Covenant Journal of Entrepreneurship (CJoE) Vol. 2 No. 2, Dec. 2018

An Open Access Journal Available Online

Simulation and Unit Cost of Using Fluid Catalytic Cracking of Soyabeans Oil for the Production of Bio-Gasoline

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Abstract*:* The fluid catalytic cracking (FCC) procedure has been in the refinery for a long time. Feedstocks and process routes have determined the development of the production of gasoline over time. However the technique has not been applied to process bio-feedstock. A new feedstock (soyabean oil) is being investigated here and compared with the product from VGO because of the absence of the technology in Nigeria. The fluid catalytic cracking unit (FCCU) was designed such that a feed temperature is raised to produce conventional cuts from soyabean oil with similar cuts from VGO. The procedure followed included taking an assumption for adiabatic condition around the reactor for the process modelling. Next the simulation was run to crack soyabean oil to produce gasoline and LCO was another major fraction of the fractionated soyabean oil. This innovation will open up an outstanding entrepreneurship and a significant change to the view of a FCCU as made strictly for petroleum processes. The acceptance in mimicking commercial FCC operation to produce similar cut from petroleum has been successfully tested by 26 licenced pilot plant industries. The feasibility study for the start-up of this industry indicated that the IRR is excellent and the productivity index is greater than one. This makes the establishment of such industry economically relevant in Nigeria.

Keywords: Fluid Catalytic Cracking, soyabean oil, feedstock, gasoline, riser.

Introduction

Fluid catalytic cracking is a standout amongst the most adaptable procedures in any refinery. It can readily be modified and changed yet sustain quality through adjustments to procedures and processing conditions. The FCCU is one unit in the refinery that can deal with an assortment of feedstock, including polluted feedstock. FCC feedstock have changed over the many years of business application (Pinheiro et. al., 2011) (NRC, 2011), developing from light gas oils (31°API) in the 1940's, to a variety of streams in the present day which may contain deposit, asphalt and hydro-treated feedstock (The adaptability of the FCC unit as utilized in the refinery in using petroleum feedstock is a profitable venture). Government orders on inexhaustible fuel guidelines have brought about innovation of co-processing vegetable oils and pyrolysis oils in refineries. New innovations are being produced to change over waste plastics to fuels) (Dupont and Theodore, 2012). The shale oil is also processed by FCCU as it has become available by evolving technology (EIA, 2011)

Literature Review

The FCC-type procedures, for example, the procedure adopted by ExxonMobil PCCSM7 and KBR Superflex™8 are intended to split naphtha run feedstock specially to light olefins. Fluidized bed types have been proposed for changing over biomass to engine fuels (Press, 2010) and biomass to benzene, toluene and xylene. FCC type of plants have additionally been used to produce propane dehydrogenation and for changing over methanol to olefins (Gayubo et. al., 2000) (Keil, 1999). Unmistakably, flowing fluidized beds are a flexible innovation and are not restricted to changing over vacuum gas oil (VGO) to petroleum products.

New feed-stocks and process design is a significant change, and in this way it is important to identify the economic profitability since a loss in any industry is a huge financial hazard. Understanding the potential yields and execution is fundamental in evaluating the financial suitability of feedstock and processing route of that feedstock. One approach to limit the hazard related with these open doors is to recreate the procedure. After a fruitful re-enactment, it is advised to simulate the production prior to business usage. The use of ASPEN HYSYS for the simulation of refining processes has been adopted by oil refiners. This is usually done to safeguard against waste of plant fabrication and operation. The popular quotation is this, ‘Confer your bungles on a little scale and make your benefits on a huge scale,' should direct everyone who goes into another business enterprise. (Baekeland, 1916) Directing testing before business usage diminishes hazard for a refiner or petrochemical producer.

In this work therefore, the simulation of gasoline production from soyabean oil is carried out, next, the results from the conventional cuts obtained from VGO using the same process line is compared with the cut from soyabean oil. The plant design economic enabled the determination of the unit price for each cost of production which is presented to showcase the unit price of the bio-gasoline produced from soyabean oil.

Methodology

ASPEN HYSYS was used for the simulation of fluid catalytic cracking of soyabean oil. Table 1 presents the average values of operating data used for running the simulated process plant for the production of gasoline. This operating condition serves as the reported limitation/scope for running of the plant. Figure 1 is a schematic illustration of the fluid catalytic cracking process line of the plant. The framework comprises of three principle units - a riser, a fractionator and a regenerating link. Both the reactor and the fractionator are furnished with side valves for control of catalyst circulation rate. The FCC riser is typically of the conventional cracker used for the production of gasoline from VGO.

Table 1 The Average values of operating data used for running the simulated process plant for the production of gasoline

Operation Conditions	**Average value for Soyabean oil**	**Average value for Vacuum Gas Oil**
Tube section occupied by catalyst	27m	27m
Reactor Pressure	3500kg/cm^2	3500k/cm^2
Feed Temperature	400^{o}C	400 ^{o}C
Feed rate	350000kg/hr	450000kg/hr
Feed pre-heat temperature	370 ^{o}C	460^{o}C
Regeneration air mass flow rate	60,000kg/hr	60,000kg/hr
Fractionator temperature	360^{o}C	360^{o}C
Stabilizer column temperature	0^{o}C	-1^{o}C

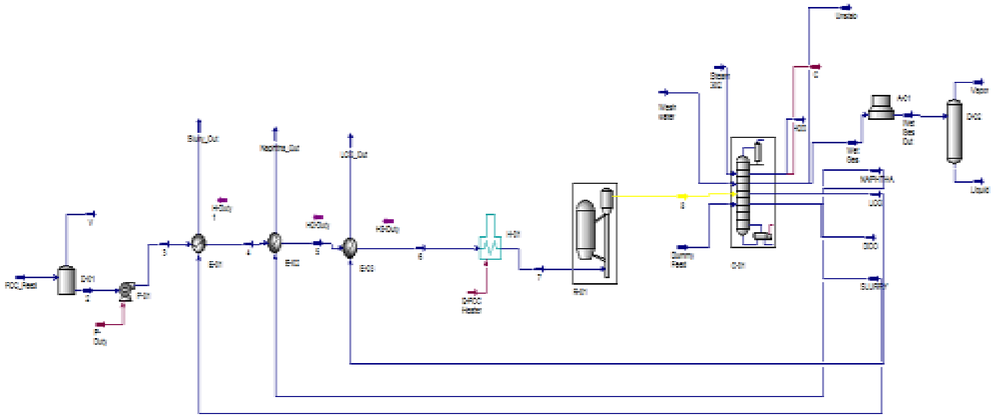

Figure 1 The simulated fluid catalytic cracking process line of the plant.

The simulated fluid catalytic cracking unit process line is presented in Fig 1. The riser worked in an adiabatic mode, where changing pre-heat feed or regenerator temperature will bring about an adjustment in catalyst circulation to keep up reactor outlet temperature. The cracking of soyabean oil occurred at a pressure 3500kg/cm^2 in reactor riser and the accompanying temperature was retained adiabatically to force the catalyst action on the feedstock. At the average data presented in Table 1, the gasoline cut from soyabean oil and VGO was obtained. The catalyst flow rate, the catalyst to oil ratio was varied and the preheat temperature was changed. As the simulation was made to run, a metering pump accurately controls the feed rate as the feed flows through a preheater. Air and steam, infused through a different preheater/vaporizer, are utilized as feed to the fluidized catalyst and each fraction go from the riser to the fractionator overhead. Each cut leaves the fractionator through a refrigerated stabilizer section to a control valve, which keeps up unit weight at the coveted level and each cut weight is obtained. Areas of the fractionator-regenerator spent catalyst are so designed to allow recirculation into the catalyst unit.

In the economic analysis, the weight of the gasoline converted was used for the determination and calculation of the productivity index. Every equipment design was given literature costing, the costing of employees pays was done, the overhead cost was obtained and the unit price of bio-gasoline was calculated (Table 3).

Results and Discussion

The adaptability of the FCC process, where a flowing fluidized bed gives superb mass and heat transfer, and where a response step can be combined with the catalyst regeneration step, have brought about appropriation of fluid catalytic cracking usage outside of the regular atomic weight lessening of the substantial part of unrefined petroleum to obtain gasoline. This utilization of fluid catalytic cracking unit for the processing of soyabean oil at high temperature splits the component to obtain gasoline was carried out at pilot plant scale (Bryden et. al., 2013). The production of gasoline from vacuum gas oil was done utilizing the same procedure of fluid catalytic cracking. The catalyst was a low metals carrying catalyst. The average outlet temperature of 450°C was utilized in the reactor riser.

Table 2 Properties of the feed-stocks

Property	Soyabean oil	VGO
^{o}API	21.6	24.7
Sulphur	0%	0.35%
Oxygen	10.5%	0%

Properties of the feedstock are provided in Table 2. The soybean oil has some carbon content and atomic weight of the material allows the material to crack at evaluated breaking points. Bio-materials sources normally have a genuine breaking point that is much lower than that recorded in heating vessels because of atomic weight impedance.

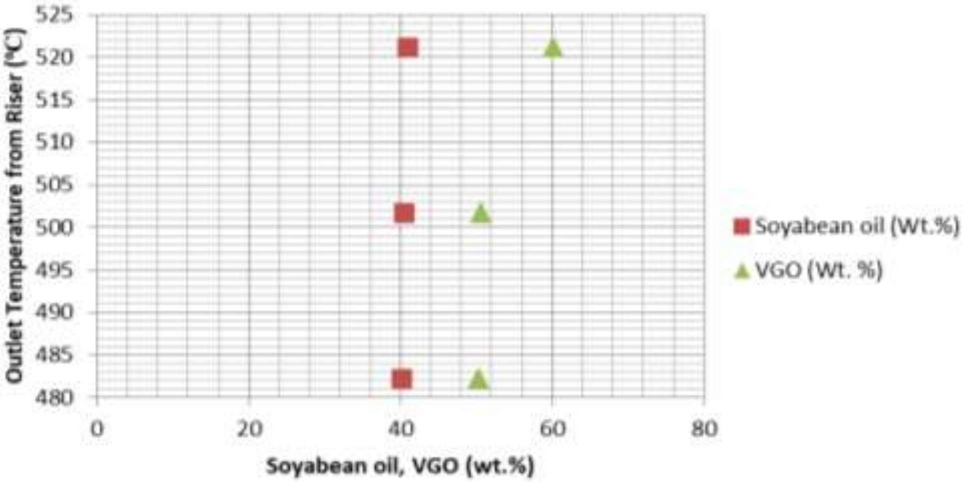

Figure 2 Yields of soybean oil and VGO at the same working conditions

Fig. 2 presents yields of soybean oil and VGO at the same working conditions. The amount of soyabean oil converted to gasoline is slightly affected by the outlet temperature of the riser. It is equally clear that the amount of VGO converted is highly affected by the outlet temperature of the reactor riser. This may amount to a high yield of coke. Whenever the coke produced is constant, the soybean oil delivered more LCO (Fig. 3), less fuel, than the VGO. However a research work (Bradey et. al., 2013) further characterized the gasoline from soyabean oil and it shows a higher octane rating compared to gasoline from VGO. For the VGO, the assumption made so that the riser ought to works in adiabatic mode during the simulation makes the top of the riser to be 20°C less than the bottom. But for the soybean oil cracking, the riser temperature profile was a plateau, with less than 1°C gradient within the riser Fig 2.

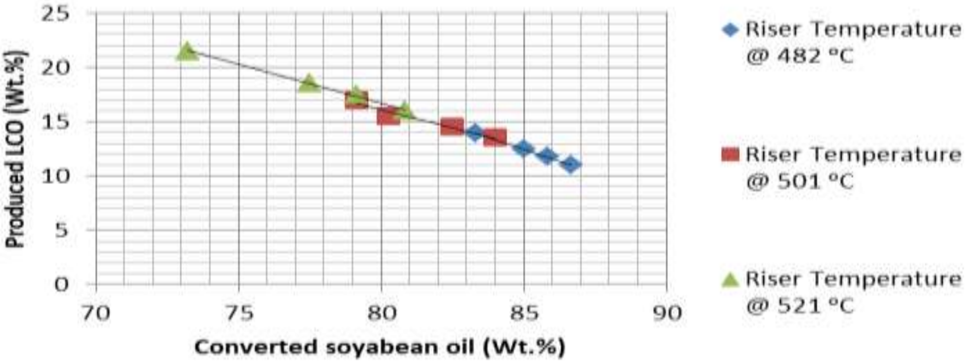

Figure 3 Low cycle oil (LCO) provided and converted amount of soyabean oil

The corresponding riser height and outlet temperature for constant conversion of oil was also compared in Fig. 4. The soyabean oil indicates a strong recommendation of the use of the same catalytic process with VGO.

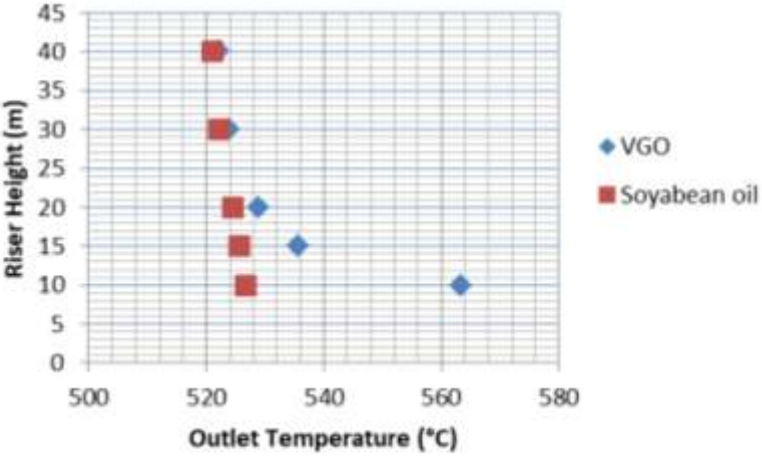

Figure 4 Riser heights versus outlet temperature for constant conversion of oil (Bryden et. al., 2013)

2.2.1 Cost effectiveness of the bio-gasoline production

Since profitability Index (PI) is greater than 1, and then the project is profitable, the internal rate or return (IRR) is 20% per year. Break even occurs at 1.5years and the payback was in 2 years. This is an indication that this industry can begin to realize profit very early. The breakeven point can be reached since the debts can be cancelled by benefits because it relies on agricultural feedstock. It is important to note that payback is very useful since this production is time sensitive. It is cost justifiable during its economic life, but there may be some external constraint (i.e. bank loans coming due). This implies that the “net profit" from the production must be realized in a defined period of time. This is a strong recommendation because the payback of the sales of this product is capable of bringing about this effect of net profit

$$\mathit{Payback\ Period}\ (T) = \frac{\mathit{Development\ Cost}\ (D)}{\mathit{Annual\ Revenues} - \mathit{Annual\ Operating\ Cost}\ (P)}$$

Data generated regarding Fluid Catalytic Cracker:
Costs \$40,500 to develop and reduces costs by \$20,500 annually.
Payback period is D/P = \$40,500/\$20,500 = 2 years.
Investment B costs \$50,500 to develop and reduces costs by \$30,500 annually.
Payback period is D/P = \$50,500/\$30,500 = 1.67 years.

2.2.2 Unit cost of soyabean gasoline and world view

Considering the current black sooth in Port Harcourt, Nigeria, be that as it may, just to consider bio-fuel cost isn't a sensible method to gauge gas benefits. Truth is told, by expanding the utilization of Biofuels the worldwide vitality supply security can be enhanced, the ozone harming substance and contamination discharges can be lessened, and furthermore the provincial economy can be moved forward. This is unmistakably comprehended by developed nations which have set up a few strategies to improve biofuel generation by decreasing taxes and duties. The cost of gasoline is from \$0.11 to \$0.18 per litre, contingent upon world oil cost. Contrary to biofuel from vegetative seed oil by means of catalytic cracking process which is from \$0.50 to \$0.80 per litre in the developed nations (Vorhies, 1998). Note that US dollars are considered in the present figures because of the way that the oil advertises is referenced on this money.

Bio-gasoline production costs are profoundly subject to feedstock costs, considering the production expenses, it can be recommended that the innovation and the sort of the crude material utilized is valuable. As per figures from the IEA regarding bio-diesel, generation costs for 6 European biodiesel manufacturing plants changed over to diesel-equal litres this may differ from \$0.80 to \$0.35 per diesel-comparable litre. Considering that expenses for production by means of improved process, lower unit prices can be achieved. Note that these cost gauges incorporate, the estimation of co-product deals, for example, LCO. Some critical perspectives must be considered based on the determination of production cost.

These days, in the US, biofuel generation depends primarily on soybean oil and creation offices are little scale measured. In this way, it is evaluated that US biofuel generation costs extend from about \$0.48 to \$0.73 per diesel-identical litre. This depends on soybean oil expenses of \$0.38 to \$0.55 per litre of biofuel, generation costs in the scope of \$0.20 to \$0.28 per litre, and side product contribution of about \$0.10 per litre (Vistisen and Zeuthen, 2008). This may be a similar about bio-petrol.

Table 3 Unit costing of the gasoline produced by soyabean oil

Product		**Units**	**Average Cost (\$)**	**Cost per Litre (\$)**
Feedstock				
	Seed Prize	0.5	0.7	0.06
	Transportation Cost	0.4	0.4	0.05
	Pre-treatment Cost	0.3	0.26	0.04
Total Cost Feedstock				
Reactions				
	Catalyst	0.005	0.005	0.004
	Regeneration	0.002	0.0025	0.002
Energy Resources				
	Electric Power	0.15	0.13	0.2

	Steam	0.23	0.23	0.3
	Cooling Water	0.0018	0.0018	0.002
Administration Cost				
	Sales and Administration	0.005	0.004	0.003
	Number of Employees	0.002	0.004	0.003
Maintenance (% of capital cost/litre)				0.003
Insurance (% of capital cost/Litre)				0.007
Cost before Interest, Depreciation and LOC Credit				0.005
LOC				
PRODUCT		**UNITS**	**AVERAGE COST**	**COST PER LITER**
Interesr and Depreciation				0.0023
Gasoline Transportation Cost				0.002
Total Cost per Litre				0.6833

2.2.3 Low cycle oil (LCO) Cost by innovative choices.

On one hand, LCO is a key co-product with bio-gasoline that is broadly utilized as a part of a few mechanical processes; then again LCO markets are great. In this way, it could happen that for an expansive scale of bio-gasoline production, an abundance of LCO in the market could cause that no clients were intrigued on paying for it and it would progress toward becoming non gainful. In any case, nowadays, LCO is an important co-product in the bio-gasoline production plant. Accepting that LCO is delivered at a proportion of 2:20, the approaching of LCO is in the request of \$0.10-\$0.20 per litre of bio-gasoline. This is similar to the case of glycerine which is also a co-product in bio-diesel production. It is delivered in a scope of \$500 to \$1,000 per ton (Oasmaa and Peacocke, 2010). Clearly these costs would fall under situations of expansive scale, newly-created plants and innovation enhanced process. Notwithstanding, in the long haul, estimations demonstrate that product costs could likewise wind up higher and LCO cost could tumble down. Subsequently, attainable technologies of biofuel production costs are examined based on its value which will be higher than that of product from oil. Note that present examination are made on the basis that the bio-gasoline is delivered in developed nations, anyway it could wind up less expensive in developing nations. No examination is found on this premise because of the absence of information.

2.2.4 The implication of using bio-material as feedstock to produce gasoline

When feedstock obtained from plants are changed over through the FCC procedure (presented in this work) to obtain bio-gasoline, or even other bio-fuels such as ethanol, propanol, butane alcohol etc. A sustainable economy may be actualized in Nigeria. gasoline is the most broadly utilized fuel in Nigeria. Most vehicles are run with the fuel extending up to 100 per cent usage (by volume) in motor cycles and small domestic machines used in cottage industries.

Bio-gasoline is a second era biofuels, or cellulosic biofuels, which is produced in this research soyabean oil, the quality is accessible from existing quality control technologies as indicated in this research. The results presented here can user the production and usage of bio-gasoline into a third era research where we can utilize green plants as feedstock.

The potential financial advantage of green growth feedstock is that it supplants petroleum products because it creates expendable assets by indulging national farming. The implication of this practice is that, bio-gasoline are delivered from sustainable feedstock. Consequently, their generation and utilize could, in principle, be managed with certainly. Research work in the past on greenhouse gas (GHG) emanations presented other financial models which shows that biofuels can prompt decreases in lifecycle GHG emanations compared to traditional petroleum (Hertel et al. 2010, Huang et al. 2013). Second and third era biofuels can possibly set Nigeria’s power generation to sky flyers since feedstock can be delivered utilizing land. In addition, an extra horticultural technique is not required, and farming market interceded unemployment outflows which is currently significant as the current employment rate is challenged.

Conclusions

The fluid catalytic cracking unit is a profitable refining processor for reproducing gasoline. By running the fluid catalytic cracking unit, at the same working conditions with a similar feedstock and catalyst, the FCCU produces yields almost indistinguishable to conventional feed stock FCC units. The FCCU can likewise be utilized to produce new feedstock to decide their relevance to sustainable business or economy. The capacity of the FCCU to create adequate amount of gasoline product from soyabean oil incredibly upgrades the estimation of LCO quality. The adiabatic reactor is a working framework which indicates that the energy needed for production can be estimated for all types of feedstock. The adaptability of the FCCU used in the assessment of process conditions and processing methods makes it easy to carry out an economic estimation of the product price. The discovery of new feedstock has contributed immensely to growth and development of the industry. Simulation of the process is a key advancement in assessing this development. Simulating the process before running a pilot plant and the fully blown plant diminishes hazard and vulnerability by recognizing the ideal feedstock and process conditions on small scale with the goal that fuel and petrochemical producers can "make their benefits on an extensive scale.

Acknowledgement

Petroleum Technology Development Fund supported the software purchase

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