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NIGERIA PALM OIL BIODIESEL PRODUCTION OPTIMIZATION AS POST COVID-19 GREEN ENERGY AND ECONOMIC RECOVERY STRATEGY

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Abstract: In recent times, climate change has significantly affected the world by creating devastating challenges like flooding, desert encroachment and unpredictable ecosystem in the globe and African continent like others have experience these issues. Fossil fuel combustion is proven to contribute to climate change however, biodiesel as a renewable and green energy identified as a factor in mitigating the problem has not been well developed by many African countries including Nigeria despite abundant availability of raw materials unlike US, China, Malaysia and Indonesia that have developed and improved biodiesel production industries. The emergence of Covid-19 pandemic have caused economic recessions globally therefore; this paper presents major issues affecting the development of Nigeria's palm oil industry that significantly affects palm oil biodiesel production, suggest possible solutions to the industry stagnation and finally, provide palm oil biodiesel production optimization strategies to cushion the negative economic impact of Covid-19 and simultaneously contributing to world's green energy initiative.

Keywords: Ecosystem, Green Energy, Covid-19, Nigeria, Biodiesel

INTRODUCTION

For many years, petroleum industries have been progressively improving in terms of output to meet the continuous demand of the products. However, the main issues associated with fossil fuel use is the limited availability and non-renewable characteristics. More so, its use is associated with high emission of gases that are harmful to the environment [1-3]. This attributed cause of environmental degradation to fossil fuels use as indicated by the 'planet deterioration' has reached a critical stage so much that the symptoms of a dying planet can be seen in all regions. The major contributor to this mayhem is a pollutant gas known as carbon dioxide (CO_2). The percentage emission of this CO_2 gas emitted to the environment and its negative impacts has risen more than anticipated. Carbon dioxide is a greenhouse gas that leads to greenhouse effect. A greenhouse effects occurs when released carbon traps the sunlight radiations within the earth atmosphere and prevents hot air from leaving the atmosphere and subsequently causing the temperature of the earth to rise. Due to atmospheric rise in temperature, global warming occurs leading to the melting of the polar ice. The effect of the melting polar ice is that it causes water levels to rise which in turn creates a flooding phenomenon where cities and regions can be completely submerged. Fossil fuels further releases other harmful pollutants like black carbon and Oxides of Nitrogen (NOx).

The emission of these pollutants leads to the exponential increase in acid rain occurrence. Acid rains leads to destabilizations in the ecological systems by destroying rainforest and contaminating clean water therefore causing health issues and diseases both already in existence and new ones to everyone irrespective of age.

As a result of social-political and economic reasons, biodiesel has generally been increasing in popularity worldwide, also; with regards to emission reduction biodiesel has played significant roles due to its limited emission and its mitigation of 'over dependence' on fossil fuels. The glaring proof of negative impacts of using fossil fuels although noted, political influence continues to limit the efforts in repairing the already damaged earth planet. The most significant way of limiting emissions and saving 'failing ecosystem' is by adopting the use of renewable sources of energy especially biodiesel [4, 5].

Biodiesels are renewable fuel derived from agricultural produce and has been a prospective good alternative to conventional diesel for industries and automotive applications since it requires no modification of engine before usage [6, 7]. According to [8] there are up to three hundred and fifty different oil-bearing known crops capable of been used in biodiesel production with soybean, rapeseed, peanuts oils, sunflower, cottonseed as well as palm oils feasible enough for replacing fuels in diesel engines considerably, some of these sources are as reported by [9-32], another main source in the production of biodiesel is from animal fats [18, 22, 25, 26]. In comparison between these two sources, there is more possibilities of vegetable oil use in larger quantity of biodiesel production than animal fats. This feature is due to their renewable nature and therefore projected to be an alternative to fossil fuels dependency hence the development of biodiesel industries in many countries including palm oil biodiesel industries.

NIGERIA'S PALM FRUIT AND PALM OIL INDUSTRY DEVELOPMENT

Palm fruits also known as 'wild oil palm' is a West African native fruit that grows majorly in the palm belt of Nigeria especially southern Nigeria and it covers an area of about 70,000.00 square miles. The Nigerian indigenous Palm trees takes about 15years from germination to fruit bearing if it is in natural competition with other weeds. The harvesting is done throughout the year however, between the months of March and May there is higher rate of harvest. In comparison of varieties to the bred plantations, Nigeria's palm fruits have very thick shell nuts with a lower oil bearing mesocarp, and according to the Eastern Oil Palm Grove Report the yield difference between the wild palm and the cultivated type is in the ratio of one (1) to five (5) therefore the cultivated plantation varieties of Nigerian palm tends to be more feasible to industry due to: more yield of oil per tree; better oil quality; reduced cost of operations; better efficiency in harvesting which is easier due to serial arrangement; and ease of estimation in harvesting time since the plantation's dates are documented. However, the development of these plantations has been plagued by the Colonial Government policies that is historically documented to have opposed the development by reiterating that only 'Indigenous Agencies of the West African Population' are allowed to develop the rich Agricultural Resources of West Africa. This was difficult due to inadequate source of funding since the country was still young within these early periods and had not fully achieved total independence from British colonialism thus, between year 1950 and 1965 all efforts by the Nigerian Government to encourage expatriate investors failed due to the imposed high export tax levied on investors by the British Government as the investors were forced to sell to 'marketing boards.

Early predictions which projected that Nigeria and other West African Countries to dominate the world palm oil industrialization drive became dampened as the early Plantation of palms in Nigeria was been continuously replaced by rubber plantations which was not over-regulated by the Colonial Government at the time. In the meantime, while Nigeria's palm oil production was slowed down by ethnic related political violence, civil war and British Policies, the Dutch Indonesian plantations were rapidly been improved and developed and within a decade Indonesia overtook Nigeria to become the leading world exporter of palm oil. The representation of early development of Nigeria palm oil sector as compared to other key-player countries is as presented in Fig. 1. These data as obtained and reproduced from "British Common Wealth Economic Committee report on Oil and Oil seed" for four selected years by [33] clearly showed Nigerian early dominance and leading role in World Palm Oil Export. It is important to note that the main utilization of palm oil as an export product was mainly for consumption and burning for room warming and lighting, until other applications were discovered including biodiesel through esterification process.

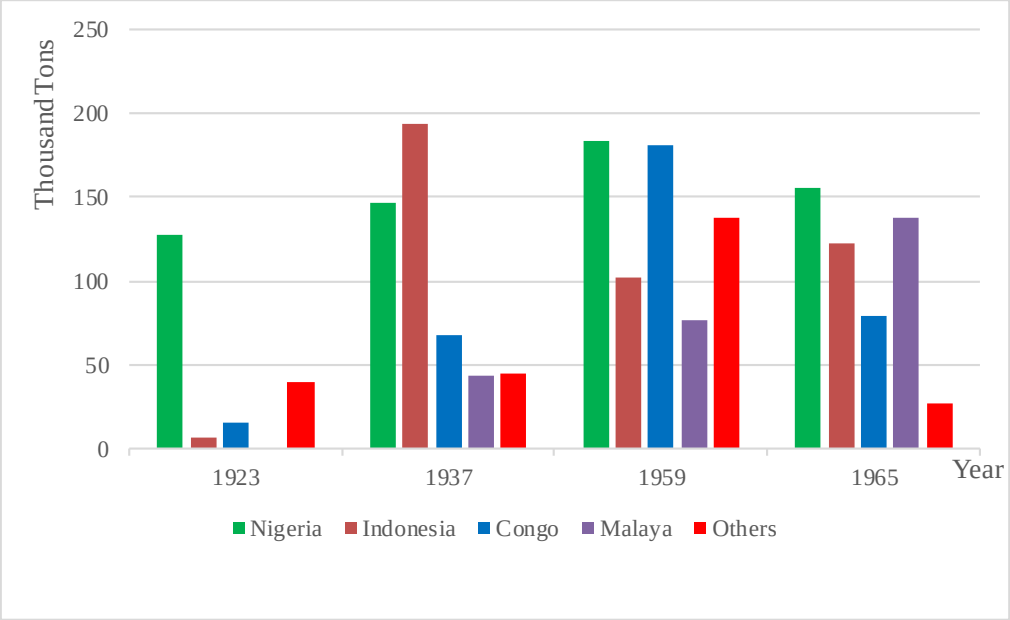

FIGURE 1: Palm Oil World Export

It is observed as presented in Fig. 1 that Malaya (current day Malaysia) for instance had zero export capacity as at Year 1923 and was not listed as world exporter of palm fruits or palm oil, however, current day Malaysia in contrast to Nigeria have improved the sector and become a key exporter of palm oil and its products, this was strategically achieved through stakeholder's involvement and research and in year 1965 Malaysia had reached almost same level of palm oil export with Nigeria which was relatively stagnated.

FACTORS AFFECTING NIGERIAN PALM OIL PRODUCTION AND DEVELOPMENT

In addition to the restrictions and discouraging policies of the past British Colonial government, the following factors can be considered to have contributed to the stagnation and underdevelopment of the Nigerian palm oil industrial sector:

- Inadequate financial support to local palm tree farmers
- Complications from land Tenure system and plot fragmentations
- Inadequate supply of seedlings to start-up palm farmers
- Insignificant price difference between high quality and lower quality palm oil by price regulating bodies
- Phobia for tax imposition on the palm trees by Nigerian government as it was done to cocoa farmers
- Civil war impact as war theatre was in Nigeria south-east that constitute major palm tree plantation
- High level corruption
- Technical factors

Among the identified factors affecting palm oil development in Nigeria, Technical factors was majorly influencing the output as production technologies adopted is to a great extent 'local'. Many European Union countries objects to importation of Nigeria's palm oil because the food authorities think that the 'local process' used in the production is not hygienic enough for their citizens thereby affecting the trade. The processing of palm is in four stages viz: heating of palm fruit for softening purposes; Maceration; Oil extraction and finally Clarification. According to the Nigerian Annual bulletin on Agriculture [33] the local technique of using mortar and piston among other hand tools for production of palm oil in Nigeria generate more oil yield per 'fruit quantity' compared with the milling machine. However, considering that local technique is labor intensive and time consuming, overall quantity produced per time is relatively lower with respect to that of milling machine at the time. Furthermore, since local consumption is also high as it was affecting export therefore the increase in Nigeria's Gross Domestic product (GDP) was minimal.

In addition, many Government officials involved in corrupt practices such as reselling of improved varieties of palm seeds to farmers at exorbitant prices discourages many Nigerians from participating in the industry. Many interventions by both indigenous and foreign investors are continuously mismanaged by some corrupt Government officials in the Agricultural ministries, this created disdain for government officials by local community, furthermore, due to cultural and traditional believe and psychological attachment to ancestral lands, lending or selling of land to government or private firms for palm plantation expansion is difficult as many times the palm oil companies are sued for 'land grabbing' and the government sometimes forcefully take over the land without adequate compensation which in turn sometimes leads to economic sabotage by the locals, a similar situation to this in Malaysia and Indonesia is as reported by [34].

In recent times, innovative techniques of oil extraction with better efficiency in operational process and yield per unit time has been developed by advanced and developing countries, massive scale production with automation including robotics have continuously been developed and improved upon, the emergence of biodiesel as fuel for diesel engines which requires no engine modification is a main contributing factor to the new competition drive among countries like Indonesia, Malaysia, USA, China and others with China considered to lead in patent with 39% as extracted data from [35] presented in Fig. 2.

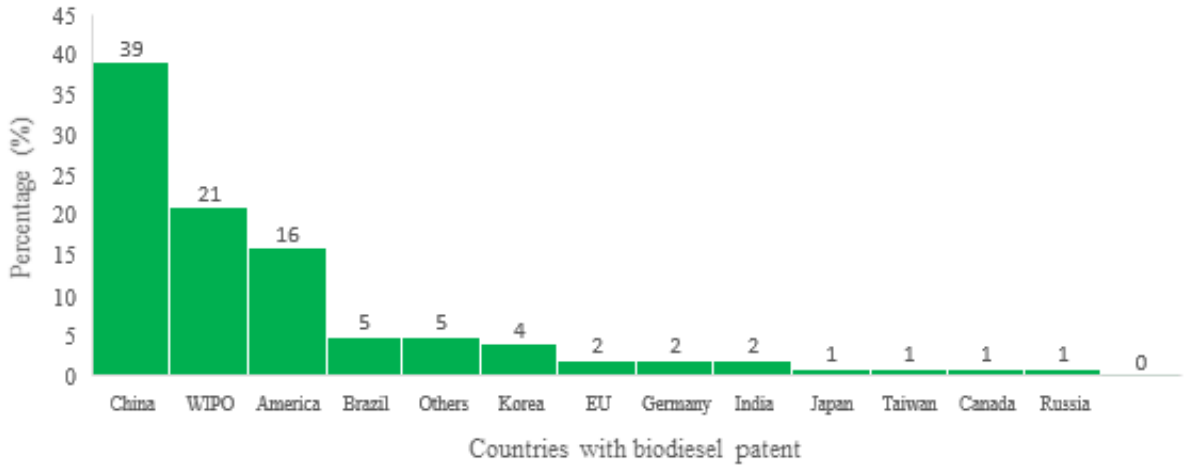

FIGURE 2: Biodiesel Production Patent between 1999 to 2018

Despite palm fruit availability in Nigeria which can influence massive palm oil biodiesel production, the biodiesel output from the country is negligible as can be deduced from Fig. 2, to curtail this and improve biodiesel production in Nigeria, there is need to:

- Provide improved seedlings and soft loans to local palm tree farmers in Nigeria as financial incentive
- Create enabling environment through stakeholders' interventions, better government policy and by international collaboration with countries like Malaysia and Indonesia through bilateral trade agreements
- Improve orientation to locals of the importance of palm trees and its recent diversification from consumption to renewable fuels, and keep them informed of the market demand internationally
- Public-Private partnership in local production line
- Optimization of the production stages

Among the suggested items to improve Nigeria's Biodiesel production, optimization of Production process is most relevant to others as more output will influence more sales and encourage investor's interest, increase GDP, create employment and mitigate the impact of the economic recession caused by the covid-19 pandemic.

NIGERIA'S PALM OIL BIODIESEL PRODUCTION OPTIMIZATION

The production of biodiesel from palm oil in Nigeria can be better optimized by first identifying the areas in the value chain from the palm seed planting and harvest to biodiesel end user which when optimized can improve firstly in terms of reduction in production time and secondly in terms of increase in yield (quantity and quality). This is as presented in Fig. 3.

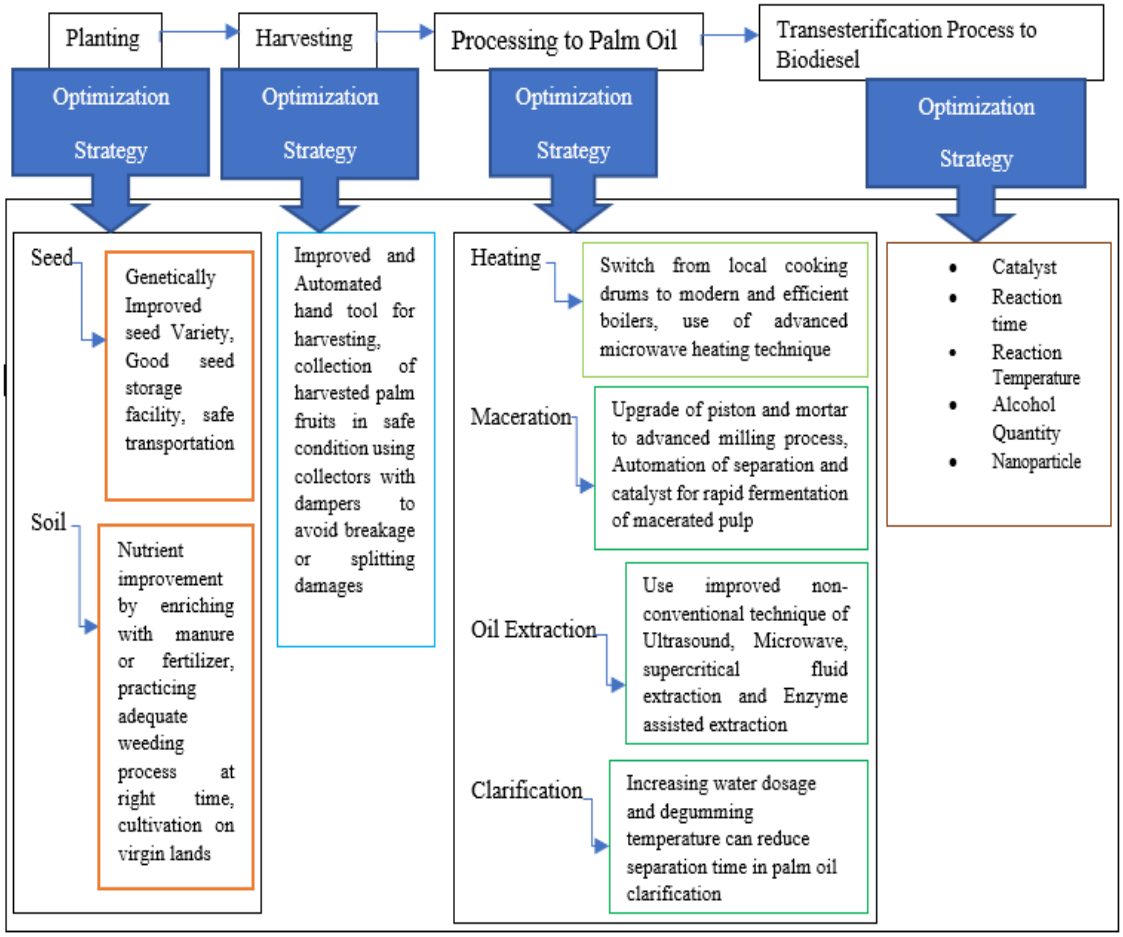

FIGURE 3: Sections for Optimization and Strategy for Nigerian Palm Oil Biodiesel Industry

Furthermore, to optimize Nigerian palm oil biodiesel production output at lesser time, it is important to examine the general production steps in biodiesel. Transesterification method is done by reacting the oil or fat with alcohol to produce esters plus glycerol in the presence of a catalyst. This follows three routes:

- Base catalyzed oil transesterification
- Acid (direct) catalyzed oil transesterification
- Converting the oil to fatty acid and then to biodiesel

$$\text{Oil/fat} + \text{Methanol} \rightarrow \text{Methyl Esters} + \text{Glycerol} \quad (1)$$

$$\text{Oil/fat} + \text{Ethanol} \rightarrow \text{Ethyl Esters} + \text{Glycerol} \quad (2)$$

Transesterification reactions is often achieved through reaction of triglycerides of oils with active intermediary and may adopt varieties of alcohols, although those with lower molecular weight are preferable. Recent studies show that the use of methanol in the transesterification reaction is technically more viable than that of ethanol. Nigeria therefore have to adopt this technique of methanol usage. Although a major challenge with the use of ethanol is the complexity of separating the glycerin which is the by-product of the reaction because when compared, methanol is easily separated through decantation [36]. Ethanol usage is relatively conditioned to be feasible when its water content is below 2%. This is because the water tends to acts as inhibitor reactor. Industrially, transesterification is done with an alkali medium since its yield is better and the reaction time is lower. According to [37, 38], Alkali include carbonates, potassium hydroxide and sodium hydroxide as well as relative Alkoxides. Some alkoxides include sulphuric and sulphonic acids, ethoxides: sodium methoxide, sodium ethoxide or sodium butoxide, as well as hydrochloric acids. These biodiesel steps are serially presented viz:

- Mixing alcohol with the catalyst
- Reaction: the mixture of alcohol and catalyst (mainly alkaline catalyst of KOH and NaOH for methanol). This reaction takes place at alcohol boiling temperature which ranges from 50^0C to 60^0C and refluxed and agitated for some time about 1hr causing a conversion efficiency between 97 to 99%. After these

procedures the reaction shows a demarcation of an upper layer and lower layer whereby the upper is methyl ester while the lower is that of glycerol mixed with unreacted methanol

- Separation of glycerin and biodiesel: the two products of reaction are separated, the amount of glycerin produced is relatively dependent on the vegetable oil type, the adoption method and the excess alcohol amount.
- The removal of excess methanol is such that the fatty esters is neutralized and then the vacuum distilled
- Glycerin neutralization: by-product of glycerin has unused catalyst and soaps at the top layer which is then neutralized using phosphoric acid that results to potassium phosphate, however, the use of potassium hydroxide as catalyst leads to crude glycerin which is in turn stored.

Finally, methyl ester is then washed and the centrifugal technique is used in separation. Basically, it can be deduced from Fig. 3 that the main challenge affecting Nigerian palm oil Biodiesel production is technical inferiority in the production process compared to other competitive countries. The emergence of covid-19 pandemic which have affected the world economy makes the development of Nigeria palm oil industry more urgent so as to tackle the issue of unemployment and economic recession as well as meet up with the Nigeria Millennium Development Goals (NMDG) and Vision 2030 (V30), extraction from Fig. 3 further show that for Nigeria palm oil biodiesel production to be optimized, Catalyst, Reaction time, Reaction Temperature, Alcohol Quantity and Nanoparticle are identified to influence the biodiesel output in quality and quantity in the transesterification process.

1. Catalyst: Nigeria can improve on indigenous biodiesel production optimally by increasing the catalyst concentration during processing. The triglyceride conversion rate significantly will be increased as well as ester content when catalyst concentration is raised up to 1.5 wt.% which is the optimum level, this suggestion is drawn from [39], catalyst concentration especially alkaline catalyst above 1.5 wt.% possibly will decrease the ester yield as more triglycerides in the reaction will lead to more soap formation with corresponding decrease in yield of ester.
2. Reaction Time: during production, Nigeria palm oil biodiesel industry can increase product yield by keeping reaction time at 90minutes as optimal period for maximum yield of the esters. Report by [39] also opined that reaction period range greater than 90minutes or above showed no increase in the output of the ester yield irrespective of the raw material source as cotton, neem, pongamia, coconut, groundnut, rice bran or even palm had all showed similar trend of no yield increase in ester.
3. Reaction temperature: Nigeria biodiesel industry have to adopt the temperature for optimal yield in ester output which is 50 ^{0}C, this is because many reports like [40] indicates that temperature increase above 55 ^{0}C showed a decline in biodiesel yield
4. Alcohol quantity: the ratio of methanol to oil affects the yield of biodiesel. Transesterification experiment carried out by [41] using different methanol amount ranging from 120-240 ml showed optimal yield of the ester was achieved at 180 ml, therefore Nigerian biodiesel industry must consider application of alcohol quantity during processing of palm oil to biodiesel to obtain maximum yield output
5. Nanoparticle: Nanomaterials include nanowires, nanosheets, nanotubes, nanorods, nanoparticles or droplets as well as nanofibers. Recent studies have indicated diverse application of nanomaterials in many engineering areas. Due to the particle size of nanomaterials which mainly fall below 100 nm, the tendency to alter physical and chemical process is elaborate. Furthermore, research by [42] opined that their application to biodiesel tends to optimize yield as well as aid catalytic recovery in the transesterification process, in fact, the report specified that catalyst were reused up to 10 times without loss of integrity in usability with the aid of Calcium Oxide (CaO) based nanoparticle. Nigeria palm biodiesel industry can improve by investing in further research and application of nanoparticles.

NIGERIA'S PALM BIODIESEL PRODUCTION PROSPECTS POST COVID-19 ERA

Nigeria despite been the leading economy and most populated African country, the economic opportunities of recovery after world Corona virus pandemic is presently unclear, this is because the country main source of revenue is the crude Oil export which currently have unstable global price. Furthermore, climate change challenges have led to most countries who are importers of Nigerian crude to plan on cutting emission thereby reducing purchase of crude oil. The Nigerian state therefore plans on diversification of the economy from crude to Agricultural products as part of the country's V30 blueprint. Palm tree plantation expansion is a major prospect of the economic diversification.

To understand clearly why Nigeria has a chance and credible prospect on economic revival in post Covid-19 era through biodiesel production and optimization, it is important to examine the chemical characteristic of the various biodiesel feedstock presently popular as presented in Table 1.

Table 1: Selected Methyl Esters Chemical Properties adopted from [40]

Biodiesel Source	Acid value (AV)	Iodine Value (IV)	Peroxide Value (PV)	High Heating Value (HV)	Saponification Value (SV)	Cetane Number (CN)	Moisture Content
Pongamia	0.5	84	15.78	40.216	194	55.53	0.16
Palm	o.2	57	11.31	40.334	201	60.62	0.19
Neem	0.6	99	16.08	40.196	189	52.9	0.35
Cotton seed	0.3	76	12.52	40.131	199	56.63	0.52
Rice bran	0.4	100	15.02	40.222	188	52.83	0.45
Gingelly	0.1	113	14.66	40.027	188	49.905	0.72
Groundnut	0.2	111	19.21	39.048	187	50.51	0.24
Coconut	0.1	9	1.52	38.676	259	65.34	0.82

It can be observed from the Table 1 that the cetane number (CN) of palm is higher compared to others except coconut, since cetane number (CN) is fuel ability to quickly ignite after injection, it is an important parameter considered by the EU and USA whose CN standard for biodiesel selection is 51 and 47 respectively as specified by EN14214 and ASTM6751, this fact makes methyl ester from palm favorable but on contrary, with increase in CN value iodine value (IV) decreases, the iodine value (IV) which is the degree of unsaturation for both palm and coconut are low at 57 and 9 respectively, the decrease in IV causes level of unsaturation to decrease correspondingly resulting to difficulty in application at lower temperatures and hence make both biodiesel sources not suitable for cold region. This therefore gives Nigeria an opportunity and better prospect to become the economic hub for African biodiesel production as African weather is most suitable for biodiesel from palm and coconut due to the high temperature of the region.

CONCLUSION

The emergence of Covid-19 pandemic worldwide has cripple many countries' economy, the global challenge of climate change makes it difficult to increase combustion of fossil fuel from manufacturing and automotive industries thereby limiting or slowing the rate of economic recovery. Nigeria as one of the countries affected by this double challenge can exit economic recession through optimization of its palm biodiesel industry. The two phases of the optimization are the palm oil process phase and the biodiesel transesterification phase. In the first instance the optimization is basically in terms of Technical upgrade and expansion of the palm plantations through improved seed varieties and modernization of tool and process. In the second instance, consideration should be given to factors like high reaction temperature which shorten reaction time by decreasing viscosity that can result in increased transesterification rate. Also, sufficient time for reaction must be enabled to completely convert the triglycerides to esters and reaction stopped at optimal level to avoid reverse reaction. The reaction conditions in achieving optimal yield of esters is: Time (90min) at Temperature (50 ^{o}C) for NaOH Catalyst (1.5 wt.%) and methanol to oil ratio of 180 ml to 1000 ml respectively. Nigerian government and policy makers can emulate Malaysia and Indonesian biodiesel blueprint of blending biodiesel with conventional diesel in commercial quantity and must consider these points in order to be a role model to other African countries that support the world green energy initiative.

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