

Modelling Batch Reactor for Milk Bush (*Thevetia peruviana*) Oil Transesterification in the Production of Biodiesel.

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Abstract: In this study, modelling equations for the simulation of batch reactor functional dimensions at isothermal condition are proposed exploiting the transesterification kinetic of Olatunji *et. al.* (2012). The kinetic model proposed by Olatunji *et. al.* (2012) was obtained through the laboratory experiment on which Biodiesel was produced using alcohol to oil molar ratio of 6:1, 9:1 and 12:1; the reaction temperature was put at constant 50^oC, and the catalyst loading percentages is between 0.5% and 1.5% as proposed by Olatunji *et. al.* (2012). From the results obtained, the modelling equations proposed are capable of simulating reactor dimensions as a function of the kinetic parameters. The simulated results obtained was analysed with MATLAB programming language which has demonstrated the dependency of reactor dimensions as proposed by the kinetic parameters proposed by Olatunji *et. al.* (2012).

Key words: Batch reactor, Milk bush oil, Transesterification, Biodiesel, Production

INTRODUCTION

In the search for alternative renewable energy sources, great deal of attention is focused on the Chemical Kinetics of Milk bush (*Thevetia peruviana*) oil transesterification process in biodiesel production (Olatunji *et. al.*,2011). The work of Olatunji *et. al.*, 2012 proposed the reaction kinetics of esters as follows:

$$\begin{aligned}\frac{dC_{TG}}{dt} &= r_{TG} = r_{1TG} + r_{2TG} \\ &= -K_1 C_{TG} C_A + K_2 C_{DG} C_E\end{aligned}\quad (1)$$

Where,

C_{TG} = Concentration of Triglyceride

C_A = Concentration of Alcohol

C_{DG} = Concentration of Diglyceride

K = Rate Constant.

But,

$K_1 C_A = K'_1$

$$\frac{dC_{TG}}{dt} = r_{TG} = r_{2TG} = -K'_1 C_{TG} + C_{TG} + K_2 C_D C_E \quad (2)$$

Where,

K'_1 = effective rate constant

C_E = concentration of Ester

In order to find a solution to equation (6) there is need to express C_D and C_E as a function of time. At the initial period when the reaction start to the final period (ie. time t_i to t_f , $t_i = 0$ and $t_f = t_{DG1}$). The diglyceride concentration was increased and then decreased.

Applying the equation proposed by Fogler (Fogler, 1999).

The suggested formula for this type of change in concentration is composed of two exponential terms.

$$C_{DG} = \frac{\beta_1(e^{-\beta_2 t} - e^{-\beta_3 t})}{\beta_3 - \beta_2} \quad (3)$$

Where,

β_1 , β_2 and β_3 are constants

t = time

$$C_{DG} = C_{DG0} + \frac{\beta_1(e^{-\beta_2 t} - e^{-\beta_3 t})}{\beta_3 - \beta_2} \quad (4)$$

Where,

C_{DGO} = Initial concentration of Diglyceride

After the final period, ie. $t_f = t_{dg1}$, diglyceride concentration went below its initial value, hence, equation (8) cannot be used to predict the final concentration of Diglyceride at this period. Therefore equation 8 may be written as equation 9.

$$C_D = C_{D0} + \frac{\beta_1(e^{-\beta_2 t} - e^{-\beta_3 t})}{\beta_3 - \beta_2} - \frac{\beta_4(e^{-\beta_5 t} - e^{-\beta_6 t})}{\beta_6 - \beta_5} \quad (5)$$

Also,

$$C_E = C_{E0} + \frac{w_1(e^{-w_2 t} - e^{-w_3 t})}{w_3 - w_2} \quad (6)$$

Substituting equation (9) and (10) into equation 6, taking the Laplace of the new equation developed; also by applying the partial fraction technique, and taking the inverse Laplace of the final equation.

C_{TG} , C_{DG} , and C_{MG} final equations were developed.

$$\begin{aligned} C_{TG} = & \frac{k_2 C_{D0} C_{E0}}{k'_1} + \frac{k_2 C_{E0} \left(\frac{\beta_1}{\beta_3 - \beta_2}\right)}{k'_1 - \beta_2} e^{-\beta_2 t} - \frac{k_2 C_{E0} \left(\frac{\beta_1}{\beta_3 - \beta_2}\right)}{k'_1 - \beta_3} e^{-\beta_3 t} \\ & - \frac{k_2 C_{E0} \left(\frac{\beta_4}{\beta_6 - \beta_5}\right)}{k'_1 - \beta_5} e^{-\beta_5 t} + \frac{k_2 C_{E0} \left(\frac{\beta_4}{\beta_6 - \beta_5}\right)}{k'_1 - \beta_5} e^{-\beta_6 t} + \frac{k_2 C_{D0} \left(\frac{\omega_1}{\omega_3 - \omega_2}\right)}{k'_1 - \omega_2} e^{-\omega_2 t} \\ & - \frac{k_2 C_{D0} \left(\frac{\omega_1}{\omega_3 - \omega_2}\right)}{k'_1 - \omega_3} e^{-\omega_3 t} + \frac{k_2 \left(\frac{\beta_1}{\beta_3 - \beta_2}\right) \left(\frac{\omega_1}{\omega_3 - \omega_2}\right)}{k'_1 - (\beta_2 + \omega_2)} e^{-(\beta_2 + \omega_2)t} \\ & + \frac{k_2 \left(\frac{\beta_1}{\beta_3 - \beta_2}\right) \left(\frac{\omega_1}{\omega_3 - \omega_2}\right)}{k'_1 - (\beta_3 + \omega_3)} e^{-(\beta_3 + \omega_3)t} - \frac{k_2 \left(\frac{\beta_1}{\beta_3 - \beta_2}\right) \left(\frac{\omega_1}{\omega_3 - \omega_2}\right)}{k'_1 - (\beta_2 + \omega_3)} e^{-(\beta_2 + \omega_3)t} \end{aligned}$$

$$\begin{aligned}
 & - \frac{k_2 \left(\frac{\beta_1}{\beta_3 - \beta_2} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right)}{k'_1 - (\beta_3 + \omega_3)} e^{-(\beta_3 + \omega_2)t} - \frac{k_2 \left(\frac{\beta_4}{\beta_6 - \beta_5} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right)}{k'_1 - (\beta_5 + \omega_2)} e^{-(\beta_5 + \omega_2)t} \\
 & - \frac{k_2 \left(\frac{\beta_4}{\beta_6 - \beta_5} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right)}{k'_1 - (\beta_6 + \omega_3)} e^{-(\beta_6 + \omega_3)t} + \frac{k_2 \left(\frac{\beta_4}{\beta_6 - \beta_5} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right)}{k'_1 - (\beta_5 + \omega_3)} e^{-(\beta_5 + \omega_3)t} \\
 & + \frac{k_2 \left(\frac{\beta_4}{\beta_6 - \beta_5} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right)}{k'_1 - (\beta_6 + \omega_2)} e^{-(\beta_6 + \omega_2)t}
 \end{aligned}$$

$$\left(\begin{aligned}
 & - \frac{(k_2 C_{D0} C_{E0})}{k'_1} - \left(k_2 C_{E0} \left(\frac{\beta_1}{\beta_3 - \beta_2} \right) \right) + \left(k_2 C_{E0} \left(\frac{\beta_1}{\beta_3 - \beta_2} \right) \right) \\
 & - \frac{\left(-k_2 C_{E0} \left(\frac{\beta_1}{\beta_3 - \beta_2} \right) \right)}{k'_1 - \beta_5} + \frac{\left(-k_2 C_{E0} \left(\frac{\beta_4}{\beta_6 - \beta_5} \right) \right)}{k'_1 - \beta_6} \\
 & - \frac{\left(k_2 C_{D0} \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - \omega_2} + \frac{\left(k_2 C_{D0} \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - \omega_3} \\
 & + \frac{\left(k_2 \left(\frac{\beta_1}{\beta_3 - \beta_2} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - (\beta_2 + \omega_2)} - \frac{\left(k_2 \left(\frac{\beta_1}{\beta_3 - \beta_2} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - (\beta_3 + \omega_3)} \\
 & + \frac{\left(k_2 \left(\frac{\beta_1}{\beta_3 - \beta_2} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - (\beta_2 + \omega_2)} + \frac{\left(k_2 \left(\frac{\beta_1}{\beta_3 - \beta_2} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - (\beta_3 + \omega_2)} \\
 & - \frac{\left(-k_2 \left(\frac{\beta_4}{\beta_6 - \beta_5} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - (\beta_5 + \omega_2)} - \frac{\left(-k_2 \left(\frac{\beta_4}{\beta_6 - \beta_5} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - (\beta_6 + \omega_3)} \\
 & \frac{\left(-k_2 \left(\frac{\beta_4}{\beta_6 - \beta_5} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - (\beta_5 + \omega_3)} + \frac{\left(-k_2 \left(\frac{\beta_4}{\beta_6 - \beta_5} \right) \left(\frac{\omega_1}{\omega_3 - \omega_2} \right) \right)}{k'_1 - (\beta_6 + \omega_2)} + C_{T0}
 \end{aligned} \right) e^{-k_1 t}$$

(7)

Where,

$K =$ rate constants

The final concentration of Diglyceride, Monoglyceride, Ester (Biodiesel) and Glycerol were derived in the same manner.

Where, α_i , β_i , ω_i , are constants derived from Fogler's equation to calculate the change in concentration of Tri, Di, Mono glycerides, Ester and glycerol. Type equation here.

These constants are determined using initial guess values. From Linear Regression method using MATLAB programming which was written to validate the model.

The aspect of modelling reactor functional parameters for large scale production of ester using the proposed Chemical Kinetic expression need to be proposed.

MATERIALS AND METHODS

The reaction mechanism demonstrated Isothermal Characteristics and the resulting design equation for a Batch Reactor is described as:

$$V_R = \frac{N_A}{t} \int \frac{dX}{-r_A} \quad (8)$$

From equation 1 it is possible that,

$$V_R = \frac{N_A}{t} \int \frac{dX_A}{K_1 C_{TG} C_A + K_2 C_{DG} C_E} \quad (9)$$

$$V_R = \frac{N_A}{t} \int (K_1 C_{TG} C_A + K_2 C_{DG} C_E)^{-1} dX_A \quad (10)$$

Applying Integration by Part,

$$V_R = \frac{N_A}{t} \left(\frac{dX_A}{K_1 C_{AO} (1 - X_A - K_2 (M + X_A))} \right) \quad (11)$$

Where,

$V_R =$ Volume of the Batch Reactor; $K_1 =$ Rate Constant

C_{AO} = Initial Concentration of Alcohol; M = Mass of the Oil

X_A = Molecular Weight of the Oil

Determination of heat generation per unit volume, Q

$$Q = \Delta H_R F_{AO} X_A \quad (12)$$

$$\frac{Q}{V_R} = \frac{\Delta H_R F_{AO} X_A}{V_R} \quad (13)$$

But,

$$\frac{Q}{V_R} = q \quad \text{and} \quad F_{AO} = \frac{N_A}{T}$$

Therefore,

$$q = \frac{\Delta H_R N_A X_A}{V_R T} \quad (14)$$

Substituting the values of V_R into equation 14 therefore,

$$q = \frac{\Delta H_R N_A X_A}{T} \left(\left(\frac{N_A}{t} \left(\frac{dX_A}{K_1 C_{AO} (1 - X_A) - K_2 (M + X_A)} \right) \right) \right)^{-1} \quad (15)$$

Determination of Overall heat transfer coefficient, u

$$q = u A \Delta T \quad (16)$$

Therefore,

$$u = \frac{q}{A_R \Delta T} \quad (17)$$

But,

$A_R = \pi R L$, therefore,

$$u = \frac{q}{\pi RL\Delta T} \quad (18)$$

Where,

u = overall heat transfer coefficient

q = heat generated per unit volume

R = radius of the batch reactor

L = length of the batch reactor, and

T = temperature

RESULTS AND DISCUSSIONS

Process optimization

The effects of catalyst concentration, alcohol-to-oil molar ratio and time were considered in the optimization of Milk bush (*Thevetia peruviana*) oil transesterification process. Tables 1.0 to 5.0, summarized the effects of catalyst concentration, alcohol-to-oil molar ratio and time in terms of conversion.

Effect of catalyst loading

The catalyst loading (KOH) was varied from 0.5 to 1.5 wt.% in this study. The reaction temperature was maintained at 50°C. The experimental results shows similar trend with the calculated results which shows that there was an increase in ester concentrations with catalyst loading. This is a typical observation which agrees with the findings of Zhous et al. (2003). However, the rate of the increase in ester concentration dropped when catalyst concentration was increased beyond 1 wt. %. In addition, the conversion increased as catalyst concentration increased. Potassium Hydroxide ions react with the methanol molecule to produce methoxide ions, and the rate of reaction increased when hydroxide concentration was increased.

TABLE 1: 0.5% KOH,6:1 alcohol to oil molar ratio at 50°C

Replicat ion	Time(m in)	α	β	α^2	β^2	$A\beta$	β_{est}	$\beta-\beta_{est}$	R^2
1	0.0	2.4423	2.4623	5.9648	6.0629	6.0137	2.4717	0.00936 731	0.0000877465
2	0.5	14.210 3	14.250 1	201.932 6	203.065 4	202.49 82	14.2361 4	0.07396 309	0.0001949679
3	1.0	20.426 1	20.475 0	417.225 6	419.225 6	418.22 44	20.4500 72	0.02492 783	0.0006213967
4	1.5	20.734 1	20.754 2	429.902 9	430.736 8	430.31 97	20.7579 80	0.00377 977	0.0000142867
5	2.0	21.124 6	21.146 9	446.248 7	447.191 4	446.71 98	21.1483 62	0.00146 262	0.00000213925 72
6	3.0	23.185 9	23.185 9	537.586 0	537.586 0	537.58 60	23.2090 44	0.02314 423	0.0005356553
7	4.0	23.297 3	23.300 0	542.764 2	542.890 0	542.82 71	23.3204 108	0.02041 081	0.0004166012
8	5.0	23.378 7	23.398 0	546.563 6	547.466 4	547.01 48	23.4017 86	0.00378 639	0.00001433675
9	6.0	23.456 6	23.467 0	550.212 1	550.700 1	550.45 60	23.4796 6	0.01266 302	0.00016035208
10	7.0	23.534 3	23.573 1	553.863 3	555.691 0	554.77 64	23.5573 4	0.01576 029	0.00024838674
11	8.0	23.612 2	23.662 9	557.536 0	550.932 8	558.73 31	23.6352 16	0.02768 37	0.00076638503 1
12	9.0	24.541 2	24.551 2	602.270 5	602.761 4	602.51 59	24.5639 4	0.01273 76	0.00016224747
13	10.0	30.764 5	30.784 5	946.454 5	947.685 4	947.06 98	30.7853 71	0.00087 065	0.00000075803 14225
		274.70 81	275.01 11	6,338.5 248	6,350.9 952	6,344.7 55			0.003

TABLE 2: 1.0% KOH,6:1 alcohol to oil molar ratio at 50°C

Replicati on	Time(m in)	α	β	α^2	β^2	$\alpha\beta$	β_{est}	$\beta-\beta_{est}$	R^2
1	0.0	2.3205 6	2.3406	5.3850	5.4784	5.4315	2.3481	- 0.007531 78	0.00005672 765
2	0.5	16.355 9	16.386 0	267.515 5	268.501 0	268.007 8	16.37786	0.008142 4	0.00006629 80
3	1.0	19.829 0	19.869 0	393.189 2	394.777 2	393.982 4	19.8496	0.01943	0.00037758 71
4	1.5	22.132 95	22.143 0	489.865 3	490.312 4	490.088 8	22.15254 7	- 0.009547	0.00009114 215
5	2.0	30.065 6	30.086 1	903.940 3	905.173 4	904.556 6	30.08207	0.004026 24	0.00001621 061
6	3.0	30.230 5	30.250 7	93.8831	915.104 9	914.493 8	30.24590 8	0.003792 2	0.00001438 08
7	4.0	30.325 3	30.345 2	919.623 8	920.831 2	920.227 3	30.34167 0	0.003530 12	0.00001246 175
8	5.0	30.415 8	30.444 6	925.120 9	926.873 7	925.996 86	30.43213 3	0.012466 32	0.00015540 913
9	6.0	30.506 5	30.516 5	930.646 5	931.256 8	930.951 6	30.52280	- 0.006297 4	0.00003965 725
10	7.0	30.597 5	30.600 0	936.207 0	936.360 0	936.283 5	30.6138	- 0.013761	0.00018936 51
11	8.0	30.689 1	30.709 1	941.820 9	943.048 8	942.434 6	30.70532 436	0.003775 04	0.00001425 55
12	9.0	30.781 0	30.791 0	947.467 0	948.085 7	947.777 7	30.79718 76	0.006187 6	0.00003828 64
13	10.0	30.873 3	30.893 3	953.160 7	954.396 0	953.778 1	30.88945	0.003849 32	0.00001481 726
		335.12 30	335.37 51	9,527.82 52	9,540.19 95	9,534.01 12			0.0011

TABLE 3: 1.5% KOH,6:1 alcohol to oil molar ratio at 50°C

Replicati on	Time(m in)	α	β	α^2	β^2	$\alpha\beta$	β_{est}	$\beta-\beta_{est}$	R^2
1	0.0	2.4528	2.4730	6.0162	6.1157	6.0658	2.4663	0.006718 88	0.000451433 48
2	0.5	16.596 7	16.596 7	275.450 5	275.795 8	275.623 1	16.6158	- 0.008738 68	0.000076364 528
3	1.0	20.681 09	20.701 9	427.707 5	428.568 7	428.137 9	20.7018 6	0.000037 564	0.000000001 411
4	1.5	22.463 8	22.473 5	504.622 3	505.058 2	504.840 2	22.4853	- 0.011785 52	0.000138898 482
5	2.0	27.404 3	27.404 3	750.995 7	750.995 7	750.995 7	27.4278	- 0.023461 72	0.000055045 23
6	3.0	27.337 5	27.377 5	747.338 9	749.527 5	748.432 4	27.3609 35	0.016565	0.000274399 23
7	4.0	27.482 0	27.507 0	755.260 3	756.360 0	755.810 0	27.5055	0.003492 8	0.000012199 652
8	5.0	27.619 9	27.679 9	762.858 9	766.176 9	764.516 1	27.6434 5	0.036452 04	0.001328751 22
9	6.0	27.758 1	27.798 1	770.512 1	772.734 4	771.622 4	27.7817	0.016396 76	0.000268853 74
10	7.0	27.897 3	27.917 3	778.259 3	779.375 6	778.817 3	27.9209 6	- 0.003658 92	0.000013387 7
11	8.0	30.037 4	30.067 4	902.245 4	904.048 5	903.146 5	30.0619	0.005485 04	0.000030085 7
12	9.0	30.178 4	30.198 4	910.735 8	911.943 4	911.339 4	30.2030	-0.457136	0.000020897 3
13	10.0	30.230 9	30.250 9	913.907 3	915.117 0	914.511 9	30.2554 92	- 0.004592 36	0.000021089 77
		318.14 02	318.45 13	8,505.91 02	8,521.81 74	8,513.85 87			0.0023

TABLE 4: 1.0% KOH,9:1 alcohol to oil molar ratio at 50° C

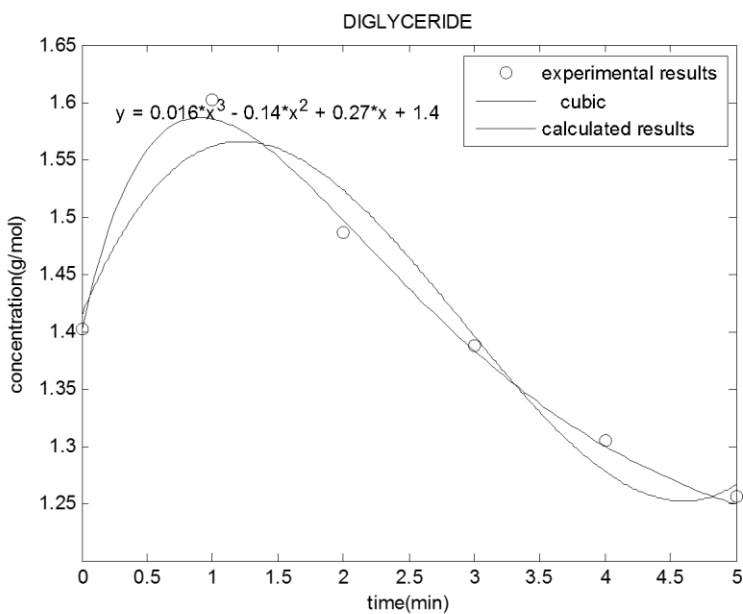
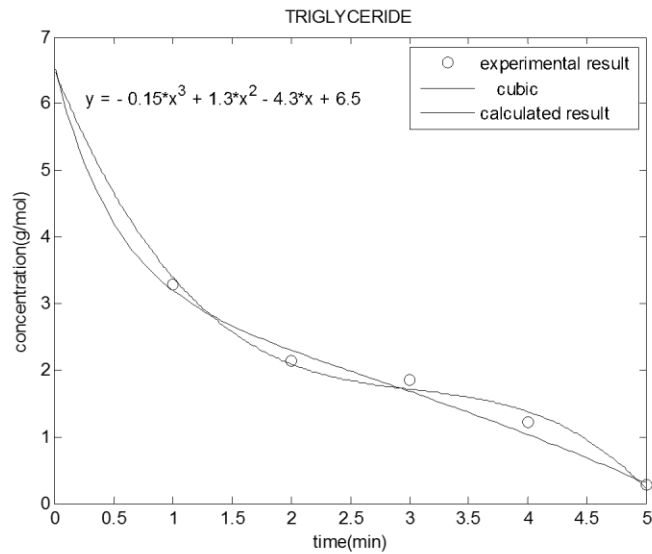
S/N O	TIME(Mi n)	α	β	α^2	β^2	$\alpha\beta$	β_{est}	$\beta-\beta_{est}$	R^2
1	0.0	2.3468	2.3668	5.50747	5.601742 2	5.5544	2.4009	0.034069 4	0.00116072192 1
2	0.5	9.1462	9.1762	83.6530	84.2026	83.927 4	9.2016	-0.02543	0.00064664624 7
3	1.0	15.200 5	15.240 5	231.0552	232.2728	231.66 32	15.2571	- 0.016640 1	0.00027689292
4	1.5	18.301 1	18.351 1	334.9303	336.7629	335.84 53	18.3584	0.007260 22	0.00005271079 445
5	2.0	18.664 6	18.684 6	348.3673	349.1143	348.74 06	18.7219	-0.03733	0.0013937469
6	3.0	24.953 5	24.983 6	622.6772	624.1803	623.42 83	25.0121	-0.2849	0.00081171998 7
7	4.0	25.336 0	25.376 0	641.9129	643.9414	642.92 63	25.3946 67	- 0.018667 2	0.00034846436
8	5.0	26.707 4	26.727 4	713.2852	714.3539	713.81 94	26.7663 4	- 0.038941 48	0.00151643887
9	6.0	27.411 6	27.441 6	751.3958	753.0414	752.21 82	27.4707	- 0.029082 32	0.00084578134
10	7.0	27.516 4	27.556 4	757.1523	759.3552	758.25 29	27.5755	- 0.019103 28	0.0003649353
11	8.0	27.627 3	27.647 3	763.2677	764.3732	763.82 03	27.6864	- 0.039125 46	0.00153080162
12	9.0	27.951 8	27.981 8	781.3031	782.9811	782.14 17	28.0110	- 0.029190 36	0.00085207712
13	10.0	28.456 6	28.496 6	809.7781	812.0562	810.91 63	28.5159	- 0.019291 32	0.00037215507
		279.61 98	280.02 99	6,844.28 56	6,862.23 70				0.01

TABLE 5: 1.0%KOH, 12:1 alcohol to oil molar ratio at 40° C

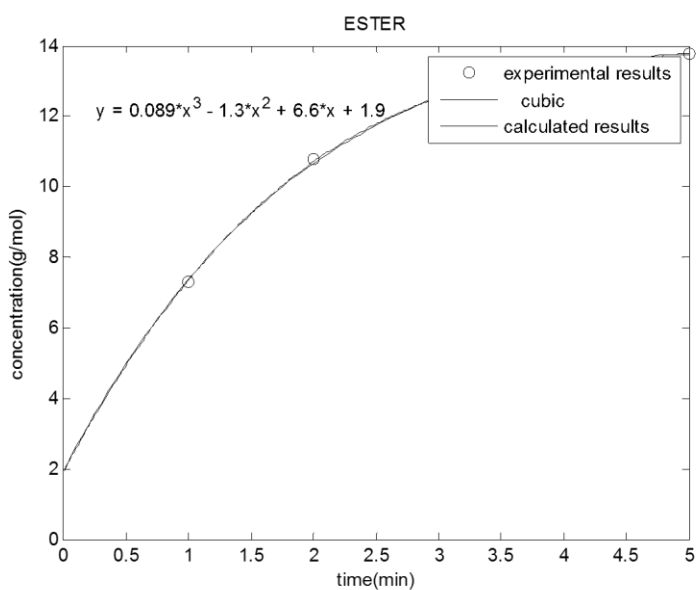
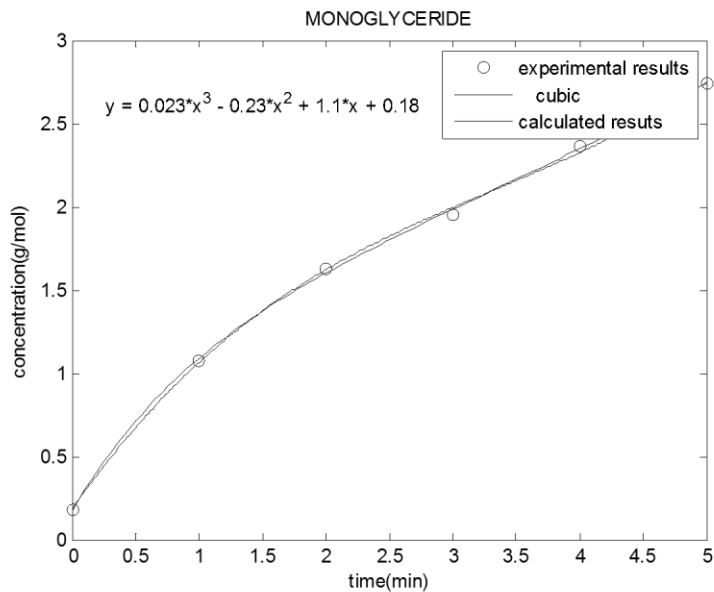
S/N O	TIME(m in)	α	β	α^2	β^2	$\alpha\beta$	β_{est}	$\beta-\beta_{est}$	R^2
1	0.0	2.1682	2.1882	4.7011	4.7882	4.7882	2.1929	- 0.000471 682	0.00002224839 09
2	0.5	9.5462	9.5762	91.1299	91.7036	91.4163	9.571654 6	- 0.004544 38	0.00002066047 934
3	1.0	14.101 2	14.141 2	198.843 8	199.973 5	199.407 9	14.12711 0	0.014089 88	0.00001985247 184
4	1.5	16.622 0	16.642 0	276.290 9	276.956 2	276.623 3	16.6482	- 0.006162 2	0.00003797270 884
5	2.0	17.746 1	17.776 1	314.924 1	315.989 7	315.456 4	17.7724	0.003725 39	0.00001387853 065
6	3.0	22.867 2	22.867 2	522.908 8	522.908 8	522.908 8	22.8939	- 0.026786 72	0.00071752836 84
7	4.0	23.615 50	23.635 5	557.691 8	558.636 9	558.164 2	23.64236 16	0.006861 55	0.00000470808 684
8	5.0	24.299 4	24.329 4	590.460 8	591.919 7	591.189 8	24.32633 00	0.003700 6	0.00000942526 844
9	6.0	24.640 1	24.680 1	607.134 5	609.107 3	608.120 1	24.66706	0.013035 99	0.00016993703 53
10	7.0	25.016 1	25.036 1	625.805 3	626.806 3	626.305 6	25.04310 2	0.007001 61	0.00004902254 259
11	8.0	25.670 2	25.700 2	658.959 2	660.500 3	659.729 3	25.69726 702	0.002932 98	0.00000860237 168
12	9.0	25.924 9	25.964 9	672.100 4	674.176 0	673.137 4	25.95199 2	0.012907 51	0.00016660381 44
13	10.0	26.250 5	26.280 5	689.088 8	690.664 7	689.876 3	26.27762 505	0.002874 95	0.00000826533 7503
		258.46 79	258.81 76	5,810.03 94	5,824.13 12	5,817.07 99			0.0015

Effect of alcohol-to-oil molar ratio

The effect of alcohol to oil molar ratio (6:1, 9:1, and 12:1) on ester concentration was studied at 50°C. This results are given in Figure 2.0 (a), (b). As shown in Figures 2.0 and Tables 1.0 to 5.0 ester concentration as well as the % conversion decreased as the alcohol-to-oil molar ratio was increased. This can be explained on the basis of the reactant (oil) concentration in the reaction mixture. By increasing alcohol to oil molar ratio, the amount of alcohol was increased, therefore the Milk bush and catalyst concentrations were diminished, which reduced the rate of reaction. Results published by Boocock et al. (1998) showed a similar trend in which the methyl ester percentage decreased as the alcohol-to-oil molar



ratio was increase. In the case of a higher reaction temperature, although the similar trend of ester concentration (ester concentration decreased with an increase in alcohol-to-oil molar ratio) was observed as shown in Figure 2.0, (b) the % conversion increased with alcohol-to-oil molar ratio (See Table 1.0 to



5.0). As alcohol molar ratio was increased, the polarity of the system was also increased thus improving ionization of KOH. As a result, the rate of the reaction as well as the % conversion was increased.

Result from this part of the study suggest that the optimum in alcohol-to-oil molar ratio operating at low temperature below 50°C was 6:1. However, the higher in alcohol-to-oil molar ratio (12:1) is recommended at higher operating temperature (50°C).

Effect of Time

From the results obtained, it could be observed that as the time increases, the concentration of ester produced also increased, this is in agreement with the findings of Olatunji et al., (2011), Suppes et al., (2004) and Darnoko and Cheryan (2000)

CONCLUSION

The rate of formation reaction temperature, catalyst concentration, or decreasing alcohol to oil molar ratio was observed. The optimum conditions for milk bush oil methanolysis are at a reaction temperature of 50°C and 1.0 wt % KOH. The 6:1 alcohol-to-oil molar ratio was found to be optimum at low reaction temperature below 50°C. At high reaction temperature (50°C), 12:1 alcohol-to-oil molar ratio is recommended.

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