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Optimization of Diesel Blending Unit in a Nigerian Refinery Company

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ABSTRACT

This work presented optimization of diesel in a Nigeria refining company (Niger Delta Petroleum refinery NDPR). Four products of diesel were analyzed and model equations of a nonlinear volume ratio were linearized and adopted. The linearized model equation was solved using the PYTHON 3.6 computer language's simplex approach. The blend ratio of the four different product were obtained as , 24% F1, 25% F2, 26% F3 and 25%F4 is needed for the production of product 1, while 24%F1, 25%F2, 25%F3, 26%F4 for the production of product 2, also 12%F1, 21%F2, 34%F3, 33%F4 for the production of product 3 and finally 28%F1, 2%F2, 68%F3, 2%F4 for the production of product 4. The produced diesel were characterized to determine the physiochemical properties which compared reasonably well with the African refiners association standard. Using the nonlinear programming models four properties of diesel cases were determined. (Cetane number, Sulphur Content, Density and Ash Content); the Cetane Number for product 1.2,3,4 were 55P1, 53P2, 50P3, 50P4; Sulphur Content for product 1,2,3,4 were 0.0002P1, 0.0004P2, 0.003P3, 0.005P4; Ash Content for product 1,2,3,4 were 0.0001P1, 0.0001P2, 0.003P3, 0.007P4 and Density for product 1,2,3,4 were 0.86P1, 0.86P2,0.86P3,
0.86P4. The four product of diesel fuel satisfied the standard specification of the Africa Refiners Association ARA. The objective function is to maximize the profit. It has been observed that a deviation in cost indicates 10.3% when multiplied with the total barrel of product gave $61000/day profit. This objective function was maximize subject to a sets of constraints which represent the quality and quantity of final diesel products. Because a refiner's volume of products sold is so large in a typical circumstances, even a 1% unit fraction savings will result in a significant profit boost.

Key words: Optimization, Objective Function, Blend Ratio , Cetane Number, Sulphur Content, Density, Ash Content

1.0 INTRODUCTION

Niger Delta Petroleum Refinery (NDPR) is an indigenous oil and gas company in Nigeria. Mainly for the processing and blending of diesel. In 2010, NDPR established a micro refinery with capacity of 1000 barrels per day (b/d) to extract diesel from crude oil produced at the Ogbele field. The NDPR was first of its kind to be a privatized. The Nigerian government granted NDPR the first License To Operate (LTO) for a private refinery in the country. NDPR celebrated the 1000th diesel truck loads out from the micro refinery in 2014, and in 2019, the company extended its plant capacity and is now processing a total of 1 million tons of diesel. (www.ngdelta.com). Diesel is named after the German inventor and mechanical engineer who created the diesel engine. Diesel engines are now employed in transportation, industry, power generation, construction, and agricultural all over the world. Akpa and Dagde (2014), explain that diesel fuel is a mixture of hydrocarbons obtained by distillation of crude oil. Its boiling point is usually between 150^{o}C to 380^{o}C. Oil refineries manufacture it by refining and transforming crude oil into different hydrocarbon fractions. Most of its refined products are blended from refinery intermediate process streams. These streams has different properties of blending components which makes the diesel blending problem more challenging due to the specification and standard required for modern refiners. Moore (2011) defines diesel and gasoline blending as the process of combining two or more components of feed stocks, produced by refinery units, together with some proportion of additives to make a mixture to meet certified quality specifications. Iminabo *et al* (2018), explained that the objective of blending in a petroleum refinery is to mix semi-finished products that have been rectified during various manufacturing processes so as to produce a product that meets specification. Diesel blending involves the mixing of various refine components from various refinery upstream units such as Straight run diesel from Crude Distillation Unit (CDU), Light cycle oil (LCO) from Fluid Catalytic Cracking Unit (FCCU), Coker light gas, (CLGO) produce from Coker unit, Hydrocracked diesel unit (HCU) along with additives to produce different grades of diesel product that satisfies the specification given. Most refined products are blended from refinery intermediate process streams.

These streams has different properties of blending components which makes the diesel blending problem more challenging due to the specification and standard required for modern refiners. According to Elzalda *et al* (2011), one of the major challenge in diesel blending is constraint optimization of parameter. Erdogdu (2008), defines Optimization in Engineering as selecting the best among the entire set by efficient quantitative methods. Kpalap et al (2020), explained that in most optimization, there must be at least an objective function and constraints. An optimization can be meaningful when there is an objective function to be optimized and there exist more than one feasible solution which does not violate the constraints. An objective function is the mathematical function which expresses the aim of the model that is to be minimized or maximized and is subject to certain constraints. The constraints are limitations on the behavior performance of the design or process variables which must be satisfied to render the process or system feasible. These constraints allow the unknown variables to take on certain values but exclude others Kumar *et al* (2015). A good diesel is known by its properties depending on its usage, there are several properties that characterize a good diesel. The Cetane Number of diesel is one of the most important property of diesel quality. According to Shixun (2016), it is the measure of how readily the diesel fuel starts to burn under diesel engine condition, it provides information about ignition delays. Sulphur Content of diesel tends to describe the amount of Sulphur in a particular diesel. Sulphur is a naturally occurring compound in crude oil. Daucik *et al* (1998), studied the determination of Sulphur content in a distillation cuts, they discovered that the Sulphur content in distillation cut was increasing as the temperature of the distillation increases. The results of their findings suggests that the majority of Sulphur substances acquire the character of the higher boiling compounds. It is very important to note the Sulphur content index for environmental organization. Sulphur content is very significant because it governs the amount of Sulphur oxides formed during combustion. Ash content is another property of diesel it is a measure of non-flammable substances present in fuel and is expressed as a percentage of the weight of the fuel sample. According to Sachdev (1983) and Konstando Poulos (2000), The accumulation of ash in diesel particulate filters is one of the most important factors limiting the filters service life and has been described as the most important problem facing diesel engine manufacturers, in their analysis they noted that Ash content usually consist of rust, tank sand, a mixture of distillates and residual oil. Ash content is important to note because it can increase problems such as abrasions, injection malfunctions and high temperature rust especially using residual oils. Diesel blending is very important, therefore finding the appropriate quantity and quality of the blending parts to utilize in order to get a high-quality product at a considerable cost of production is difficult. In this work a linear objective function. The goal is to increase the manufacturing quality and quantity with while maximizing profits.

1.0 MATERIALS AND METHODS

1.1 MATERIALS

This research work does not involve experimental techniques therefore model equations relating to diesel blending will be applied. The quality control department of the Refining Company sampled four (4) different diesel blending properties, Cetane Number, Sulphur, Density and Ash Content. An optimization tool, mass balances, tank model, blending models, literature data and thermodynamic data will be used. Python V3.6 and MATLAB V11 Compiler was used in writing the program.

1.2 METHODS

This involves the mixing of various refined components from various refinery upstream units such as Straight run diesel from CDU, Light cycle oil (LCO) from FCCU, Coker light gas, (CLGO) produce from Coker unit, Hydrocracked diesel unit (HCU) along with additives to produce different grades of diesel product that satisfies the specification given. There are several properties that are important in characterizing diesel, this work will be limited to considering the Cetane number, Sulphur Content, Density, and Ash Content. In this work a linearized blending models are used where the objective function is linear and the constraints are nonlinear. The objective function is to maximize the profit. This objective function will be maximized subject to a set of constraints which represent the demands for quality of the final diesel products.

2.2.1 blending models

The qualities of the outlet stream of the diesel blending unit, which is the final diesel products, are assumed to blend linearly as a function of the quality of the streams sent to the diesel blending. It is expressed mathematically;

$$\boldsymbol{diesel_{blend}} = \sum_i \frac{q_i f_i}{f_t}$$
1

Where

$diesel_{blend}$ Final quality of diesel product.

q_i Quality of component i in j

f_i V olume/mass fraction of component i

f_t Total volume/mass fraction of the product

Demand for each product is given as

$X_{11} + X_{21} + X_{31} + X_{41} \geq 2500$
2

$X_{12} + X_{22} + X_{32} + X_{42} \geq 2000$
3

$X_{13} + X_{23} + X_{33} + X_{43} \geq 1000$ 4

.10) $X_{14} + X_{24} + X_{34} + X_{44} \geq 500$ 5

Ratio of blend $= \frac{X_{i,j}}{X_{1,j} + X_{2,j} + X_{3,j} + X_{4,j}}$
6

Where the value for i and j range from 1 to 4

$Numbers\ of\ diesel\ type\ i\ used = X_{i1} + X_{i2} + X_{i3} + X_{i4}$ 7

$Numbers\ of\ diesel\ type\ j\ produced = X_{1j} + X_{2j} + X_{3j} + X_{4j}$
8

Table 1 Properties of the Feedstock

property	F1	F2	F3	F4
CN	58	56	42	48
SC (PPT)	0.005	0.007	0.02	0.02
AC (%mm/m)	0.002	0.001	0.02	0.03
Density (gml^{-1})	0.868	0.866	0.846	0.848

Considering Cetane number product 1

$$\frac{58X_{11}}{X_{11}+X_{21}+X_{31}+X_{41}} + \frac{56X_{21}}{X_{11}+X_{21}+X_{31}+X_{41}} + \frac{42X_{31}}{X_{11}+X_{21}+X_{31}+X_{41}} + \frac{48X_{41}}{X_{11}+X_{21}+X_{31}+X_{41}} \geq 50$$ 9

Therefore $8X_{11} + 6X_{21} - 8X_{31} + 2X_{41} \geq 0$ 10

Considering Cetane number product 2

$$\frac{58X_{12}}{X_{12}+X_{22}+X_{32}+X_{42}} + \frac{56X_{22}}{X_{12}+X_{22}+X_{32}+X_{42}} + \frac{42X_{32}}{X_{12}+X_{22}+X_{32}+X_{42}} + \frac{48X_{42}}{X_{12}+X_{22}+X_{32}+X_{42}} \geq 49$$
11

$9X_{12} + 7X_{22} - 7X_{32} - X_{42} \geq 0$
12

Considering Cetane number product

$$\frac{58X_{13}}{X_{13}+X_{23}+X_{33}+X_{43}} + \frac{56X_{23}}{X_{13}+X_{23}+X_{33}+X_{43}} + \frac{42X_{33}}{X_{13}+X_{23}+X_{33}+X_{43}} + \frac{48X_{43}}{X_{13}+X_{23}+X_{33}+X_{43}} \geq 46$$
13

$12X_{13} + 10X_{23} - 4X_{33} + 2X_{43} \geq 0$ 14

Considering Cetane number product 4

$$\frac{58X_{14}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{56X_{24}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{42X_{34}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{48X_{44}}{X_{14}+X_{24}+X_{34}+X_{44}}\geq 46$$

15

$$12X_{14}+10X_{24}-4X_{34}+2X_{44}\geq 0$$ 16

Considering Sulphur content product 1

$$\frac{0.005X_{11}}{X_{11}+X_{21}+X_{31}+X_{41}}+\frac{0.007X_{21}}{X_{11}+X_{21}+X_{31}+X_{41}}+\frac{0.02X_{31}}{X_{11}+X_{21}+X_{31}+X_{41}}+\frac{0.02X_{41}}{X_{11}+X_{21}+X_{31}+X_{41}}\leq 0.01$$

17

$$-0.005X_{11}-0.003X_{21}+0.01X_{31}+0.01X_{41}\geq 0$$ 18

Considering Sulphur content product 2

$$\frac{0.005X_{12}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.007X_{22}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.02X_{32}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.02X_{42}}{X_{12}+X_{22}+X_{32}+X_{42}}\leq 0.015$$ 19

$$-0.015X_{12}-0.008X_{22}+0.005X_{32}+0.005X_{42}\geq 0$$ 20

Considering Sulphur content product 3

$$\frac{0.005X_{13}}{X_{13}+X_{23}+X_{33}+X_{43}}+\frac{0.007X_{23}}{X_{13}+X_{23}+X_{33}+X_{42}}+\frac{0.02X_{33}}{X_{12}+X_{23}+X_{33}+X_{42}}+\frac{0.02X_{43}}{X_{12}+X_{23}+X_{33}+X_{43}}\leq 0.018$$ 21

$$-0.013X_{13}-0.011X_{23}+0.02X_{33}-0.02X_{43}\geq 0$$ 22

Considering Sulphur content product 4

$$\frac{0.005X_{14}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{0.007X_{24}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.02X_{34}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.02X_{44}}{X_{12}+X_{22}+X_{32}+X_{42}}\geq 0.01$$ 8

23

$$-0.013X_{14}-0.011X_{24}+0.002X_{34}-0.002X_{44}\geq 0$$ 24

Considering Density for product 1

$$\frac{0.868X_{11}}{X_{11}+X_{21}+X_{31}+X_{41}}+\frac{0.866X_{21}}{X_{11}+X_{21}+X_{31}+X_{41}}+\frac{0.846X_{31}}{X_{11}+X_{21}+X_{31}+X_{41}}+\frac{0.848X_{41}}{X_{11}+X_{21}+X_{31}+X_{41}}\geq 0.86$$

25

$$0.018X_{11}+0.16X_{21}-0.004X_{31}-0.002X_{41}\geq 0$$ 26

Considering Density number product 2

$$\frac{0.868X_{12}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.866X_{22}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.846X_{32}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.848X_{42}}{X_{12}+X_{22}+X_{32}+X_{42}}\geq 0.86$$ 27

$$0.018X_{12}+0.016X_{22}-0.004X_{32}-0.002X_{42}\geq 0$$ 28

Considering Density number product 3

$$\frac{0.868X_{13}}{X_{13}+X_{23}+X_{33}+X_{43}}+\frac{0.866X_{23}}{X_{13}+X_{23}+X_{33}+X_{43}}+\frac{0.846X_{33}}{X_{13}+X_{23}+X_{33}+X_{43}}+\frac{0.848X_{43}}{X_{13}+X_{23}+X_{33}+X_{43}}\geq 0.86$$ 29

$$0.018X_{13}+0.016X_{23}-0.004X_{33}-0.002X_{43}\geq 0$$ 30

Considering Density number product 4

$$\frac{0.868X_{14}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{0.866X_{24}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{0.846X_{34}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{0.848X_{44}}{X_{14}+X_{24}+X_{34}+X_{44}}\geq 0.86$$ 31

$$0.018X_{14}+0.016X_{24}-0.004X_{34}-0.002X_{44}\geq 0$$ 32

Considering Ash content for product 1

$$\frac{0.002X_{11}}{X_{11}+X_{21}+X_{31}+X_{41}}+\frac{0.001X_{21}}{X_{11}+X_{21}+X_{31}+X_{41}}+\frac{0.02X_{31}}{X_{11}+X_{21}+X_{31}+X_{41}}+\frac{0.03X_{41}}{X_{11}+X_{21}+X_{31}+X_{41}}\leq 0.01 \quad 33$$

$$-0.008-0.009\,X_{21}+0.01X_{31}+0.02X_{41}\leq 0 \quad 34$$

Considering Ash content number product 2

$$\frac{0.002X_{12}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.001X_{22}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.02X_{32}}{X_{12}+X_{22}+X_{32}+X_{42}}+\frac{0.03X_{42}}{X_{12}+X_{22}+X_{32}+X_{42}}\leq 0.01 \quad 35$$

$$0.008X_{12}-0.009X_{22}-0.01X_{32}-0.02X_{42}\leq 0 \quad 36$$

Considering Ash content number product 3

$$\frac{0.002X_{13}}{X_{13}+X_{23}+X_{33}+X_{43}}+\frac{0.001X_{23}}{X_{13}+X_{23}+X_{33}+X_{43}}+\frac{0.02X_{33}}{X_{13}+X_{23}+X_{33}+X_{43}}+\frac{0.03X_{43}}{X_{13}+X_{23}+X_{33}+X_{43}}\leq 0.01 \quad 37$$

$$-0.008X_{13}-0.009X_{23}+0.01X_{33}+0.02X_{43}\leq 0 \quad 38$$

Considering Ash content number product 4

$$\frac{0.002X_{14}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{0.001X_{24}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{0.02X_{34}}{X_{14}+X_{24}+X_{34}+X_{44}}+\frac{0.03X_{44}}{X_{14}+X_{24}+X_{34}+X_{44}}\leq 0.01 \quad 39$$

$$-0.008+0.009X_{24}+0.01X_{34}+0.02X_{44}\leq 0 \quad 40$$

2.2.2 Optimization of the Blending Process Objective Function Equation

The objective function is to maximize profit of diesel blend. Similar procedures to that in Iminabo and Alfred (2018) were adopted. The component prices of diesel used in this work are as shown in Table 2. Therefore, the objective function is given as

$$\text{Profit} = \sum X_j * \text{Price}_j - \sum F_i * \text{Cost}_i$$
41

Where;
X_j: Volume of diesel produced or blended
Price_j: Cost price of blended diesel product
F_i: Volume of unblended diesel or feedstock
Cost_i: Cost of unblended diesel or feedstock

Table 1b: Feedstock Prices

FEEDSTOCK	F1	F2	F3	F4
COST	92	90	86	87

2.2.3 Constraints equations (Quality specification)

The quality specification of the product is given upper and lower bound

$\text{diesel}^{L}{}_{i} \leq \text{diesel}_{t} \leq \text{diesel}^{U}{}_{i}$
42

It is also assumed that there is upper and lower specification of the volume of a given blend component used in the final diesel product. That is:

$f_i^L \leq f_t \leq f_i^u$
43

Demand of different grade of diesel must be satisfied.

Equation 1 to 40 was solved using PYTHON V 3.6 Solver

2.2.4 Optimization of the blending process

The objective function is to maximize profit of diesel blend. Similar procedures to that in Iminabo and Alfred (2018) were adopted. The component prices of diesel used in this work are as shown in Table 2

Therefore, the objective function is given as

$$\text{Profit} = \sum X_j * \text{Price}_j - \sum F_i * \text{Cost}_i \quad 44$$

Where;
X_j: Volume of diesel produced or blended

$Price_j$: Cost price of blended diesel product

F_i: Volume of unblended diesel or feedstock
$Cost_i$: Cost of unblended diesel or feedstock

Product specification requirement
For properties that can be predicted by linear correlations

$$Pr_{j,z} = \sum x_{i,j} * \in_z$$
45

$$Pr_{j,z} = \sum w_{i,j} * \in_z$$
46

Where, $Pr_{j,}$ is the value of property z of product j, x_{ij} is volume fraction of component i in product j, ϵ_z is the value of property z of component i. w, is mass fraction of component i in product j.

2.2.5 Blending properties considered in this work include;

I. Sulphur content based on weight fractions of blending components.
II. Cetane number
III. Density
IV. Ash content based on weight fractions of blending components.

The blending properties of the components are calculated as:

$$P_j = \frac{\sum XX_{(i,j)} X P_i}{\sum YY_{(j)}}$$
47

Where P_j is the final property of the blend
$XX_{i,j}$ is the mass of i in product j
P_i is the initial property of i
YY_j is the demand of product j

2.2.6 Solution Techniques

Nonlinear models are very complex and difficult to solve because of too many number of equations and variables that are considered. Moro *et al.* (1998), explained that Researchers tries to breakdown the problems to make it easier to solve and arrive at the desired solution. Due to the difficulties and challenges encountered during diesel blending, it could be very difficult to solve the nonlinear problem directly. It is recommended to linearized the problem and a good initial guess be adopted. The Mathematical Nonlinear Programming problem is expressed as;

$$Maximize\ f(x);$$

$$Subject\ to\ \ g(x) \leq 0$$

$$l \leq x \leq u$$

Where;

x Represent a vector of variables that contains real numbers.

$f(x)$ Represent the objective function

$g(x)$ Represent the sets of constraints

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It is recommended that you give the first value in the first place of all variables in the calculation. The sum of this initial number determines whether the problem can be resolved or not and the duration of the solution. A poor initial value can lead to a lot of settling time and unwanted consequences from the solver and a good initial value can allow for a quick convergence to get the right value.

As there are additional constraints in the diesel integration problem, the problems are divided into two parts, objective function and the blending process, from the first part, the most important constraints related to this research in the objective function are from model equation 1 to 40 which has been solved using the simplex method embedded in PYTHON 3.6 programming language. After the first part was solved to obtain the blend and the objective function, the second part is added into the constraint in model equation 47 to obtain the different properties of the diesel products using MATLAB V11 Compiler.

3.0 RESULTS AND DISCUSSION

Table 3a shows the different blending ratio of the feedstock that yielded the various products.

A diesel blending ratio tends to describes how diesel feedstocks are blended into diesel products. It also determines the composition and properties of a diesel product. The diesel blending ratio for this work is given in Table 3a

Table 2: Diesel blending ratio

Product 1 (%)	24	24	12	28
Product 2 (%)	25	25	21	2
Product 3 (%)	26	25	34	68
Product 4 (%)	25	26	33	2
FEEDSTOCKS	**F1**	**F2**	**F3**	**F4**

Table 3: Shows the specifications of the products according to the African Refiners Association (ARA) 2020, standard.

The specification of the products are very important and is the key constraints in diesel production. Recall that properties are also key to determine the price and optimize the cost of diesel blending process. Inaccurate property of diesel calculation can lead to profit loss the reason why many refiners battles to develop a model of refining process and product blending of diesel fuel.

Table 3: Product Specification

Property	P1	P2	P3	P4
Sulphur Content (PPT)	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01
Density [15°C (gml^{-1})]	0.85 – 0.86	0.85 – 0.86	0.85 – 0.86	0.85 – 0.86
Ash content [% (m/m)]	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01
Cetane Number	≥ 50	≥ 50	≥ 50	≥ 50
Demand (bbl)	2500	2000	1000	500

Table 4: indicates the product properties of the different blends of the produced diesel

Table 4: Targeting maximization of diesel products based on the properties of the products

	P1	P2	P3	P4
Cetane number	55	53	50	50
Sulphur content (PPT)	0.0002	0.0004	0.003	0.005
Density [15°C (gml^{-1})]	0.86	0.86	0.86	0.86
Ash content [% (m/m)]	0.01	0.01	0.01	0.01
Cost of product	93	91	90	90
Demand (bbl)	2500	2000	1000	500

Table 5 clearly shows the variation of the current cost of diesel product and the optimized product.

Table 5: Variation between refinery current cost and the optimized cost

Diesel Product	Cost of current Production ($/bbl)	Cost of Optimized Production ($/bbl)	Percentage Deviation (profit) (%)
P1	92	93	1.09
P2	90	91	1.11
P3	86	90	4.65

P4	87	90	3.45

Table 6a Shows the Comparison between the standard specification and product 1 (P1) where the property of Cetane number shows a 10% increase above the standard, density shows 1.2% increase, the Sulphur content reduced to 98% and no deviation in the Ash content but satisfies the specification of Africa refiners association (ARA).

Table 6a: Comparison between the standard and the properties of product 1.

Property	Standard specification	Product 1	Percentage Deviation (%)
Cetane number	50	55	10
Sulphur content (PPT)	0.01	0.0002	98
Density [15^{o}C (gml^{-1})]	0.85	0.8617	1.2
Ash content [%(m/m)]	0.01	0.01	0.00

Table 6b shows the comparison between the standard and the properties of product 2. The Cetane number shows a 6% increase and the density shows a 1.2% increase while the Sulphur and the ash content shows 96% and 90% decrease.

Table 6b: Comparison between the standard and the properties of product 2.

Property	Standard specification	Product 2	Percentage Deviation (%)
Cetane number	50	53	6
Sulphur content (PPT)	0.01	0.0004	96
Density [15^{o}C (gml^{-1})]	0.85	0.8612	1.2
Ash content [% (m/m)]	0.01	0.001	90

From table 6c, it is obvious that the corresponding property of Cetane number and Ash content of product 3 equals the standard specification and satisfies the Africa Refiners Association specification of products while the Sulphur content shows a 70% decrease and the density indicates 0.8% increase, since a high Sulphur content property is not good for the refiner therefore any decrease in property will yield in an increase in price.

Table 6c: Comparison between the standard and the properties of product 3

Property	Standard specification	Product 3	Percentage Deviation (%)
Cetane number	50	50	0

Sulphur content (PPT)	0.01	0.003	70
Density [15°C (gml^{-1})]	0.85	0.857	0.8
Ash content [% (m/m)]	0.01	0.01	0

Table 6d is an indication that all the properties of the feedstock produced a better blend as there various specifications are in agreement with the standard specification.

Table 6d: Comparison between the standard specification and the properties of products 4

Property	Standard specification	Product 4	Percentage Deviation (%)
Cetane number	50	50	0
Sulphur content (PPT)	0.01	0.005	50
Density [15°C (gml^{-1})]	0.85	0.855	0.6
Ash content [% (m/m)]	0.01	0.01	0.

From Table 2 to Table 6d above it can be seen clearly that the model solution produces a better blend and the profit of production increased, this implies that the optimization objective function which is a profit function has been achieved.

Secondly the optimization of the blending process was done to achieve the specifications of the four (4) diesel products. The data used in this work are standard, this implies that the general evaluation of the model is feasible and is a good agreement with the specifications of the product. The variation of the total objective function from the refinery and the optimized product was 10.3% which also indicates the profit in total barrel of diesel produced.

Fig 1 shows a representation of the optimized diesel product cost versus the volume. It was observed that the cost was maintained at $90/bbl but at a volume of 2500bbl the cost increased to $93/bbl these indicates that , as volume increases, the profit increases but as the volume decreases the diesel blend loss its properties, as such there will be profit loss and decreases to a product. Also, at the optimum results, profit was made, the volume fraction of the blended diesel product was suitable for the market with very high value.

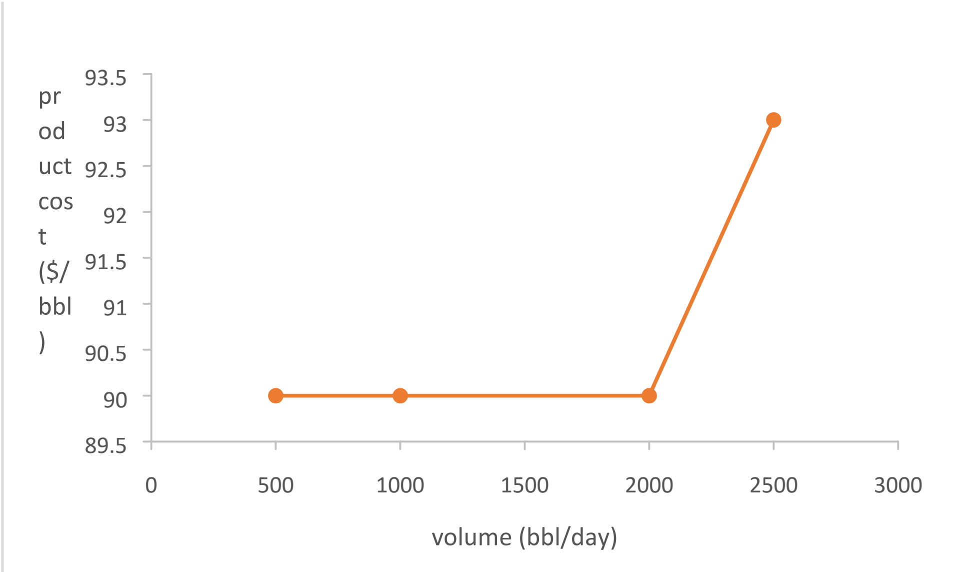

Fig: 1 Plot of optimized cost against volume

4.0 Conclusion

The objective of this research is to examine the quality of diesel for industrial and domestic utilization, as such establish a model for diesel blending process which will yield a high quality diesel with stringent environmental regulation and profit.

An investigation was carried out on the following properties of diesel component Density, Cetane number, Sulphur content and Ash point. A nonlinear model was developed to optimize diesel blending which is mostly used by refiners. Property prediction of diesel blending was applied to improve the model accuracy. The blending model and the optimization model were developed and MATLAB V11 and PYTHON 3.9 code was written to solve the equation using nonlinear programming language.

A nonlinear programming (NLP) model has been used to determine the optimum production cost of diesel fuel with refinery benefits. Four type of diesel blends can be produced satisfying the Africa Refiners Association specifications. The volume percentage ratio of the various blends are seen as 24% F1, 25% F2, 26% F3 and 25%F4 are needed for the production of product 1, while 24%F1, 25%F2, 25%F3, 26%F4 for the production of product 2, also 12%F1, 21%F2, 34%F3, 33%F4 for the production of product 4 and finally 28%F1, 2%F2, 68%F3, 2%F4 for the production of product 4. It has been found that it is necessary to increase the production, if maximum profit of diesel

product by the refinery is targeted. The diesel table components ratio of blending were analysed as shown in Table 2 and from the analysis it is found that the diesel satisfy ARA specification.
The total product capacity of this research is six thousand barrel per day (6000bbl/day).

Care was taken to avoid inaccurate correlation that may possibly lead to unqualified products based on the specifications and standard. From Table 5, the deviation in cost indicates 10.3% increase when multiplied with the total barrel of product gave $61000/day production profit.

5.0 RECOMMENDATIONS

Based on my limitations I wish to recommend the following;

i. More accurate property prediction like cold filter plugging point, pour point, viscosity, cloud point etc. Should be adopted and investigated in Nigerian Refinery Company.
ii. Offline blending was considered in this research, however, inline blending should be adopted using the methodology developed in this work.

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