Sensitivity Analysis of Selected Project Parameter on the Feasibility of Converting Maize Cob to Bioethanol as a Means of Promoting Biorefinery Establishment in Nigeria

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Abstract- Biofuels have been a centre of attraction in renewable energy science, owing to the depleting nature of fossil fuels. Solid waste products like maize cob have been used to produce bioethanol. This helps in recycling waste. However, the production process has not been cost-effective when done on a large scale. Optimisation studies on the production of biofuel and the economic feasibility of setting up a biorefinery in Nigeria have been carried out by different researchers on different feedstock. This study aims at reviewing the impact of government policies on subsidy, tax and cost of raw material will have on the establishment of biorefineries in Nigeria. Efficient models for determining ROI (return on investment) and NP (net profit) were deduced. It was understood from this study that subsidy had more effect on ROI and NP than the cost of raw materials alone.

Keywords Biofuel, Biomass, Economics Feasibility, Optimization, Waste, RSM.

1. Introduction

Fossil fuel is a significant source of global energy. The world's reserves of fossil fuels are depleting and not being replaced because they are non-renewable. Also, the production, processing, and usage of fossil fuels have resulted in alarming environmental pollution, discouraging farming, threatening the livelihood of aquatic lives, inhibiting other agricultural activities, and depleting the ozone layer [1]–[3]. Greenhouse effects and threats to the environment and human health have led to the need to redirect energy research to other sources that are greener, cleaner, and more effective [4]–[10].

The possibility of producing energy from various sources that are renewable is a blessing to modern man. This is the concept or idea behind green energy. Unlike fossil fuels, they are ecologically friendly and have little or no lethal effect on the health of the populace. It is also worthies of note that the usage of renewable energy does not out way its production. This makes it possible for a generation of the human race to use energy and not deprive the next generation of the availability of the same resources, i.e., sustainability. The energy produced from renewable sources has been reported to meet the global energy demand. Biomass, amongst other renewable sources of energy such as solar, hydropower wind etc., is considered the dominant contributor of energy [11]–[16].

Biofuels are fuels obtained from biomass pretreatment, which could be either in carbohydrates or lipid. They include, biodiesel [17]–[21], biogas [22]–[25], bioethanol [26]–[33]. Bioethanol, being the most popular of them, has found use in vehicles and engines originally dependent on fossil fuel. One of the threats posed towards biofuels has been food security, as some of the biomass rich in carbohydrates are required by humans or farm animals for food. To prevent the possible challenge of food security, non-edible parts of the feedstock have been deployed. Feedstock such as maize cob is of no threat to food security. To further authenticate the biodiesel and its blended grade like B20 diesel, Mohite & Maji [34] study stressed the significance of a biofuel performance certification and why communities needed to embrace it to improve and maintain better a high-quality biofuels distribution and consumption in our respective communities.

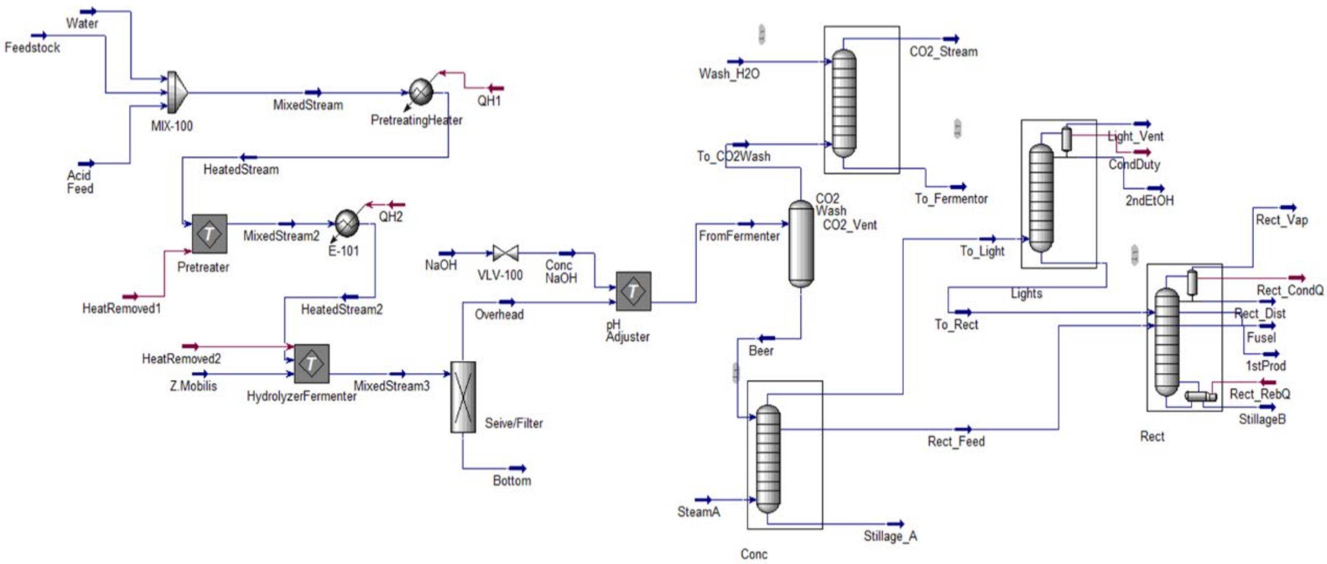

Fig. 1. The process flow for bioethanol production from maize cob [35].

Many works across the globe have been engaged in different forms of a search to establish an economically viable processing plant for the production of bioethanol from diverse feedstock. The trend of the research and developmental studies works on the bioethanol fuel promotion in Nigeria has been widely reported in a recent report [36], where several contributions made by the different authors were reported. Among the work reported include some work that looked into the transformation of the biomass like rice husk [37], [38], yam peels [39], water hyacinth biomass [40], Solanum nigrum fruits [41], cassava peels [29], oil palm empty fruit bunches [42], sugarcane bagasse [43]–[45], potato peels [27], [46], maize or corn stover [47], empty fruit bunch [48], and a lot more into the bioethanol. Some of these works look into the laboratory investigation of this process to improve or invent a better technique or technology of obtaining higher yield with cheaper materials [7], [27], [29], [47], [49], [50]. Whereas others looked into the investigation of the constraints involved in the scale-up of the processes established at the laboratory scale to understand its commercial potential benefits and constraints, alongside with the search for ways to improve its economic viability in order to attract the interest of the public to invest in the idea [12], [35], [38], [44], [51]–[56].

The existing report employs the MATLAB-based Economic Analyzer Algorithm developed by Oyegoke and Dabai [40], [41] to ascertain the profitability of the plant project and understand the economic ease of the bioethanol substituting the use of petrol in Nigeria. While the report categorically indicated that it was found to be unfavourable, some optimized conditions were reported from the optimization studies carried out. However, to better understand how selected parameters influence the viability of the bioethanol project, this present study seeks to present the impact of change in the cost of raw material and change of government policies in terms of revision of tax rate, and approval or denial of subsidy on bioethanol production in Nigeria. Findings from this report would provide guidance for policymakers to innovate better policies that would promote and ease the setting up of bio-refineries in developing countries like Nigeria.

2. Materials and Methods

2.1. Process Studied and its Description

The process investigated is a production plant that employs the use of biomass known as maize cob, which is largely rich in cellulose and hemicellulose, as stated in literature [35]. The existing report presented several processes involved in transforming the aforementioned biomass (maize cob) into bioethanol fuel, providing the various equipment specifications for the plant, including the total equipment cost for the use of maize cob. Some of these processes include biomass pretreatment to improve accessibility to the cellulose and hemicellulose component of the biomass, biomass hydrolysis to simple sugar [8], sugar fermentation to bioethanol, and bioethanol purification. The model reported for the process simulation and modelling of the maize cob to bioethanol process in the previous studies [35] is presented in Fig. 1.

Moreover, the report [35], [55] of the process simulation indicated that 68.36 kg of sulphuric acid, 6565.11 kg of water, 36.67 kg of NaOH, and 11.35 kg of *Z. Mobilis* is continuously used in the processing of the 567.30 kg of maize cob into 4,154.94 kg of bioethanol every hour. The choice of the process adopted for converting maize cob to bioethanol has been made based on the existing report cited in the literature [57]–[59].

2.2. Techno-economic Analysis Approach: Impact of Selected Parameter on the Project

This study employed the use of the MATLAB code, whose details are given in Supplementary Information for the investigation of the selected parameter's impact on the bioethanol plant projects, economic viability in terms of net profit (NP) and return on investment (ROI). Raw material cost (RM), consideration of Government subsidy (SD), and taxation rate (TX) on bioethanol fuel and its production were the selected parameters whose impact on the project viability were investigated. Some of the vital models present in the code used are presented in Equations 1 to 4.

$$GI = SP * V - COM \tag{1}$$

$$NP = GI * (1 - TR) \tag{2}$$

$$ROI = \frac{NP}{TCI} * 100\% \tag{3}$$

$$NPW = \sum \frac{(B_n - C_t)}{(1+r)^{\wedge}t} \tag{4}$$

Where TCI is the total capital investment, SP is the selling price, V is the quantity or volume of bioethanol produced, NPW is the net present worth of the project, ROI is the return on investment, COM is the cost of manufacturing, r is the discount rate, t is the project life, NP is the net profit, GI is the gross profit, TX is the tax rate, B is the benefit available in the project life, and C is the cost in the project life's cash flow.

Table 1. Relevant data deployed [35], [55], [60]–[64] (where ** indicated variable selected for sensitivity analysis).

Criteria/Parameters	Details	Unit	Amount
Working details	Time	h	24
	Days	days	365(0.9)
Manufacturing cost	Raw material (**RM)	N/kg	**100-500
	Acid H_2SO_4	$/kg	0.40
	NaOH sale price	$/kg	0.30
	Z-mobilis	$/kg	5.60
	Cooling water	$/ton	5.71
Bioethanol production	Rate	kg/h	4,154.94
	Volume	L	42,129,561.81
	Proposed selling price	N/L	140
Other Cost	Total plant equipment cost	$	996,950
	Total capital estimation method	-	Factorial method
	Total capital investment	$	5,643,494.68
	Electricity rate	N/kWh	43.38
Other parameters	Discount rate / Interest rate	% / %	10 / 10
	Exchange rate	N/$	360
	Tax rate (**TX)	%	**0-30
	Economic project life	Year	25
	Depreciation method	-	Straight line
	Depreciation period	Year	10
	Subsidy (**SD)	-	**0-30

A 2 by 3 response surface design approach with the Box Behnken (BB) design technique were employed in the investigation. Three factors with two levels (that is, the raw material (RM: 100 to 500 Naira per kg), subsidy (SD: 0 to 30 %), and tax rate (TX: 0 to 30%) were considered for this study while measuring how it impacted the two-output variable (that is, dependent variables) which includes return on investment (ROI) and net profit (NP). The use of Design Expert application was deployed in the design of the study matrix and the analysis of variance (ANOVA) analysis. Table 2 presents the summarized form of the study design used in the analysis, resulting in 17 runs/combinations of different conditions.

The analysis includes developing models that would effectively predict the impact of the selected parameters on the ROI and NP. From which, various model suitability was investigated using ANOVA (along with F-test), descriptive statistics and R-square values. These models include linear, two-factor interaction (2FI), quadratic, and cubic models. The most suitable model was deployed to investigate the change in the selected variable to understand its impact on the ROI and NP. Response surface plots were deployed to showcase the effect of these changes on the economics of the bioethanol plant project.

Table 2. Design Summary for the analysis.

Factor	Units	Low	High	Response	Units	Obs
RM	=N=/kg	100.00	500.00	NP	$	17
SD	%	0.000	30.00	ROI	%	17
TX	%	0.000	30.00	-	-	-

Other relevant data employed in the study using the MATLAB-based economic analyzer code and Design Expert is presented in Table 1, excluding the output variable that is expected to be changing like ROI, COM, NP, and others dependent on the selected parameters analyzed. The table further indicated the variables selected for the sensitivity analysis with a sign (**) and range of values considered for the study.

3. Results and Discussions

The design matrix showcasing the different runs or combinations evaluated in the analysis of the studying the impact of raw material cost (RM), government subsidy, (SD), and tax rate (TX) on the viability of the investment which was measured using the net profit (NP) and return on investment (ROI) is presented in Table 3.

3.1. Screening of statistical models' fitness for the response (NP and ROI) prediction

The screening process was carried out to identify the model that best fits the net present (NP) and return on investment (ROI)'s data (in Table 3) whose model would accurately predict other unevaluated conditions. The models evaluated include linear, two-factor interaction (2FI), quadratic, and cubic models using analysis of variance (ANOVA) and other statistical parameters like R-squared value, Standard deviation, and Prediction error sum of squares (PRESS).

Table 3. Design matrix for the analysis showing the factors (inputs) and responses (outputs)

Run	Factors (Inputs)			Responses (Outputs)	
	RM	SD	TX	NP	ROI
1	300.00	30.00	0.00	-2492.4	-0.044164
2	300.00	15.00	15.00	-3.6383E+06	-64.469
3	500.00	15.00	30.00	-3.67506E+06	-65.12
4	500.00	30.00	15.00	-826391	-14.643
5	100.00	0.00	15.00	-5.35936E+06	-94.965
6	300.00	15.00	12.00	-3.76671E+06	-66.744
7	300.00	15.00	14.00	-3.6811E+06	-65.227
8	100.00	15.00	30.00	-2.31744E+06	-41.064
9	300.00	13.00	15.00	-4.02839E+06	-71.381
10	500.00	0.00	15.00	-7.0079E+06	-124.18
11	133.33	15.00	15.00	-2.95139E+06	-52.297
12	300.00	30.00	30.00	-1744.7	-0.030915
13	100.00	30.00	15.00	822154	14.568
14	500.00	15.00	0.00	-5.25009E+06	-93.029
15	300.00	0.00	30.00	-5.0924E+06	-90.235
16	300.00	0.00	0.00	-7.27486E+06	-128.91
17	100.00	15.00	0.00	-3.31062E+06	-58.663

(a) Analysis of variance

The results collected from the analysis of variance (ANOVA) for selection of the appropriate models that best fit the data collected for the forecast of the net present (NP) and return on investment (ROI) is presented in Table 4 and 5.

The study of the results presented in Table 4 for net profit (NP) showed that the cubic model is aliased, which implies that the cubic model has some aliased terms (that is, terms that are insignificant but largely contribute noise to the model) and would not suitably fit well for the set of data analyzed. In contrast, the tendency that the linear, two-factor-interaction (2FI), and quadratic model will best predict the NP is <0.0001, 0.0638, and <0.0001, respectively. Using a 95% confidence level, it was identified based on the analysis that both linear and quadratic models can have good NP predictions. This was because the F-Values of both quadratic and linear models are respectively highly statistically significant relative to the F-value of two-factor-interaction (2FI). The aliased terms (that is, terms that contribute to noise or error to a model) were identified as the cubic terms that rendered the cubic model invalid for predicting NP and ROI effectively while confirming models of lower degrees like quadratic and linear to be more suitable. Further evaluation of the results presented for return on investment (ROI) in Table 5 discloses that the cubic model is unsuitable (that is, aliased). In contrast, the consideration of the linear, two-factor-interaction (2FI), and quadratic model potentials for the excellent prediction of ROI were obtained to be <0.0001, 0.0637, and <0.0001, respectively. With the use of a 95 % confidence level, the linear and quadratic models were both confirmed to have the possibility for good NP prediction based on highly statistically significant F values for both quadratic and linear models, respectively, in line with the literature [65], [66].

Further evaluation of the results presented for return on investment (ROI) in Table 5 discloses that the cubic model is unsuitable (that is, aliased). In contrast, the consideration of the linear, two-factor-interaction (2FI), and quadratic model potentials for the excellent prediction of ROI were obtained to be <0.0001, 0.0637, and <0.0001, respectively. With the use of a 95 % confidence level, the linear and quadratic models were both confirmed to have the possibility for good NP prediction based on highly statistically significant F values for both quadratic and linear models, respectively, in line with the literature [65], [66].

Table 4: NP model for the plant project

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Mean	1.936E+014	1	1.936E+014		
Linear	8.527E+013	3	2.842E+013	145.30	< 0.0001
2FI	1.275E+012	3	4.249E+011	3.35	0.0638
Quadratic	1.250E+012	3	4.165E+011	155.23	< 0.0001
Cubic	1.878E+010	7	2.683E+009	-	Aliased
Residual	0.000	0	-		
Total	2.814E+014	17	1.655E+013		

Table 5: ROI model for the plant project

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Mean	60772.84	1	60772.84	-	-
Linear	26772.98	3	8924.33	145.31	< 0.0001
2FI	400.26	3	133.42	3.35	0.0637
Quadratic	392.25	3	130.75	155.31	< 0.0001
Cubic	5.89	7	0.84	-	Aliased
Residual	0.000	0	-		
Total	88344.22	17	5196.72		

(b) Model statistics summary

In the search for models that best fit Net Profit (NP), selecting the appropriate model has often been guided through the use of statistical parameters such as R-squared values and PRESS stated in Table 6. The quadratic model was considered the best due to the largest R^2 of 0.9998, the largest adjusted R^2 of 0.9995, the most significant value Predicted R^2 of 0.9969, and the smallest value of prediction error sum of squares (PRESS) with a value of 2.745E+011.

Table 6: NP model for the plant project

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS
Linear	4.423E+005	0.9710	0.9644	0.9432	4.983E+012
2FI	3.561E+005	0.9856	0.9769	0.9419	5.102E+012
Quadratic	51799.72	0.9998	0.9995	0.9969	2.745E+011
Cubic	-	-	-	-	Aliased

Table 7: ROI model for the plant project

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS
Linear	7.84	0.9710	0.9644	0.9433	1564.65
2FI	6.31	0.9856	0.9769	0.9419	1601.53
Quadratic	0.92	0.9998	0.9995	0.9969	86.12
Cubic	-	-	-	-	Aliased

This finding suggests that the quadratic model has a higher predictive ability. Based on having the least prediction error sum of squares, it is the most accurate model relative to the other competing models that best fit NP. Therefore, the quadratic model is the best model for fitting Net Profit (NP) based on this present study's evidence.

Also, in Table 7 above, the appropriate model selection was made via the use of statistical parameters (as selection criteria) given in Table 7. These statistical parameters indicated that a quadratic model would best fit the ROI data, which displayed the largest R^2 (0.9998), the largest adjusted R^2 (0.9995), most considerable value predicted R^2 (0.9969), and the smallest value of prediction error sum of squares (PRESS) with a value of 86.12. Therefore, the quadratic model was suggested as the best for predicting ROI due to its lower PRESS criterion displayed than other models. This once again highlights the high predictive power of the quadratic model for fitting the ROI data.

3.2. Analysis of the selected model for the NP and ROI predictions

(a) Analysis of variance for the NP model

The quadratic model obtained for the prediction of net profit (NP) from the use of Response Surface Methodology (RSM) approach using Box Behnken (BB) design [67], [68] is given in equation (5). The variance analysis for the model and its composed variables, which evaluates the significance of different factors (in the form of variables in the model) to the NP's rise in this study, is presented in Table 8.

Table 8: Analysis of the selected NP model before the elimination of insignificant Variables

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model (NP)	8.779E+013	9	9.755E+012	3635.39	< 0.0001
RM	5.829E+012	1	5.829E+012	2172.30	< 0.0001
SD	7.654E+013	1	7.654E+013	28526.59	< 0.0001
TX	2.835E+012	1	2.835E+012	1056.39	< 0.0001
RM^2	15494.41	1	15494.41	5.775E-006	0.9981
SD^2	1.246E+012	1	1.246E+012	464.54	< 0.0001
TX^2	8680.11	1	8680.11	3.235E-006	0.9986
RM*SD	0.000	1	0.000	0.000	1.0000
RM*TX	8.463E+010	1	8.463E+010	31.54	0.0008
SD*TX	1.190E+012	1	1.190E+012	443.49	< 0.0001
Residual	1.878E+010	7	2.683E+009		
Cor Total	8.781E+013	16			

Table 8 gives an overview of the linear, quadratic, and interaction effects of the variables. The p-value (Prob>F) is used as a tool to confirm the significance of each factor (variable) and the interaction between the factors. In general, each variable's significance is determined by the P-value of the variable's coefficient. The P-values lower than 0.05 suggest that the model's variables are statistically significant. Otherwise, they are insignificant. Therefore, based on the ANOVA results presented in Table 8, the linear effect of RM, SD, and TX each as a p-value of <0.0001 and has the largest effect on Net Profit in line with the literature [65]. This is followed by the effects of SD^2 (quadratic), RM*TX (interaction) and SD*TX (interaction), with p values of <0.0001, 0.0008, and <0.0001, respectively.

$$NP = -5.87 * 10^6 - 4849.62 * RM + 1.70 * 10^5 * SD + 61434.60 * TX + 1.55 * 10^{-3} * RM^2 + 2424.60 * SD^2 - 0.20 * TX^2 + 5.04 * 10^{-13} * RM * SD + 48.49 * RM * TX - 2424.12 * SD * TX \quad (5)$$

The quadratic effect of RM^2 in Table 8 above could not significantly affect the Net Profit (NP) due to its p-value (0.9981). Similarly, the TX^2 (quadratic) has no significant effect on Net Profit (NP) with a p-value of 0.9986, and the interaction effect of RM*SD has no significant effect on Net Profit (NP).

Based on the NP model in equation (5) above, low coefficient of 1.55E-03, 0.20, and 5.04E-013 for RM^2, TX^2, and RM*SD, respectively, resulted in the variables (terms) being excluded from the model to reduce the noise present in the model, and so that the prediction of the model is improved. This consequently gave rise to the model in equation (6).

$$NP = -5.87 * 10^6 - 4848.70 * RM + 1.70 * 10^5 * SD + 61428.55 * TX + 2424.59 * SD^2 + 48.49 * RM * TX - 2424.12 * SD * TX \quad (6)$$

Further analysis of the improved NP prediction model provides greater confidence in prediction, as shown by the results of the ANOVA presented in Table 9. The analysis of the improved NP quadratic model after the elimination of insignificant variables shown in Table 9 reveals that for each of the variables of the model, the first-order effects of all variables (RM, SD, and TX) respectively have a significant effect on the Net Profit with a p-value of 0.0001. Also, the quadratic effect indicated that B^2 affects net profit with a p-value of 0.0001. Two-levels interaction of RM*TX and SD*TX had a significant effect on net profit with a p-value of 0.0001 in accordance with the literature [66], [69].

Table 9: Analysis of the selected NP model after the elimination of insignificant variables

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	8.779E+013	6	1.463E+013	7790.12	< 0.0001
RM	5.855E+012	1	5.855E+012	3117.08	< 0.0001
SD	7.656E+013	1	7.656E+013	40763.09	< 0.0001
TX	2.837E+012	1	2.837E+012	1510.64	< 0.0001
SD^2	1.250E+012	1	1.250E+012	665.25	< 0.0001
RM*TX	8.463E+010	1	8.463E+010	45.06	< 0.0001
SD*TX	1.190E+012	1	1.190E+012	633.55	< 0.0001
Residual	1.878E+010	10	1.878E+009		
Cor Total	8.781E+013	16			

These results imply that the improved NP model in equation (6) would excellently make the right prediction for NP scenarios' different conditions to be evaluated. Hence, as mentioned earlier, the results highlight the importance of using an appropriate model built on sound foundations in predicting NP so that the model's findings are credible and can credibly inform decision-making.

(b) Analysis of variance for the ROI model

The selected quadratic model obtained for the prediction of ROI from the use of the Response Surface Study approach using Box Behnken (BB) design [68] yields equation (7).

The ANOVA for the ROI model in equation (7) and its composed variables that evaluate the significance of different factors (in the form of variables in the model) to the rise in the ROI of this project are presented in Table 10. Table 10 gives an analysis of the selected model before eliminating insignificant variables. The result in Table 10 shows that the linear effect of RM, SD, and TX had a significant effect on the return on investment (ROI) with a p-value of <0.0001, respectively.

$$ROI = -103.98 - 0.086 * RM + 3.01 * SD + 1.09 * TX + 2.37 * 10^{-8} * RM^2 + 0.043 * SD^2 - 4.28 * 10^{-6} * TX^2 + 3.33 * 10^{-7} * RM * SD + 8.59 * 10^{-4} * RM * TX - 0.043 * SD * TX \quad (7)$$

Also, SD's quadratic effects were significant in the statistical analyses with a p-value of <0.0001. In Table 10, the interaction coefficient between RM (cost of raw materials) and TX (tax rate) turned out to have a significant effect on Return on Investment (ROI), with a p-value of 0.0008 in accordance with the literature [70].

Table 10: Analysis of the selected ROI model before the elimination of insignificant variables

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	27565.49	9	3062.83	3638.07	< 0.0001
RM	1830.18	1	1830.18	2173.91	< 0.0001
SD	24033.73	1	24033.73	28547.57	< 0.0001
TX	890.06	1	890.06	1057.22	< 0.0001
RM^2	3.615E-006	1	3.615E-006	4.294E-006	0.9984
SD^2	391.29	1	391.29	464.78	< 0.0001
TX^2	3.854E-006	1	3.854E-006	4.577E-006	0.9984
RM*SD	4.000E-006	1	4.000E-006	4.751E-006	0.9983
RM*TX	26.57	1	26.57	31.56	0.0008
SD*TX	373.68	1	373.68	443.87	< 0.0001
Residual	5.89	7	0.84		
Cor Total	27571.38	16			

Also, the interaction between SD (government subsidy) and TX (tax rate) proved to have a significant effect on the return on investment (ROI), at a p-value of 0.0001. The interaction between RM*SD had no significant effect on ROI with a p-value of 0.9983. The quadratic effects of RM and TX were insignificant in the statistical analyses, with a p-value of 0.9984 in line with the literature report [65], [66] on ANOVA.

The variables RM^2, $TX^{2,}$ and RM*SD were insignificant, displaying insignificant coefficients of 2.36937E-08, 4.27566E-006, and 3.33333E-007 for their respective terms in the model. These variables were removed to reduce the noise present in the ROI model to improve the model prediction. Therefore, the improved ROI model was expressed in equation (8).

$$ROI = -103.99 - 0.086 * RM + 3.01 * SD + 1.09 * TX + 0.043 * SD^2 + 8.59 * 10^{-4} * RM * TX - 0.043 * SD * TX \quad (8)$$

Similarly, a further assessment of the improved ROI prediction model gives better confidence in prediction demonstration with the ANOVA results presented in Table 11. After excluding insignificant variables, ANOVA's result got the selected model's analysis shown in Table 10 for each model variable. According to the P-values, the first-order effects of all variables (RM, SD, and TX) significantly affect the return on investment (ROI) at a p-value of 0.0001 in line with the literature [65], [69], [70].

Also, the quadratic effect indicated that B^2 has an effect on return on investment (ROI) with a p-value of 0.0001. Two-level interaction of RM*TX and SD*TX significantly affected Return on Investment (ROI) with a p-value of 0.0001. The results indicated that the improved ROI model in equation (8) would excellently make a good prediction for different conditions of ROI scenarios to be evaluated.

Table 11: Analysis of the selected ROI model after the elimination of insignificant variables

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	27565.49	6	4594.25	7795.85	< 0.0001
RM	1838.32	1	1838.32	3119.40	< 0.0001
SD	24040.14	1	24040.14	40793.04	< 0.0001
TX	890.95	1	890.95	1511.83	< 0.0001
SD^2	392.25	1	392.25	665.60	< 0.0001
RM*TX	26.57	1	26.57	45.09	< 0.0001
SD*TX	373.68	1	373.68	634.09	< 0.0001
Residual	5.89	10	0.59		
Cor Total	27571.38	16			

3.3. Effect of subsidy, tax, and raw material cost on the NP and ROI in the production

The influence of the change in the tax rate (TX) by the government on bioethanol production, fluctuation of the prices of raw material (RM), and the government's decision to approve the subsidy for the sales of bioethanol fuel in Nigeria were investigated. The results obtained are presented in Fig. 2, where Fig. 2(a-b) displayed the effect of the raw material (RM) and subsidy (SD); Fig. 2(c-d) displayed the effect of government tax (TX) and subsidy (SD); while Fig. 2(e-f) displayed the effect of the government tax rate (TX) and raw material cost (RM) on the project's NP and ROI.

The study of the results presented in the surface plot (Fig. 2(a-b)) indicates that a rise in the raw material cost (RM) results in a fall in the NP and ROI, whereas a rise in government subsidy (SD) results in a rise in the NP and ROI. Although, the contribution of the rise in the SD was observed to be more significant than the RM influence, which was graphically displayed with the sloppy surface observed for the axes of the SD. The more significant effect of the rise in government subsidy over raw materials may reflect more the subsidy use, especially where it is used to meet significant capital cost, which is relatively high as observed in this study. Such a subsidy from the government would not require massive capital investment into bioethanol production by the producer, thus substantially reducing its overall production costs.

Also, the contour plot with yellow background displayed a more linear contour, which implies the contribution of the RM*SD interaction is not significant due to continuous straight-line contour displayed on the contour plot indicating that RM contributes more negligible effect on the change in the ROI and NP.

Further study of the plots presented in Fig. 2(c-d) indicates that a rise in government subsidy (SD) results in a rise in the ROI and NP, while a rise in the government tax rate (TX) results in a fall in the project benefit. Both factors, SD, and TX, were significant. Still, SD's contribution was more outstanding than TX's contribution, significantly when SD and TX rose simultaneously. The contour plot displayed more non-linear contours for the SD*TX interaction than that recorded for RM*SD, which implies the contribution of the RM*SD interaction is much more significant due to its continuous non-linear contours displayed on the plot. This finding reveals that the SD*TX interaction contributes a better effect to the change in the ROI, and NP relative to the RM*SD interaction contribution was earlier recorded to be less.

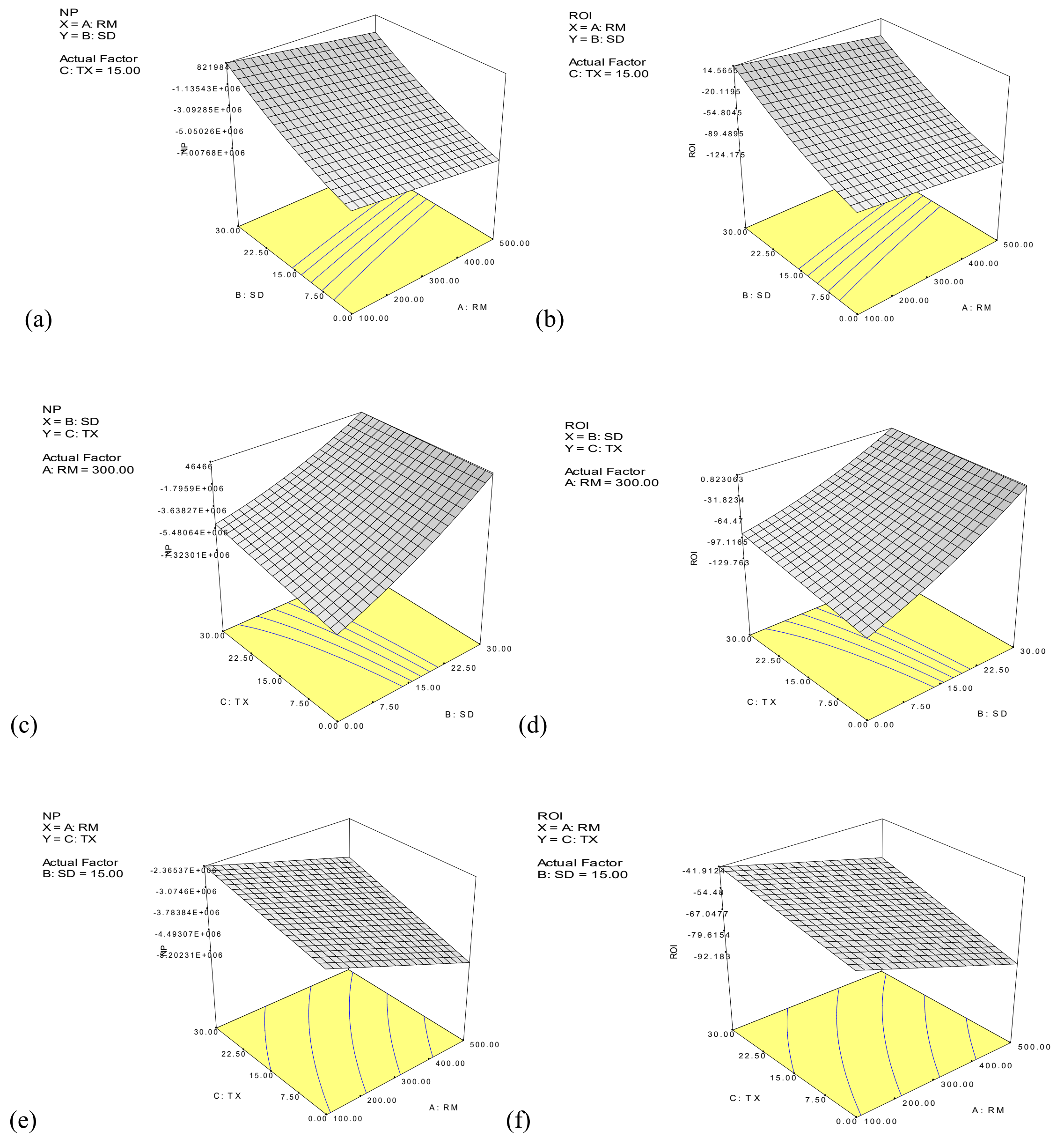

Fig. 2. Response surface plot displaying the indicating effect of RM (a-b), SD (c-d), and TX (e-f) on the change in NP and ROI for the use of maize cob for bioethanol production

Also, findings from the study of the plots displayed in Fig. 2(e-f) shows that a decrease in the raw material cost (RM) resulted in a rise in the ROI and NP, while the rise in the government tax rate (TX) resulted in a fall in the project benefit. The findings are graphically displayed in the surface plot slope. It was further identified that RM and TX contribute significantly to change in ROI and NP. The study of the contour plot in Fig. 2(e-f) displayed more non-linear contours with a significant level of curve/non-linearity. This observation implies that the RM*TX interaction contributes significantly to the change in ROI and NP due to the non-linearity of the lines displayed on contour plots. Each line indicates the effect of rising or fall caused on the ROI and NP as the interaction changes.

The overall evaluation of the surface plot displayed in Fig. 2 indicated that the RM*TX interaction recorded the highest contribution while RM*SD interaction recorded the most negligible contribution to ROI and NP, based on this study using a quadratic model. These results agree with the suggestions obtained from the ANOVA output presented in Table 8 (NP) and Table 10 (ROI), which earlier indicated that the contribution of RM*SD interaction is insignificant and should be neglected to improve the prediction accuracy of the models.

Bioethanol remains promising as clean and efficient energy. However, it is not cost-effective when mass-produced in large scale biorefineries compared to its counterpart fossil fuels. For biorefineries to thrive in developing countries, there is a need for government collaboration with large investors, as the government cannot handle it alone. The more lucrative an investment in terms of ROI, the more the attraction of both local and foreign investors [71].

Effective government policies are required for the establishment of biorefineries [72]. A policy like tax evasion for investors has been seen to favour Investment. Subsidy on raw materials would also reduce the overall cost of the production of biofuel.

4. Conclusion

The establishment of biorefineries in developing countries like Nigeria is still in its infancy. This paper seeks to analyse the effect of some parameters like subsidy, cost of raw materials and tax on the economics of maize cob conversion into bioethanol (that is, through the evaluation of the impact on the ROI and NP) so as to promote the establishment of biorefinery in Nigeria. Different analytical methods were deployed to arrive at more effective and efficient factors to aid government policies and public investments.

The quadratic model was suggested as the best for predicting ROI due to its lower PRESS criterion displayed than other models. This once again highlights the high predictive power of the quadratic model for fitting the ROI data. In other to guide decision making, it was stated in this work that good models for NP should be used. A rise in both raw material cost (RM) and government subsidy (SD) in the RM*SD resulted in a rise in the ROI and NP. This deduction was due to the contribution of the rise in the SD, which was observed to be more significant than the RM, suppressing the possible negative impact of raising the cost of RM. This finding indicates that with the provision of the government subsidy, the impact of raw material cost fluctuation would not significantly impact the investment cash flow.

It was also observed that a rise in tax led to a decrease in project benefits. A reduction in the cost of raw materials led to an increase in ROI but wasn't very significant compared to an increase in subsidy. The rise in ROI resulting from the implementation of factors argued in this paper would attract investors and promote the establishment of biorefineries.

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Conflict of interest

The authors declare that there is no conflict of interest

Nomenclature

A, B, C	Response variable
ANOVA	Analysis of variance
B	Benefit in the project life's cash flows
BB	Box Behnken design
C	Cost in the project life's cash flows
CaPv	Capital per liter
CDCF	Cumulative discounted cash flow
CNDCF	Cumulative non-discounted cash flow
COM	Cost of manufacturing bioethanol
CoPv	Cost price
DMC	Direct manufacturing cost
DP	Depreciation
DPC	Direct plant cost
FCI	Fixed capital cost
GE	General expenses
GI	Gross income
IPC	Indirect plant cost
n	Project life,
NDCF	Non-discounted cash flow
NP	Net profit
NPW	Net present worth
OL	Operating labor
PBP	Payback period
r	Discount rate
R	Revenue
RM	Raw material
ROI	Return on investment
SD	Subsidy
SP or SPv	Selling price
t	Period
TCI	Total capital investment for the project
TPC	Total plant cost
TX	Tax Rate
V or nV	quantity of bioethanol produced
WC	Working capital
X	Exchange rate
Y1, Y2	Response variables

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