047	1.213
16.00	1.108	1.313
18.00	1.075	1.270
20.00	1.031	1.417
Average (6 to 10 times of retention time)	1.058	1.318

Table H.18 Raw data of esterification under the condition of 15 v% of methanol, 2.5 v% of sulfuric acid, retention time of 2 min and stirrer speed at 1000 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.172	0.872
2.00	1.368	1.823
4.00	1.689	2.210
6.00	1.045	1.890
8.00	1.024	1.720
10.00	1.084	1.893
12.00	1.181	2.030
14.00	1.215	1.880
16.00	1.284	1.753
18.00	1.305	1.727
20.00	1.276	1.313
Average (6 to 10 times of retention time)	1.252	1.741

Table H.19 Raw data of esterification under the condition of 25 v% of methanol, 2.5 v% of sulfuric acid, retention time of 2 min and stirrer speed at 1000 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	13.562	0.468
2.00	1.208	1.553
4.00	0.971	1.767
6.00	0.629	1.300
8.00	0.909	1.233
10.00	0.970	1.290
12.00	0.889	1.343
14.00	0.968	1.290
16.00	0.923	1.060
18.00	0.998	1.317
20.00	0.935	1.387
Average (6 to 10 times of retention time)	0.943	1.279

Table H.20 Raw data of esterification under the condition of 15 v% of methanol, 2.5 v% of sulfuric acid, retention time of 2.5 min and stirrer speed at 1000 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.495	0.387
2.50	1.267	1.213
5.00	1.306	1.303
7.50	1.257	1.163
10.00	1.127	1.233
12.50	1.073	1.443
15.00	1.341	1.233
17.50	1.326	1.197
20.00	1.301	1.263
22.50	1.359	1.190
25.00	1.329	1.277
Average (6 to 10 times of retention time)	1.331	1.232

Table H.21 Raw data of esterification under the condition of 15 v% of methanol, 1.5 v% of sulfuric acid, retention time of 2 min and stirrer speed at 1000 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.079	0.536
2.00	1.764	1.123
4.00	1.046	1.177
6.00	1.284	1.280
8.00	1.145	0.980
10.00	1.692	1.013
12.00	1.734	1.163
14.00	1.797	1.430
16.00	1.650	1.503
18.00	1.721	1.347
20.00	1.641	1.227
Average (6 to 10 times of retention time)	1.709	1.334

Table H.22 Raw data of esterification under the condition of 10 v% of methanol, 2 v% of sulfuric acid, retention time of 2.25 min and stirrer speed at 800 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.652	0.869
2.25	1.915	1.207
4.50	1.796	1.400
6.75	1.487	1.127
9.00	1.805	2.280
11.25	1.837	2.417
13.50	2.114	1.573
15.75	2.201	1.440
18.00	2.054	2.220
20.25	2.319	1.477
22.50	2.106	1.677
Average (6 to 10 times of retention time)	2.159	1.677

Table H.23 Raw data of esterification under the condition of 25 v% of methanol, 1.5 v% of sulfuric acid, retention time of 2.5 min and stirrer speed at 1000 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	15.165	0.433
2.50	0.930	1.173
5.00	1.239	0.970
7.50	0.945	1.253
10.00	0.984	1.330
12.50	0.880	1.317
15.00	0.956	1.307
17.50	0.949	1.373
20.00	0.978	1.410
22.50	0.947	1.307
25.00	0.928	1.383
Average (6 to 10 times of retention time)	0.952	1.356

Table H.24 Raw data of esterification under the condition of 15 v% of methanol, 2.5 v% of sulfuric acid, retention time of 2 min and stirrer speed at 600 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	13.768	0.764
2.00	1.355	1.170
4.00	1.391	1.687
6.00	1.243	1.540
8.00	1.531	1.140
10.00	1.395	1.467
12.00	1.276	1.433
14.00	1.198	1.643
16.00	1.284	1.630
18.00	1.375	1.427
20.00	1.254	1.737
Average (6 to 10 times of retention time)	1.277	1.574

Table H.25 Raw data of esterification under the condition of 20 v% of methanol, 3 v% of sulfuric acid, retention time of 2.25 min and stirrer speed at 800 rpm

Retention time (min)	FFA (wt%)	WT (wt%)
0.00	14.467	0.748
2.25	1.053	1.360
4.50	0.958	1.533
6.75	0.828	1.407
9.00	0.837	1.573
11.25	1.231	1.403
13.50	1.092	1.407
15.75	1.094	1.650
18.00	1.029	1.453
20.25	1.047	1.853
22.50	1.044	1.640
Average (6 to 10 times of retention time)	1.061	1.601

Table H.26 Raw data of esterification under the optimization condition of 23.04 v% of methanol, 2.07 v% of sulfuric acid, retention time of 2.22 min and stirrer speed at 793 rpm

Sample	Retention Time (min)	1st experiment				2nd experiment			
		FFA (wt%)	FFA disappearance (mol)	WT (wt%)	WT appearance (mol)	FFA (wt%)	FFA disappearance (mol)	WT (wt%)	WT appearance (mol)
1	0.00	18.943	0.000	0.385	0.000	18.828	0.000	0.477	0.000
2	2.22	0.701	0.601	1.213	0.460	0.916	0.590	1.440	0.535
3	4.44	0.658	0.602	1.313	0.516	0.920	0.590	1.513	0.576
4	6.66	0.652	0.602	1.270	0.492	0.900	0.591	1.597	0.622
5	8.88	0.610	0.604	1.417	0.573	0.652	0.599	1.527	0.583
6	11.10	0.669	0.602	1.583	0.666	0.880	0.591	1.720	0.691
7	13.32	1.014	0.591	1.507	0.623	0.909	0.590	1.397	0.511
8	15.54	1.027	0.590	1.333	0.527	0.784	0.594	1.563	0.603
9	17.76	0.728	0.600	1.243	0.477	0.688	0.597	1.400	0.513
10	19.98	0.848	0.596	1.570	0.658	0.727	0.596	1.377	0.500
11	22.20	0.950	0.593	1.773	0.771	0.691	0.597	1.507	0.572
12	24.42	0.929	0.593	1.647	0.701	0.732	0.596	2.160	0.935
13	26.64	0.849	0.596	1.377	0.551	0.695	0.597	1.990	0.841
14	28.86	0.815	0.597	1.337	0.529	0.704	0.597	1.383	0.503
15	31.08	0.786	0.598	1.313	0.516	0.618	0.600	1.470	0.552
16	45	0.845	0.596	1.457	0.596	1.166	0.582	1.637	0.644
17	60	0.891	0.595	1.363	0.543	1.167	0.582	1.373	0.498
18	90	0.842	0.596	1.300	0.508	1.005	0.587	1.483	0.559
19	120	0.921	0.594	1.317	0.518	0.860	0.592	1.690	0.674
20	150	0.808	0.597	1.357	0.540	1.005	0.587	1.457	0.544
21	180	1.083	0.589	1.507	0.623	0.993	0.588	1.363	0.492
22	210	0.942	0.593	1.916	0.851	0.956	0.589	1.900	0.791
23	240	0.927	0.594	1.990	0.892	1.170	0.582	1.517	0.578
24	270	0.940	0.593	1.863	0.821	0.991	0.588	1.357	0.489
25	300	1.019	0.591	1.463	0.599	0.957	0.589	1.693	0.676
26	330	0.905	0.594	1.547	0.646	0.948	0.589	1.367	0.494
27	360	1.054	0.589	1.373	0.549	0.879	0.591	1.400	0.513
28	390	1.110	0.588	1.267	0.490	0.900	0.591	1.397	0.511
29	420	1.114	0.588	1.390	0.558	0.786	0.594	1.553	0.598
30	450	0.836	0.596	1.383	0.554	0.896	0.591	1.337	0.478
31	480	1.077	0.589	1.543	0.643	0.926	0.590	1.413	0.520
Average (6 to final times of retention time)		**0.931**	**0.593**	**1.485**	**0.611**	**0.886**	**0.591**	**1.535**	**0.588**

Table H.27 Raw data of decanter separation

Sample	Retention time (min)	1st experiment				2nd experiment			
		Before		After		Before		After	
		Acid value (g KOH/L of oil)	WT (%wt)	Acid value (g KOH/L of oil)	WT (%wt)	Acid value (g KOH/L of oil)	WT (%wt)	Acid value (g KOH/L of oil)	WT (%wt)
1	30	17.067	1.337	2.633	0.566	20.933	1.383	3.167	0.327
2	60	21.167	1.363	2.567	0.278	23.400	1.373	2.700	0.468
4	180	24.600	1.317	2.167	0.498	21.333	1.690	2.533	0.299
5	240	27.300	1.507	2.233	0.420	23.233	1.363	2.433	0.513
6	300	30.200	1.990	2.467	0.396	22.000	1.517	2.567	0.420
7	360	22.300	1.463	2.700	0.282	21.000	1.693	2.433	0.509
8	390	25.400	1.373	2.833	0.500	22.967	1.400	2.800	0.394
9	420	23.800	1.390	2.567	0.359	24.033	1.553	2.800	0.318
10	480	21.967	1.543	2.667	0.342	20.933	1.413	2.500	0.424
Average		**23.756**	**1.476**	**2.537**	**0.405**	**22.204**	**1.487**	**2.659**	**0.408**

Table H.28 Raw data of transesterification under the condition of 24 v% of methanol, 1 %wt/v of potassium hydroxide, retention time of 4.50 min and stirrer speed at 793 rpm

Sample	Time (min)	ME (wt%)	Sample	Time (min)	ME (wt%)
1	0	16.33	12	45	97.56
2	4	95.69	13	60	97.56
3	8	97.09	14	120	97.56
4	12	94.34	15	180	97.09
5	16	95.24	16	240	96.62
6	20	99.5	17	300	96.62
7	24	95.24	18	360	96.62
8	28	100	19	420	96.62
9	32	97.09	20	480	96.62
10	36	98.52	**Average (Sample 7-20)**		**97.23429**
11	40	97.56			

Table H.29 Raw data of methanol recovery

Sample	Retention time (min)	1st waste solution (wt%)	Crude biodiesel (wt%)	Crude glycerin (wt%)
1	0	59.00	5.08	19.68
2	180	48.50	0.47	0.57
3	240	43.40	1.21	0.71
4	300	15.00	1.47	0.85