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ECONOMIC PERFORMANCE OF ACID AND ALKALINE CATALYST PROCESSES FOR BIODIESEL PRODUCTION FROM ANIMAL FAT

[1]B. Suleiman*, [1]A.S Abdulkareem, [1]U. Musa, [1]I.A Mohammed, [1]Y.B Suleiman and [1]S.S Oluwadamilare

[1]Department of Chemical Engineering, School of Engineering and Engineering Technology, Federal University of Technology Minna PMB 65, Niger State, Nigeria
bilyaminusuleiman@futminna.edu.ng, kasaka2003@futminna.edu.ng, umar.musa@futminna.edu.ng, ma.ibrahim@futminna.edu.ng, bays2b@yahoo.com, tiwatiwa007@gmail.com
*Corresponding Author: email: bilyaminusuleiman@yahoo.com, bilyaminusuleiman@futminna.edu.ng, Cell: +2347036970741

ABSTRACT

Several processes have been proposed for biodiesel production but the ultimate aim of any process is to be economically feasible. The quest to identify the most economically feasible process configuration for biodiesel production from animal fats suggest the use of simulation approach to obtain the necessary data at optimal operating parameters and specified feed and product specifications for economic assessment. Two process configurations for biodiesel production from virgin and waste animal fat using acid and alkaline catalysts were identified and selected respectively. Acid and alkaline process configurations using both virgin and waste animal fat as feed were simulated to produce biodiesel with minimum purity of 99.9 % using Aspen Hysys version 7.2 at oil feed flow rates of 1.16 kmol/h and 1.19 kmol/h respectively. The raw materials requirement, product flow (desired and undesired), utility consumption and equipment sizes were evaluated from the simulation process. The result of economic analysis of alkaline transesterification of waste fat oil shows that the process has the highest total capital investment of $935 353.67 but yet is the most favoured with highest profit before tax resulting from its higher gross income and low cost of raw materials. Similar observation was made in the acid catalyzed process where the use of waste animal fat had the highest total capital investment of $1 995 507 and the most preferred option with highest net profit of $384 410. Among all the various processes investigated an alkaline process using waste animal fat is the most economical option for biodiesel production capable of handling industrial scale production.

Keywords: Economic, Analysis, Biodiesel, Simulation, Animal fats, configuration.

1.0 INTRODUCTION

Biodiesel is an alternative diesel fuel that can be derived from vegetable oils or animal fats (Ma and Hanna, 1999). It is also referred to as the mono-alkyl esters of long chain fatty acids derived from a renewable lipid feedstock which could be vegetable oil or animal fats. However, there are large amounts of fats and oils available that can be unsuitable for human consumption (non-edible) that could be converted to biodiesel at lower cost (Canakci *et al*., 1999). Biodiesel is generally considered to be renewable, environmental friendly, substitute to petroleum diesel as an alternative fuel and provides support to farmers as well as reducing dependency on petroleum (Elsolh, 2011). The advantage of biodiesel to petroleum based diesel is its renewability, quality as an exhaust emission, biodegradability, photosynthetic nature of all its carbon content and its

low combustion of carbon dioxide (CO_2) into the atmosphere (Kumar and Padam, 2013). Transesterification is a reversible reaction of fats or oil (Triglycerides) with an alcohol to form fatty acid alkyl esters and glycerol. Stoichiometrically, the reaction requires a 3:1 molar alcohol-to-oil ratio, but excess alcohol is usually added to drive the equilibrium toward the products side. The catalyst for transesterification can be alkali, acid or enzyme (Ma and Hanna, 1999). However, the use of enzyme is less effective as it requires longer reaction time and cannot yet be implemented at commercial scale level (Nelson and Schrock, 1996). The alkali catalyst used is NaOH or KOH in the presence of methanol or ethanol with any kind of oil (Crude, refined or waste). The limitation of catalyzed transesterification process is the sensitivity to the water and free fatty acids. Acid catalyst such as sulphuric acid gives very high yield in esters but the reaction is usually very slow and requires a high ratio of alcohol and glycerides. The high cost of biodiesel production is the major impediment to its large scale commercialization (Canakci and Van Gerpen, 2001).

Besides the efficiency of the energy integration, the economic performance expressed by the production costs determines the process thermo-economic performance (Tock, 2009). The production costs are defined by the total annual costs of the system divided by the produced amount of fuel (Tock, 2009). The total annual production costs consist of annual capital investments, operating and maintenance costs, biomass feedstock expenses and electricity costs. The economic evaluation is based on the size of the different equipments determined by the process productivity defined by the different decision variables and operating conditions (Tock, 2009). The cost for operating a system depends on the type of financing, the required capital and expected life of a component etc.

Previous economic analysis of biodiesel processes include that of Araujo *et al.* (2010) that carried out an economic analysis of biodiesel production using waste frying oils (WFO) as the feedstock and developed a mathematical programming model for vehicle routing which determines the logistics costs involved in biodiesel production from waste fuel oil (WFO). Yii-Der *et al*. (2008) evaluated the economic costs of three biodiesel plants with capacities of 8000, 30 000, and 100 000 tons/year. The plants employ continuous processes using alkali catalyst and soybean oil as the raw material of biodiesel production for which six major economic cost factors namely the fixed capital cost (FCC), total capital investment cost (TCC), total manufacturing cost (TMC), net annual profit after taxes (NNP), after-tax rate of return (ARR), and biodiesel break-even price (BBP) were examined.

Zhang *et al.* (2003) also carried out an economic analysis of four continuous processes to produce biodiesel. The processes assessed are alkali- and acid-catalyzed processes using waste cooking oil and the standard process using virgin vegetable oil as the raw material. It was discovered that even though the alkali-catalyzed process using virgin vegetable oil had the lowest fixed capital cost, the acid-catalyzed process using waste cooking oil was more economically feasible, providing a lower total manufacturing cost, a more attractive after-tax rate of return and a lower biodiesel break-even price.

To the best of the author's knowledge, the economic potentials of using acid and alkaline processes to produce biodiesel from waste animal fat have not been investigated. The aim of this work is to determine the economic viability of using acid and alkaline processes to produce biodiesel and identify the most economically efficient process route.

2.0 METHODOLOGY

2.1 Process Identification and Selection

There are various process configurations developed in literature for commercial production of biodiesel (Marchetti *et al*., 2008, Keat *et al*., 2008, Karmakar *et al*., 2010).Two biodiesel process configurations were chosen from the works reported in literature for alkaline (West *et al*., 2008, Zhang *et al*., 2003; Ellis *et al*., 2011) and acid processes (Zhang *et al*., 2003). For biodiesel production, the selected methods of production relying on the type of catalyst utilize for production which include Alkali-catalyzed, Acid-catalyzed, Heterogeneous, enzymes and supercritical methods. Two configurations were identified from the work of Ellis *et al.* (2011) for alkaline process and Zhang *et al.* (2003) for acid process. The selected configurations were simulated using Aspen Hysys version 7.2 as a process simulator.

2.2 Simulation of Selected Configurations

2.2.1 Simulation of alkaline process configurations

In the simulation of the two selected configurations of alkaline processes, the choice of Aspen Hysys was based on its simulation

competency, thermodynamics properties and its capacity to incorporate calculations using the spreadsheet tool. In Aspen Hysys, the foremost action in building a process simulation was the selection of chemical components for the process, as well as a thermodynamic model (fluid package). Moreover, unit operations and operating conditions, plant capacity and input conditions were selected and stated. The unit operations, plant capacity and input conditions for the virgin and waste animal fats was based on Ellis *et al*. (2011). One of the critical factors in the modeling of transesterification process is the choice of a model compound to characterize the triglyceride which comprises different constituents of fatty acids. Triolein was chosen as a model compound of vegetable oils in different studies (Zhang *et al*., 2003; Haas *et al*., 2006; West *et al*., 2008). Triolein constitute three oleic acids with a glycerol bond, but oleic is the main fatty acid in many vegetable oil and animal fats. It comprises between 40-80 % of fatty acids in rapeseed, canola, olive, palm and peanut oil (Ma and Hanna, 2003). A hypothetical component of Triolein was created in Hysys using the density of chicken oil (912 kg/m^3) and the density of animal fats obtained from Canakci *et al*. (2011). To estimate the waste animal fat, the density of triolein was reduced by inputting 10 % weight of oleic acid to represent the high fatty acid in the waste. Hysys Non-random two liquid (NRTL) model was chosen as a property package for both Alkali- fresh and waste animal fats processes because of the polar compounds present in the simulation. The flowsheet shown in Figure 1 and 2 was developed in the Aspen Hysys simulation environment. In developing the flow sheet mixer was selected from object pallet, the inlet streams condition was specified for stream 1 (methanol) and 2 (NaOH) as shown in Table 1. Pump was selected from object palette and it was specified based on its outlet pressure meant to increase the pressure of the mixed stream (S3A).The fresh oil enter the pump (P-100) whose exit pressure was also specified. Heater was selected to heat the fresh oil before it enters into the reactor. Stream 3A mixed with recycle methanol stream 6C, the mixer exist stream 3B and fresh oil from the heater enters the reactor. The reactor was simulated by specifying the reaction type, the conversion and the outlet temperature. However, the exit streams from the reactor containing biodiesel and other components were passed to remove excess methanol in its recovery column. The column was simulated by selecting a distillation column from the object palette, specifying the number of stages, pressure, the reflux ratio, molar flow-rates of the top product, number of stages and feed position. Others include operating parameters such as temperature, pressure and flow rate were specified as contained in Table 1. The component splitter used in the water washing act like a gravity settler and its percentage split was specified. However, other equipment used in developing the process flow sheet follows the same procedures. Similarly, flow sheet building in Figure 2 followed the same procedure as that of Figure 1 except that heat exchanger was used for the waste process in the pre-treatment stage specified by the hot stream temperature.

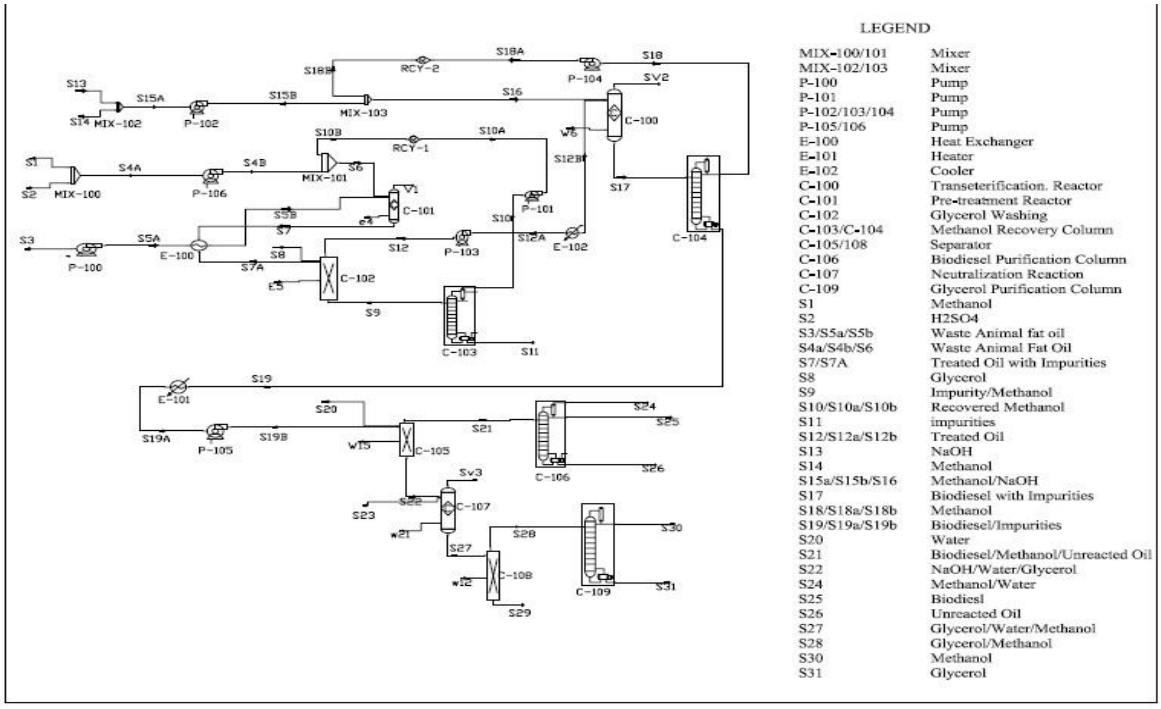

Figure 1. Process Configuration I (Alkali-catalyzed process using fresh animal fat)

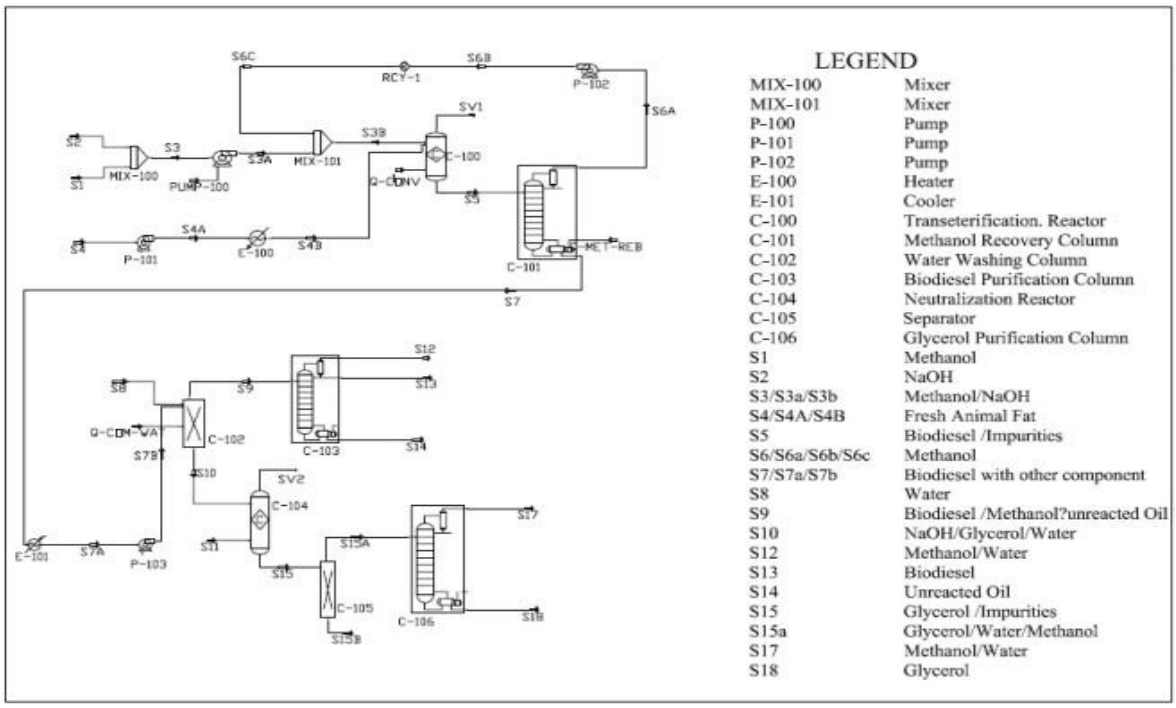

Figure 2. Process Configuration 2 (Alkali-catalyzed process using fresh animal fat)

Table 1. Aspen Hysys input parameters for the two selected Alkaline process configurations

Pre-treatment Stage	Fresh Animal Fat	Waste Animal Fat
Oil feed flow (kmol/hr)	-	1.19
Methanol feed flow(kmol/hr)	-	3.75
Catalyst H_2SO_4 feed flow	-	0.1
Numbers of stage of stage of Methanol recovery	-	5
Pressure of Methanol recovery(kPa)	-	20
Methanol feed flow	3.66	3.66
Oil feed flow	1.19	1.19
NaOH feed flow	0.25	0.25
Temperature of Methanol feed (^{o}C)	25	25
Temperature of Oil feed flow(^{o}C)	60	60
Temperature of NaOH (^{o}C)	25	25
Number of theoretical stage of Methanol recovery	5	5
Number of theoretical stage of Biodiesel purification stage	5	5
Number of Glycerol purification stage	5	5
Pressure in the Methanol recovery stage(kPa)	20	20
Pressure of Biodiesel purification stage(kPa)	10	10
Pressure of Glycerol purification stage(kPa)	20	20
Temperature of transesterification Reactor	60	60
Temperature of Neutralization Reactor	60	60
Feed flow of glycerol washing	-	1.39
Feed flow of water washing	0.611	0.611
Temperature of water washing ^{o}C	25	25
Pressure of water washing(atm)	1	1
Pump (P-100, P-101, P-102)	400	400
Pump (P-103)	200	-
Pump (P-103, P-104,P-106)	-	400
Pump (P-105)	-	200
Heat Exchanger 1 (Temperature ^{o}C)	-	85

Heat Exchanger 2 (Temperature ^{o}C)	60	60
Heat Exchanger 3 (Temperature ^{o}C)	60	60
Reaction Conversion	95 %	95 %

2.2.2 Simulation of the acid process configurations

The two (2) selected configurations (Figure 3-4) from the work of Zhang *et al*. (2003) were simulated using Aspen Hysys version 7.2 because it is equipped with comprehensive thermodynamic packages, vast component libraries and advanced calculation techniques (West *et al.*, 2008). In the simulation process, the basic procedures involves defining chemical components, selecting appropriate thermodynamic model and building of the process flow sheet from one unit to another. This involves defining all inputs streams parameters (flow rate, temperature, pressure and composition). Selection of appropriate equipment and specification of its optimal operating variables for a set of operations and finally running the overall flow sheet developed to achieve convergence and ensure the target objective was achieved at an optimal condition.

Information on most of the components used in this research work was available in the version used (version 7.2) except for a few components like calcium oxide and calcium sulfate. These components were defined using ''the Hypo Manager'' tool in Hysys. Regarding the animal oil feedstock, beef tallow was considered as the raw material in both virgin and waste form. Because oleic acid is the major fatty acid in beef tallow (Gerpen *et al.,* 2004), triolein ($C_{57}H_{104}O_6$) was chosen to represent beef tallow in the Hysys simulation. Accordingly, methyl-oleate ($C_{19}H_{36}O_2$) was taken as the resulting biodiesel product and its properties were available in the Hysys component library. The waste oil in the simulation was also defined in the Hysys and the major difference that exists in the waste oil is its density and the value for the waste animal fat density was obtained as 870 kg/m3 from the work of Bousbaa *et al.* (2013). The major parameters needed to develop a Hypo are molecular mass, density and boiling point of the particular component (Zhang *et al.,* 2003). Due to the presence of the highly polar components i.e. methanol and glycerol, the Non-Random Two Liquid (NRTL) thermodynamic/activity model was recommended to predict the activity coefficients of the components in a liquid phase.

The main processing units include reactors, distillation columns, extraction columns, heat exchangers, pumps and separators. Because detailed information on the kinetics was not available, a simple conversion reactor model with 97 % of oil conversion to FAME was used to describe both reactions. It was assumed that the reactor was a continuous stirred tank reactor and the fill factor of the reactor (the ratio of reaction to reactor volumes) was set at 0.5. Multi-stage distillation was used for methanol recovery as well as purification of both the FAME and glycerine products. Although the boiling point of methanol (65 °C at 1 atm) is much lower than that of FAME (approximately 320 ^{O}C at 1 atm) or glycerol (300 °C at 1 atm), simulations suggested that the desired purities of biodiesel and glycerol (greater than 90 wt.%) could not be achieved by a simple flash unit. The ASTM standard for purity of biodiesel product (i.e., 99.65 wt %) was applied to both processes in the present study. However, the large difference in the boiling points of the components facilitates distillation of which only five theoretical stages in the columns are sufficient to yield high quality biodiesel and glycerine. A tray efficiency of 60–70 % was assumed in the distillation column. FAME and glycerol are very easy to decompose thermally above 250 and 150 °^{O}C, respectively, and then vacuum operation was applied for both columns in which FAME and glycerin were purified. This was necessary in order to suppress their temperatures at a considerable low level (not to exceed 150 ^{o}C). The use of component splitter was employed as suggested (West *et al.,* 2007) to separate biodiesel from the other components (after methanol distillation column). After the input information and operating unit models were set up, the process steady-state simulation was executed by Hysys with input simulation parameters as contained in Table 2.

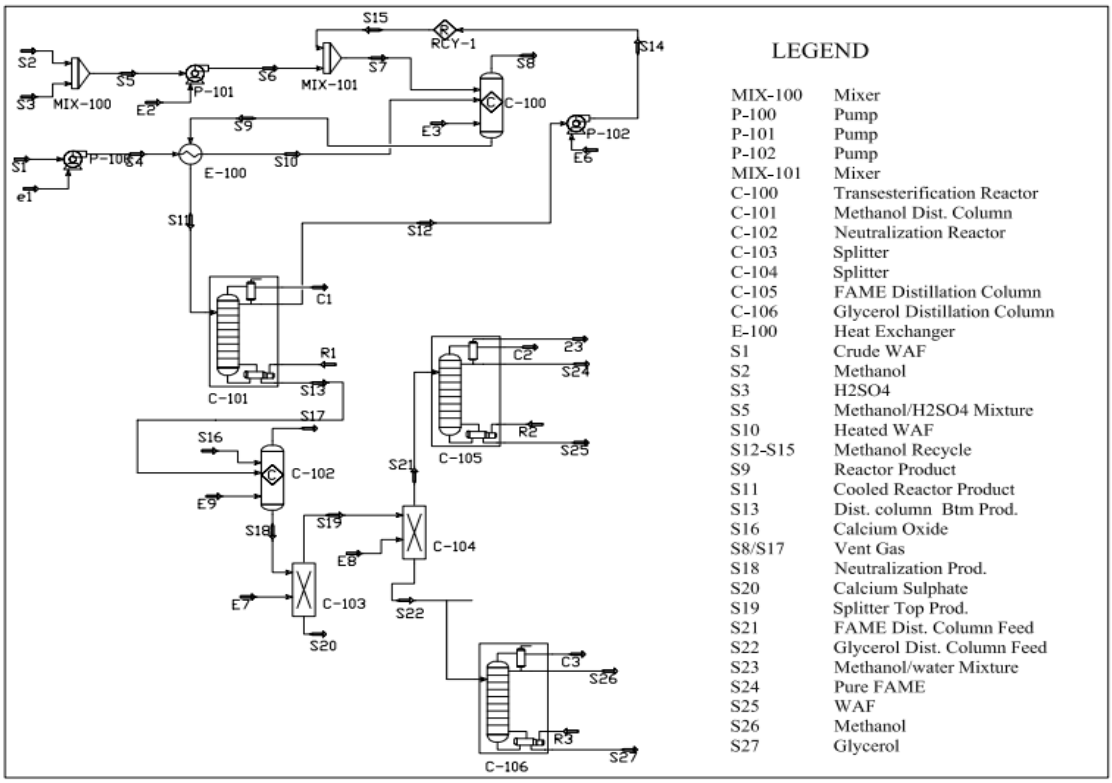

Figure 3. Process Configuration I (Acid-catalyzed process using fresh animal fat)

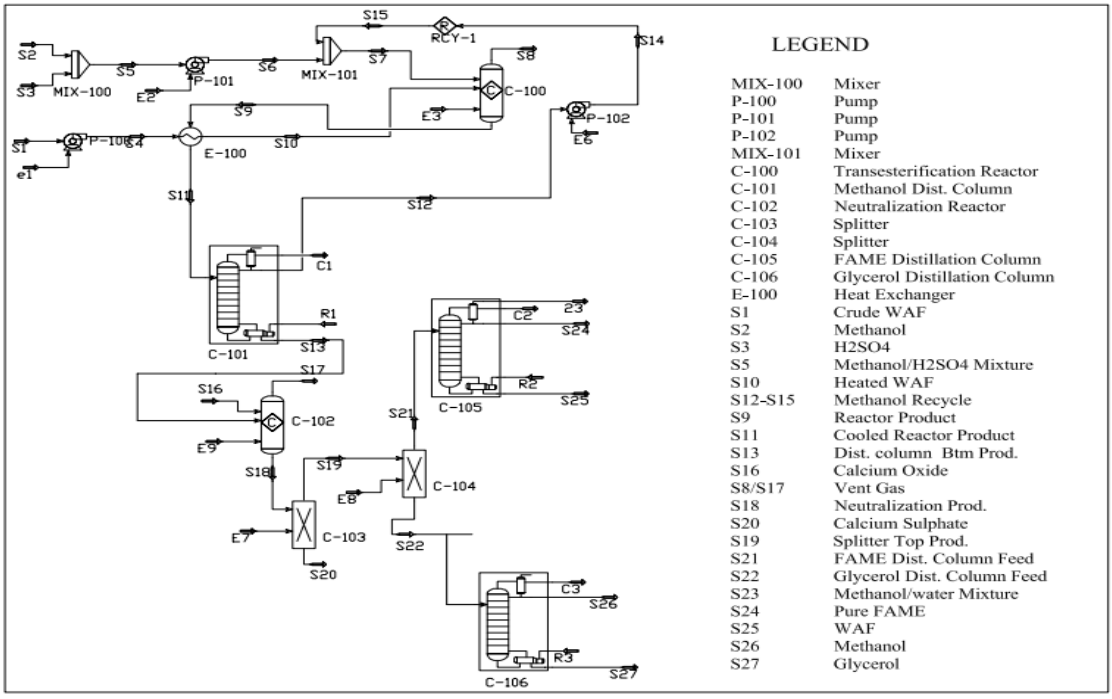

Figure 4. Process Configuration 2 (Acid-catalyzed process using waste animal fat)

Table 2. Aspen Hysys input parameters for the two selected Acid process configurations

.Operating conditions	FAF	WAF
Oil feed flow (kmol/hr)	1.16	1.16

Methanol feed flow(kmol/hr)	6.75	6.75
Catalyst(H_2SO_4) feed flow	1.53	1.53
Water feed (kmol/hr)	-	1.551
Fresh Methanol feed(kmol/hr)	-	27.81
Methanol recovery column stages	5	5
Methanol recovery column Pressure (kPa)	20&30	20&30
Temperature of Methanol feed (^OC)	25	25
Temperature of Oil feed flow(^OC)	25	25
Temperature of H_2SO_4 (^OC)	25	25
Biodiesel recovery column stages	5	5
Glycerol recovery column stages	5	5
Biodiesel recovery column pressure (kPa)	20&30	10&20
Glycerol recovery column pressure (kPa)	20&30	20&30
Transesterification Rxt temperature(^OC)	80	82
Neutralization Rxt temperature(^OC)	60	60
n-Hexane feed flow (kmol/hr)	-	0.9996
Pump (P-100, P-101, P-102)	400	400
Pump (P-103)	-	100
Transesterification Rxt pressure (kPa)	400	400
Neutralization Rxt pressure (kPa)	30	160
Heat Exchanger Duty (kJ/h)	4386	7.369e4
Cooler (Temperature Duty(kJ/h)	-	3.226e7
$CaSO_4$ Splitter Temperature (^OC)	60&60	40&40
$CaSO_4$ Splitter Pressure (kPa)	130&130	160&160
FAME/Glycerol Splitter Temperature (^OC)	50&60	25&40
FAME/Glycerol Splitter Pressure (kPa)	110&120	180&190
FAME/n-Hexane Splitter Temperatre (^OC)	-	60&60
FAME/n-Hexane Splitter Pressure (kPa)	-	150&160
Glycerol/$CaSO_4$ Splitter Tempeture (^OC)	-	40&40
Glycerol/$CaSO_4$ Splitter Pressure (kPa)	-	160&160

3.0 RESULTS AND DISCUSSION

3.1 Alkali catalyzed processes

The result presented in Table 3 to 5 shows the economic analysis and comparison of this two selected process configurations on the basis of equipment cost, utility cost and profitability analysis. Table 3 and Table 4 shows the cost of utility and equipment used for the production of biodiesel using fresh and waste animal fats respectively. The sizes of the equipment were obtained from Hysys version 7.2 simulation results and Pro-econs process economic spreadsheet on MATLAB was used to evaluate the cost of equipment used for the simulation using 2014 chemical engineering equipment cost index (CEPCI) of 685.74.

Table 3 and 4 shows the cost of equipment with the heater (E-100) having the lowest cost. The equipment with highest cost was the transesterification reactor with a cost of $ 58 128 which is the main equipment in the process using fresh oil. The total capital cost was $ 173 169.67.

Table 3. Cost of Equipment for fresh animal fat process configuration

Equipment	Cost ($)	Utility ($/yr)
Mix- 100	250	
P-100	1600	
P-101	800	
Mix-101	250	
E-100	33.82	
Crv-100	58128	
T-100	20049	
P-102	800	
E-126	83.648	
P-103	1600	
X-100	800	

X-101	800	
T-101	1600	
T-102	56259	
CRV-101	30116	
Total	173,169.67	1,491,283

However, the used of waste oil also recorded a total capital cost of $ 288,834.89 greater than that for fresh oil feedstock by 67 % ($ 115 665.22). This can be justified by the increase in purification equipment to reduce fatty acid content and other impurities for the subsequent transesterification process. In the case of individual unit cost, heater (E-102) had the lowest cost of $ 32.73 and transesterification reactor was having the highest cost of $ 59178. This cost distribution follow similar trend while using fresh oil an indication that the reactor is the main equipment in the process.

Table 4. Cost of Equipment for waste animal fats process configuration

EQUIPMENT	Cost ($)	Utility ($/yr)
MIX-100	250.00	
P-101	900.00	
P-100	1600.0	
E-100	34.8387	
CRV-100	59178	
X-100	800.00	
T-100	31743	
P-102	800.00	
P-103	1600.0	
E-101	40.320	
MIX-102	250.00	
P-104	800.00	
MIX-103	250.00	
CRV-101	59362	
T-101	20050	
E-102	32.729	
P-105	800	
P-106	1600	
X-101	800	
T-102	56259	
CRV-102	31085	
X-102	800	
T-103	20050	
TOTAL	288,834.89	3,422,307

Table 5 present the result of variable cost and the profitability analysis of the two selected process configuration. It is obvious that the use of waste feed cost higher than using fresh feed. But, remarkably the cost of raw material for waste process configuration ($ 4,996,607.00) is much lesser than that of fresh process configuration ($ 7,396,843.00). The cost in raw material obtained was reaffirmed by Haas *et al*. (2006). The cost of products and by-products produced and sold for waste and fresh feed configurations was $ 9,872,474.00 and $ 9,963,358.00 respectively. Meanwhile, profitability analysis shows that the net profit of fresh and waste process configurations was $ 471,896.00 and $ 625,299.00 respectively. From the two selected process configurations, the waste process configuration is the most favoured from profitability analysis and this can also be linked to its low cost of raw materials an indication that the effect of the raw material cost is more significant than that of capital and variable cost.

It was also observed in Table 3 and 4 that there was a significant difference in the utility requirement in using fresh and waste animal fat. Though the impact of this difference on the profitability analysis was not much but the waste process utility requirement requires higher utility

which could be attributed to the additional units requiring more utility.

Table 5.Variable costs and profitability analysis for fresh and waste fat configurations.

S/N	Variable Costs	Fresh Process	Waste Process
1	Fixed capital cost ($)	477416.62	1735223.57
2	Direct cost ($)	304,432.00	493,330.00
3	Indirect cost ($)	176,571.00	286,1131.00
4	Working capital ($)	96,200.60	155,892.25
5	Purchase equipment ($)	173,170.00	288,834.89
6	Total capital investment ($)	577,203.60	935,353.67
7	Total income from products and bi-products ($)	9,963,358.00	9,872,474.00
8	Gross income ($)	674,137.00	893,284.00
9	Raw material cost ($)	7,396,843.00	4,996,607
10	Net profit ($)	471,896.00	625,299.00

3.2 Acid catalyzed processes

Economic analysis of the selected simulated acid process configurations was carried out successfully. This includes the equipment costs, utility cost and the economic evaluation. But for the utility cost of both configurations, Hysys version 8.0 NET was used to determine that. For the fresh and waste process configuration, utility cost was calculated by Hysys 8.0 as $1 615 683 and $1 896 880 respectively. But the whole economic analysis was carried out using the approach developed by Peters and Timmerhaus (1991) for chemical plant economic evaluation. It should be interesting to know that even though the same equipment may be used, they may not have the same cost due to change in some of the parameters such as ratio of oil to alcohol changes (increases), then larger reactors will be needed thus, incurring more cost (Zhang *et al*., 2003).

In Table 6 and Table 7 below, the cost of equipment used for the production of biodiesel using fresh and waste animal fats are listed. The size of equipment was obtained from Hysys version 7.2. The Pro-econs process economic spreadsheet on MATLAB was used to evaluate the cost of equipment used for the simulation using 2014 chemical engineering equipment cost index (CEPCI) of 685.074. Table 6 and 7 shows the equipment and total utility cost for the fresh and waste feed configurations respectively.

Table 6. Equipment and utility cost for fresh animal fat process configuration

S/N	Equipment	Cost ($)	Total Utility Cost ($)/yr
1	MX-100	250	
2	P-101	1100	
3	P-100	1600	
4	MX-101	250	
5	E-100	2.21	
6	T-100	18330.64	
7	CRV-100	41567.8	
8	CRV-101	56467.76	
9	P-102	1900	
10	X-100	800	
11	X-101	800	
12	T-101	59792.95	
13	T-102	12193.65	
TOTAL		195 055	1 615 683

Table 7. Equipment and Utility Cost for waste animal fat process configuration

S/N	Equipment	Cost ($)	Total Utility($)/Yr
1	MX-100	250	
2	P-101	1100	
3	P-100	1600	
4	MX-101	250	
5	E-100	37.1	
6	T-100	16272	
7	CRV-100	43453.45	
8	CRV-101	6939.41	
9	P-102	1900	
10	X-100	800	
11	X-101	800	
12	T-101	316121.4	
13	T-102	274137.9	
14	E-101	41237.65	
15	P-103	2500	
16	MX-104	250	
17	MX-102	250	
18	MX-103	250	
19	X-102	800	
TOTAL		708949	1 896 880

It is evident from the costs of equipment for both configurations that the cost of waste process is higher than the fresh with values of $708 949 and $195 055 respectively. This is due to additional equipment for the hexane extraction procedure for the waste process configuration. The variable cost and profitability result for the two configurations is presented in Table 8 below.

Also, the utility cost of using the waste feed was slightly higher than using the fresh feed. These differences could be linked to the additional units and extra effort required to reduce the impurity level of the oil appropriate for the biodiesel production.

Table 8.Variable costs and profitability analysis of waste and fresh feed configurations

S/N	Variable Costs	Fresh Process	Waste Process
1	Fixed capital cost ($)	477 416.62	1 735 223.57
2	Direct cost ($)	329 252.84	1 196 705.91
3	Indirect cost ($)	148 163.78	538 517.66
4	Working capital ($)	71 612.49	260 283.54
5	Purchase equipment ($)	195,055.00	708 949.00
6	Total capital investment ($)	549 029.11	1 995 507.11
7	Total income from products and bi-products ($)	9 942 373	10 087 093.2
8	Gross income ($)	329 696	384 410
9	Raw material cost ($)	7 536 495	6 015 717.232
10	Net profit ($)	230 787	269 087

It is evident from the results presented that the process employing waste feed is more expensive than that employing the fresh feed because the cost of raw materials for the fresh feed ($ 7 536 495) is higher than that of the waste feed ($ 6 015 717.2). This fact has been ascertained by many researchers' such as Van Gerpen (2008) and Duncan (2003). The costs of products and by-products produced for the fresh and waste process was calculated as $ 9 942 373 and $ 10 087 093.2 respectively. Profitability analysis shows that the fresh and waste feed processes had the net profit of $ 230 787 and $269 087 respectively. From this result, it is evident that, it will be a profitable idea to go for the waste process when compared to the fresh process despite the use of hexane in the extraction process.

4.0 CONCLUSION

The economic potentials of using acid and alkaline processes for biodiesel production with fresh and waste animal fat have been investigated. In both processes the capital investment cost, working capital, direct and indirect cost of the processes utilizing waste feed are higher but the low cost of the raw material (waste oil) favoured it in both acid and alkaline processes making it more profitable. However, alkaline proves more profitable in using both waste and fresh animal fat and therefore a preferred alternative route for biodiesel commercial production from animal fat.

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