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Performance Optimization and Economic Analysis of Oil Palm Broom Processing Machine

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Research Article

Abstract

The optimal performance and economic potentials of oil palm broom processing machine were examined in this study in order to ascertain its viability, adoption and commercialization. A Box-Behnken Response Surface Experimental design was used to investigate the optimal operational parameters and responses; while standard investment markers such as Payback Period, Accounting Rate of Return (ARR), Net Present Value (NPV) and Benefit cost Ratio (BCR) were evaluated to ascertain its sustainability and viability. The optimal peeling efficiency and throughput of this machine were determined as 94% and 6311 bristles/hr, respectively when operated at rotary peeler speed, stationary peeler arc length and peelers clearance of 536 rpm, 459 mm and 3.9 mm, respectively. Also, an annual initial sum of N 1,816,378.00 is required for start-up whereas average cash inflow of N 1,074,248.00 can be realized yearly. Payback period, Accounting Rate of Return, Net Present Value and Benefit Cost Ratio were also determined as 1.69, 7.89%, N 6,700,123.00, and 1.76, respectively. It can therefore be seen that this mechanized broom processing technology is profitable and thus recommended for both small and medium scales oil palm processors.

Keywords
Broom, machine, benefit, cost, investment, economic

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1. Introduction

The preference for oil palm bristles/fiber as a domestic tool for sweeping floors and reinforcements for concrete and laterite-based roof tiles, due to its low cost and environmental-friendly nature have been on the rise (Momoh and Osofero, 2019; Yunus et al., 2008; Momoh and Dahunsi, 2017). Concerns have been to improve its supply and brighten export potentials to carter for both present and evolving applications. Meeting these demands with the traditional method of broom processing has not only been challenging, but has limited the earnings of broom processors and discouraged investments in this craft. As a result, Nwankwojike et al., (2014) mechanized the oil palm broom bristle production. Although this machine performed efficiently, binding the bristles into a handy broom still necessitated a manual effort that quelled its adoption commercially by stakeholders. Manual broom tying is tedious and the firmness of the broom depends on the expertise of the processor, thus, the improved design (Figure 1) for oil palm broom bristle production and tying by Onwuka and Nwankwojike (2019). This machine removes the lamina from the midrib of dry oil palm leaflets by abrasion when a rotating abrasive-covered drum rubs the leaflet against a half pipe whose internal surface have been lined with abrasive. The leaf debris (chaff) falls off through the mesh-chute while the bristles are collected in a trough with their 'head' in a chuck. Attached to the chuck is a strapping pin that holds and winds the rope in tension around the broom bristles before being sealed. The speed of the rotary peeler, clearance between rotary and stationary peelers, and arc length of the stationary peeler have been observed during the evaluation of this machine as critical parameters that affect its efficiency and throughput. Since every investor's interest in any investment is to get a good return on investment, there is need for a thorough representation of the financial outlook and sustainability of this innovation at its optimal operational condition; thus, strengthening how well it will be embraced. While Response Surface Methodology (RSM) gives optimal operational settings that are always or nearly close to the real system's optimal operating conditions (Oehlert, 2000; NIST, 2006), Cost-Benefit Analysis (CBA) systematically x-rays the fiscal outlook of an investment decision over a long-term by evaluating its costs and benefits (Davide et al., 2015). RSM determines and concurrently solves multi-variant models using quantitative data from appropriate experimental designs with the objective of finding the optimal settings of design factors relative to a performance indicator or response (Cornell, 1990; Myer and Montgomery, 2002; Buyske and Trout, 2009). CBA on the other hand, utilizes investment decision pointers such as Benefit Cost Ratio (BCR), Net Present Value (NPV), Payback period and Accounting Rates of returns to ascertain the economic efficiency of a project.

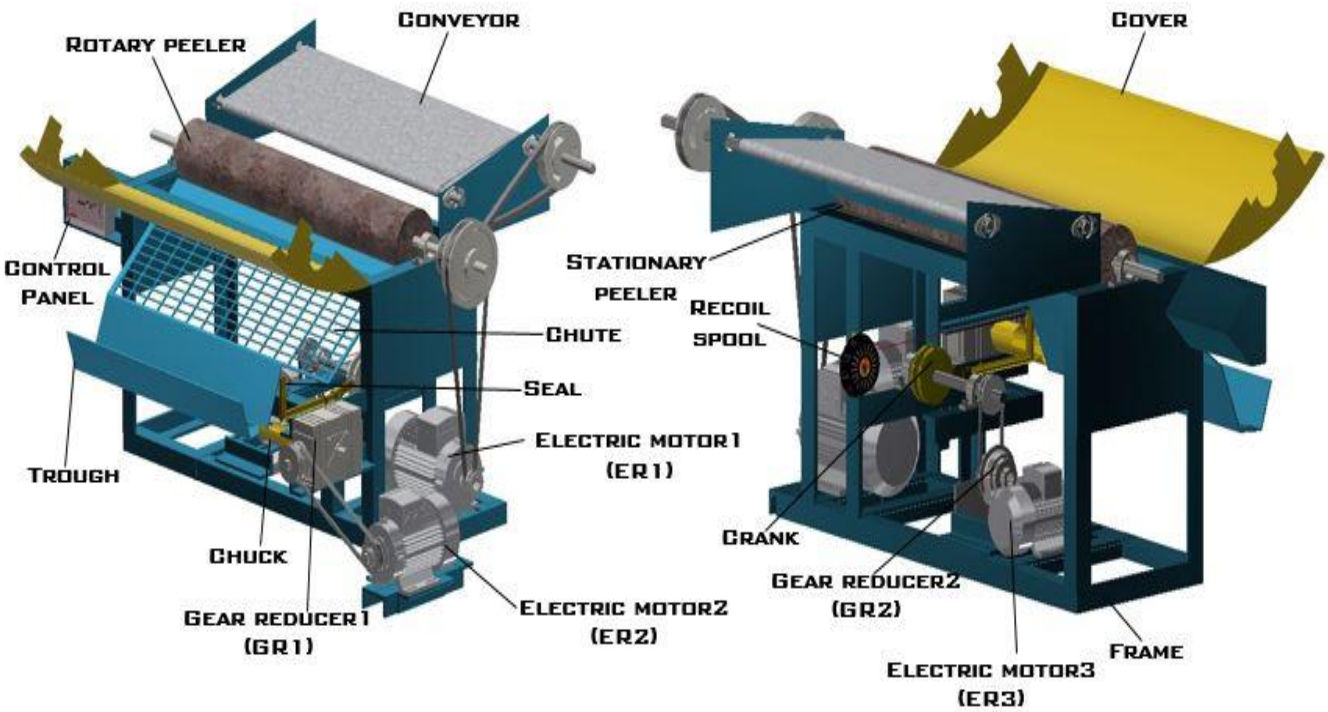

Figure 1: Oil palm broom processing machine

Sylvanus *et al.,* (2015), employed RSM to determine the optimal operating settings of a multistage centrifugal pump used in gas plants. Results revealed a reduction in energy consumption when pump was operated at the optimal factor settings obtained. Panagiotis *et al.,* (2018), established mathematical models for the prediction of thrust force and cutting torque when drilling Al7075 work piece using RSM. Models' predictions showed good accuracy when compared to experimental results. Daniyan *et al.,* (2016), also analyzed the effect of peeling time and operational speed on flesh loss of cassava using RSM. Optimal shaft speed for minimal flesh loss and peeling efficiency was obtained using this technique. Ajila (2017), analyzed investments in gari processing machines in Ondo State, Nigeria and the NPV, BCR and internal rate of return (IRR) showed that gari processing enterprises are profitable. Ohimain et al., (2014) investigated the viability of processing palm oil on a small-scale in Elele, Rivers state, Nigeria. BCR and IRR showed that oil palm processing is profitable. Nwankwojike et al., (2012), assessed the benefits of introducing a palm nut-pulp separating machine in small scale palm fruit processing. The costs and revenue accrued showed higher profitability when compared with the manual method of processing. Toluwase and Abdu-raheem (2013), examined the cost and returns analysis of cassava production in Ekiti state, Nigeria. Results revealed a cost benefit ratio that is greater than one, thus a profitable venture. Aurangzeb *et al.,* (2007), carried out a comparative benefit cost analysis of mechanized and traditional maize farming systems in North West Frontier Province, Pakistan. Results revealed that the BCR of mechanized farms was higher than that of traditional farms. Thus, RSM and CBA were employed in this study in other to determine the financial potentials of oil palm broom processing machine operating at optimal conditions.

2. Materials and Methods

2.1 Response surface optimization

The effect of three significant parameters: rotary peeler speed, stationary peeler arc length and peelers clearance on the peeling efficiency and throughput of the oil palm broom processing machine were investigated using a Box-Behnken Response Surface Experimental Design. The Box-Behnken design is an independent quadratic design in that it does not contain an embedded factorial or fractional factorial design. This design requires fewer treatment combinations than CCDs in cases involving 3 factors (Montogomery, 2005). The factor levels (Table 1), described as the limits below or beyond which there are no observable significant changes in the machine's performance indices were determined during preliminary evaluation of the machine.

Table 1: Limits of the machine's factors

S/No	Factors	High level	Low level
1	Rotary peeler speed, N (rpm)	1250	60
2	Clearance between rotary and stationary peelers, x (mm)	6	0.2
3	Arc length of stationary peeler, l_a (mm)	480	94

A completely randomized uncoded Box-Behnken response surface experimental design (Table 2) was generated using Minitab 18.0.

Table 2: Design layout of the response surface study

RunOrder	PtType	Blocks	N	x	l_a
1	2	1	1250	2.1	480
2	2	1	655	4	480
3	2	1	655	4	94
4	2	1	655	0.2	480
5	0	1	655	2.1	287
6	0	1	655	2.1	287
7	2	1	60	4	287
8	2	1	655	0.2	94
9	2	1	1250	2.1	94
10	2	1	60	2.1	94
11	2	1	60	2.1	480
12	0	1	655	2.1	287
13	2	1	1250	0.2	287
14	2	1	1250	4	287
15	2	1	60	0.2	287

In each run, the time, t taken to remove the lamina from the midrib of 450 oil palm leaflets as well as tie and seal them as broom was measured using a stop watch. The number of defective fibers, n_s (which consists of those that the lamina was not properly removed and/or broken ones) was also noted and thereafter, the peeling efficiency, η (%) and throughput TP (kg/h) were estimated using equations (1) and (2) respectively:

$$TP \text{ (brooms/h)} = \frac{q}{t} \quad (1)$$

$$\eta(\%) = \frac{q - n_s}{q} \times 100 \quad (2)$$

Where q is the quantity of palm leaflets processed in each experimental run = 450 oil palm leaflets.

Variation of the clearance between rotary and stationary peelers was achieved using a feeler gauge while the rotary peeler speed was varied using a variac and tachometer.

Response surface models in the form of equation (3) was estimated for each response under consideration.

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i z_i + \sum_{i=1}^{k} \beta_{ii} z_{ii}^2 + \sum_{i<j}^{\frac{k(k-1)}{2}} \beta_{ij} z_i z_j + \epsilon \quad (3)$$

Where y = responses, z = factors, β = coefficient of each term, k = number of factors in the model, ϵ = error term. Key outputs for determining the adequacy of the models includes the p-value, coefficients, R^2 and residual plots. If the p-value of a term (factor) is less than or equal to the significance level, i.e. 0.05, it is said to be statistically significant and all level means are equal. If the coefficient of a squared term is significant, then a non-linear relationship exist between the factor and the response. If the coefficient of an interaction term is significant, the relationship between the response and a factor depends on the factors in the terms. Stepwise elimination method was used to ensure only statically significant terms remain in the model. Also, a model is said to describe the response well for larger R^2-value and smaller S-value. Furthermore, small outliers in the normal probability plots, close residuals ballparks and/or formation of an 'S' shape along a straight line depicts the models adequately fits the data. Also, if the residuals versus fitted value and residual versus observation order plots reveal a normal distribution of the residuals, and there is negligible skewness and outliers in the histogram, the model is adequate (NIST, 2006). Finally, to validate the model, the models' predicted responses were compared to actual experimental responses at 95% prediction interval. Consequently, the optimal responses and their corresponding factor settings were determined using desirability function and verified experimentally.

2.2 Cost Benefit Analysis (CBA)

The integrated approach of cash flow analysis by Degarmo *et al.* (1984) was employed in this study for a projected machine useful life of ten years. The nonrecurring cost and revenues considered include cost of machine, installation cost and salvage of machine while recurring annual costs and revenues include: power, maintenance, material and labor costs as well as broom sales. Prevailing economic indicators/market prices of materials in Nigeria between September and October 2019 were used for this analysis. Depreciation, inflation rate, interest rate, sales, and operating cost are assumed to be constant for each year. Also, a zero scrap value is assumed at the end of the useful life of this machine.

The yearly depreciation of this machine was estimated using straight line depreciation method given by equation (4) Blank and Tarquin (2012)

$$d = \frac{(P - s)}{n} \quad (4)$$

Where P = original cost of machine, s = scrap value and n = number of useful years of machine = 10 years.

The annual energy cost of the machine, ε was estimated using equation 5:

$$\varepsilon = C_n E_a \quad (5)$$

Where C_n = cost per kWh of electrical power = ₦ 35.3 (Nnodim, 2019) and E_a = Machine's annual energy requirement

$$E_a = P_t u_t n_y \quad (6)$$

Where P_t = machine's total power requirement = 2.983 kW (design capacity); u_t = machine's daily operational time = 8 hrs/day; and n_y = number of days machine will be operated in a year = 260 days.

The annual raw material cost of this machine, C_r was computed using equation (7)

$$C_r = TP \times u_t n_y C_o \quad (7)$$

Where TP = machine's optimal throughput determined from the response surface analysis and C_o = cost of oil palm leaflet = ₦ 0.05/leaflet

Annual sales, S_a estimated from equation (8)

$$S_a = TP \times u_t n_y C_b \quad (8)$$

Where C_b = cost of broom bristle = ₦ 0.2

The Machine's Replacement Value, MRV was evaluated using equation (9) by (Blank and Tarquin, 2012)

$$MRV = P(1 + f)^n \quad (9)$$

#The Annual Maintenance Cost (AMC) for this machine was taken as 2.5% of MRV (Gupta *et al*., 2004).

Where f = inflation rate = 11.24% (CBN, 2019)

The Payback period, Accounting Rate of Return, Net Present Value and Benefit Cost Ratio given by equations (10), (11), (14) and (15) respectively (Onwualu *et al*., 2002; Gerald and Marta, 2015) constitute the major investment evaluation parameters investigated.

$$P_b = \frac{C_i}{C_{inflow}} \quad (10)$$

The cash inflow at year t is given by the total revenue at year t less the total expenses for that year.

$$ARR = \frac{P_a}{I_a} \quad (11)$$

$$P_a = C_{inflow} - \left(\frac{cost\ of\ machine - salvage\ value}{2}\right) \quad (12)$$

$$I_a = \frac{book\ value\ at\ beginning\ of year\ 1 + book\ value\ at\ the\ end\ of\ useful\ life}{2} \quad (13)$$

$$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+\kappa_i)^t} - C_i \quad (14)$$

$$BCR = \frac{PVB}{PVC} \quad (15)$$

$$PVC = \sum_{t=1}^{n} \frac{C_t}{(1+\kappa_i)^t} \quad (16)$$

$$PVB = \sum_{t=1}^{n} \frac{B_t}{(1+\kappa_i)^t} \quad (17)$$

Where C_i, C_{inflow}, P_a, I_a, κ_i, C_t, PVC and PVB are the total annual initial investment cost, average annual cash inflow, average annual profit, average investment, discount rate = 13.5% (CBN, 2019), cash flow at time *t*, present values of costs and present value of benefits respectively.

The smaller the payback period, the more desirable the investment. Also, the Net Present Value and Benefit cost ratio must be greater than zero and one respectively for a viable investment.

3. Results and Discussion

3.1 Performance evaluation and optimization

3.1.1 Performance evaluation

The responses for each experimental run are presented in table 3:

Table 3: Experimental design with responses

Run Order	Pt Type	Blocks	N	x	l_a	η	TP
1	2	1	1250	2.1	480	43.2	7150
2	2	1	655	4	480	91.7	6187
3	2	1	655	4	94	85.4	6234
4	2	1	655	0.2	480	23.2	6176
5	0	1	655	2.1	287	45.3	6342
6	0	1	655	2.1	287	47.6	6298
7	2	1	60	4	287	92.3	3214
8	2	1	655	0.2	94	20.4	6301
9	2	1	1250	2.1	94	42.3	7423
10	2	1	60	2.1	94	76.5	3204
11	2	1	60	2.1	480	78.3	3146
12	0	1	655	2.1	287	51.3	6311
13	2	1	1250	0.2	287	18.9	7067
14	2	1	1250	4	287	56.7	7212
15	2	1	60	0.2	287	15.6	3303

Equations (18) and (19) gives the respective fitted RSM models for peeling efficiency and throughput of the oil palm broom processing machine. Step-wise elimination at significance level of 0.05 ensured only significant terms are present in the models. The presence of all the factors (rotary peeler speed, stationary peeler arc length and peelers clearance) in the models depicts that factors influenced the responses significantly with curvature, thus implying a nonlinear relationship. Analysis of variance results for the throughput and peeling efficiency models presented in tables 4 and 5 also corroborates the level of significance of each of the factors in the models. It can be seen that the P-values of all the factors as well as their square and interactions terms in the tables are < 0.05 which implies statistical significance. Furthermore, smaller S-values (12.94 and 5.76) and high R-sq values (99.9% and 97.04%) for throughput and peeling efficiency, respectively shows that the models are good fit of the data.

$$\eta = 35.7 - 0.0077\,N + 25.39\,x - 0.1603\,l_a + 0.000004\,N^2 - 0.982\,x^2 + 0.000286 l_a^2 - 0.00860\,Nx - 0.000002\,Nl_a + 0.00239\,xl_a \quad (18)$$

$$TP = 2803 + 7.291\,N + 23.1\,x + 0.337\,l_a - 0.002982N^2 - 17.2\,x^2 - 0.00082\,l_a^2 + 0.0517\,Nx - 0.000468\,Nl_a + 0.053\,xl_a \quad (19)$$

Table 4: Analysis of variance for throughput

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	7	36120439	5160063	969.86	0.030
Linear	3	31971654	10657218	2003.08	0.012
N	1	31940028	31940028	6003.29	0.010
X	1	0	0	0.00	0.030
La	1	31626	31626	5.94	0.002
Square	2	4123539	2061770	387.52	0.025
N*N	1	4122647	4122647	774.87	0.025
x*x	1	13277	13277	2.50	0.005
la*la	1	419.1	419.12	8.74	0.032
2-Way Interaction	2	25245	12623	2.37	0.002
N*x	1	13689	13689	2.57	0.008
N*la	1	11556	11556	2.17	0.030
x*la	1	1521	1521	0.24	0.035
Error	7	37243	5320		
Lack-of-Fit	5	36221	7244	14.18	0.023
Pure Error	2	1022	511		
Total	14	36157682			
	S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**	
	12.9412	99.90%	99.79%	99.06%	

Table 5: Analysis of variance for efficiency

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	9810.3	1962.07	59.02	0.020
Linear	3	8995.7	2998.58	90.19	0.032
N	1	1290.3	1290.32	38.81	0.048
x	1	7688.0	7688.00	231.24	0.010
la	1	17.4	17.40	0.52	0.042
Square	1	436.3	436.32	13.12	0.006
la*la	1	436.3	436.32	13.12	0.006
2-Way Interaction	1	1	378.3	378.30	0.008
N*x	1	378.3	378.30	11.38	0.008
N*la	1	0.2	0.20	0.00	0.034
x*la	1	3.1	3.06	0.06	0.811
Error	9	299.2	33.25		
Lack-of-Fit	7	280.9	40.13	4.38	0.198
Pure Error	2	18.3	9.16		
Total	14	10109.6			
	S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**	
	5.76595	97.04%	95.40%	94.86%	

Figures 2 and 3 represents the residual plots for throughput and peeling efficiency, respectively. Residuals in figures 2a and 3a approximately follow a straight line, thus validates the assumption that the residuals are normally distributed for both models. This is further validated by the histogram shown in Figures 2b and 3b, as the probabilities for values further away from the mean taper off equally in both directions. In Figures 2c and 3c, (i.e, residuals versus fits plots) for throughput and peeling efficiency, respectively, the points fall randomly on both sides of the center line with no recognizable pattern in each case, hence satisfying the assumption that the residuals are randomly distributed and have constant variance. More so, the random pattern exhibited by the residuals in the residuals versus order plots shown in figures 2d and 3d reveals that the assumption that the residuals are independent is true. These ratifies that the developed models are sufficient for describing the responses.

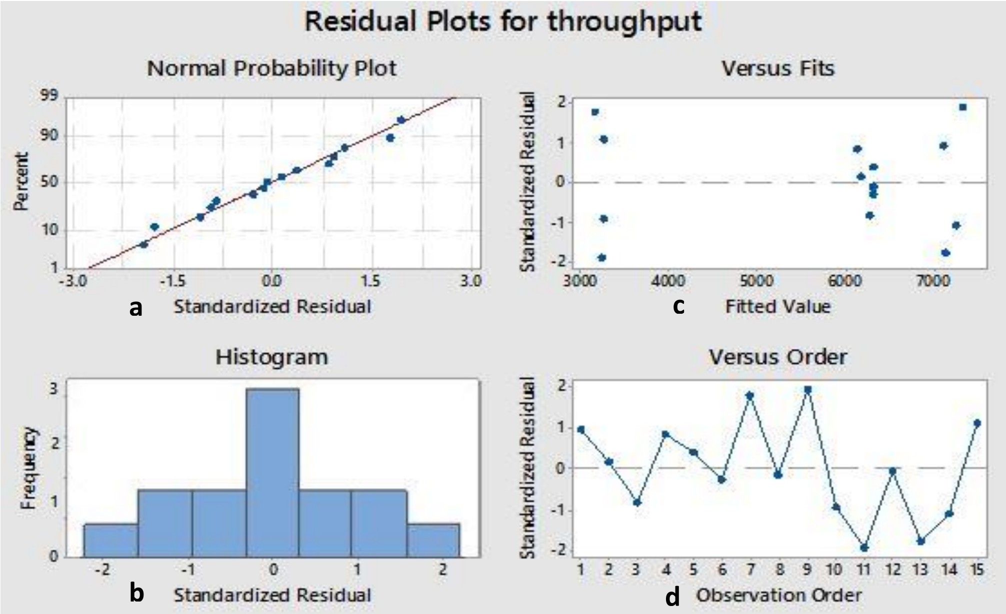

Figure 2: Residual plot for the throughput model

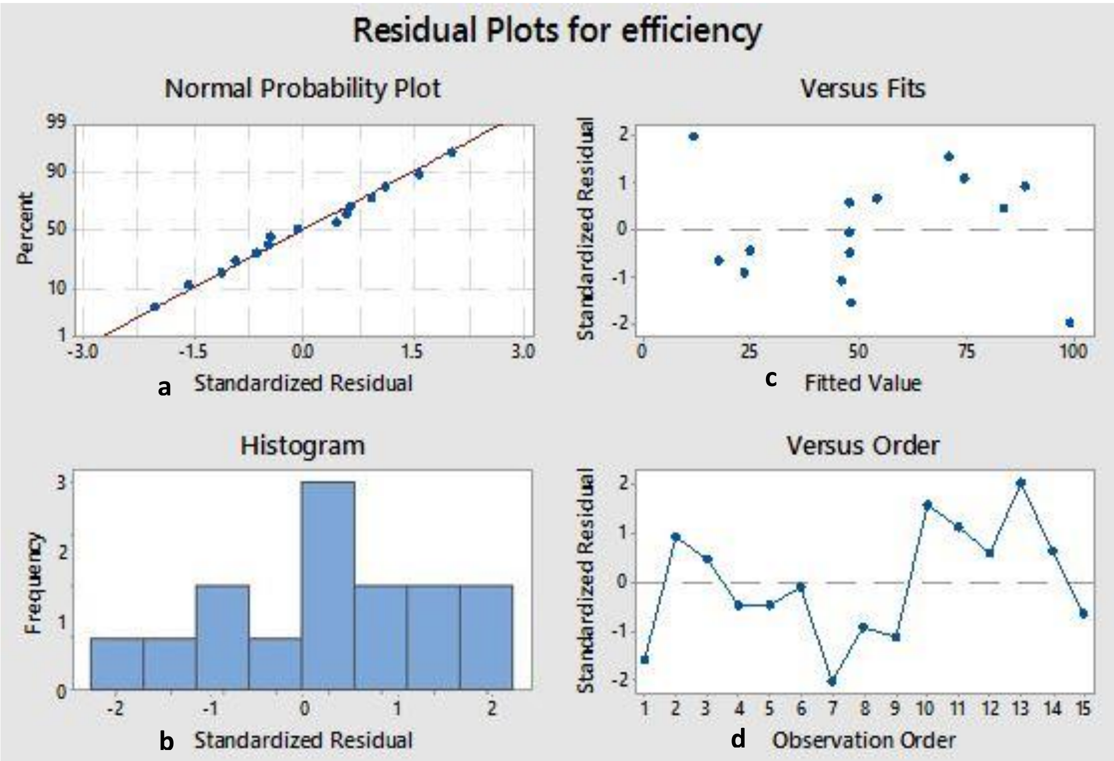

Figure 3: Residual plot for the peeling efficiency model

Furthermore, the model confirmatory test plots presented in figures 4 and 5 revealed an acceptable error margin (i.e. ± 5%) between the actual and predicted values of both responses, thus can be used to predict, calibrate, or even optimize the system.

The surface plots presented in figure 6 shows how the peeling efficiency and throughput of this machine relate to the rotary peeler speed, stationary peeler arc length and peelers clearance. The curvature in the response surface is due to the statistically significant quadratic terms present in the models. The peak values for throughputs (fig. 6a-b) correspond to mid-values of clearance and stationary peeler arc length of the plot. Peeling efficiency increased progressively with clearance (fig. 6c) while a high speed does not favor peeling efficiency (Figure 6)).

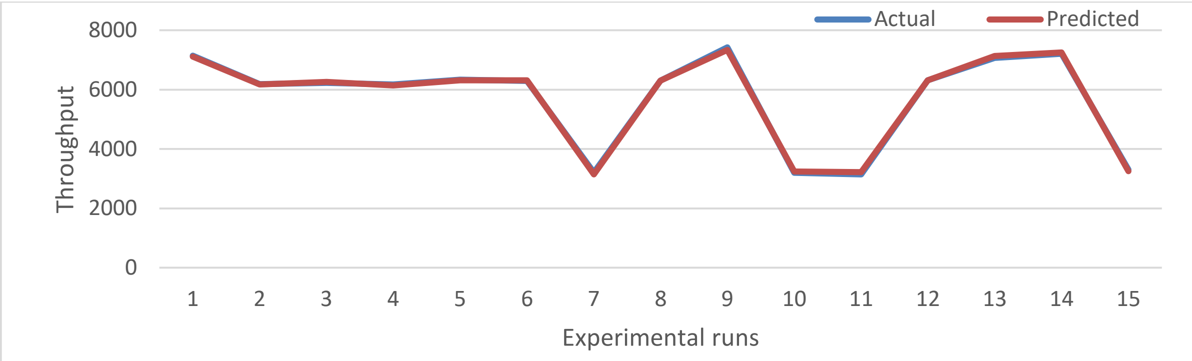

Figure 4: Confirmatory test for throughput model

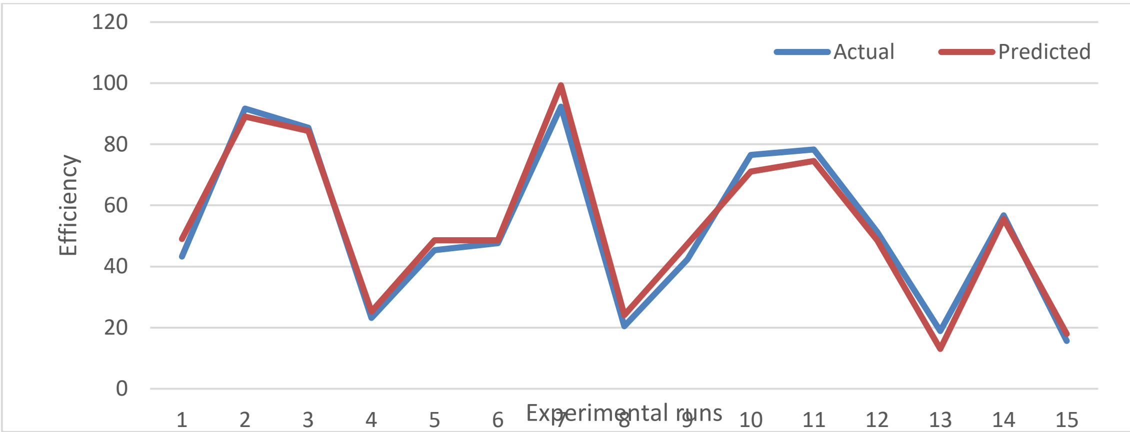

Figure 5: Confirmatory test for the peeling efficiency model

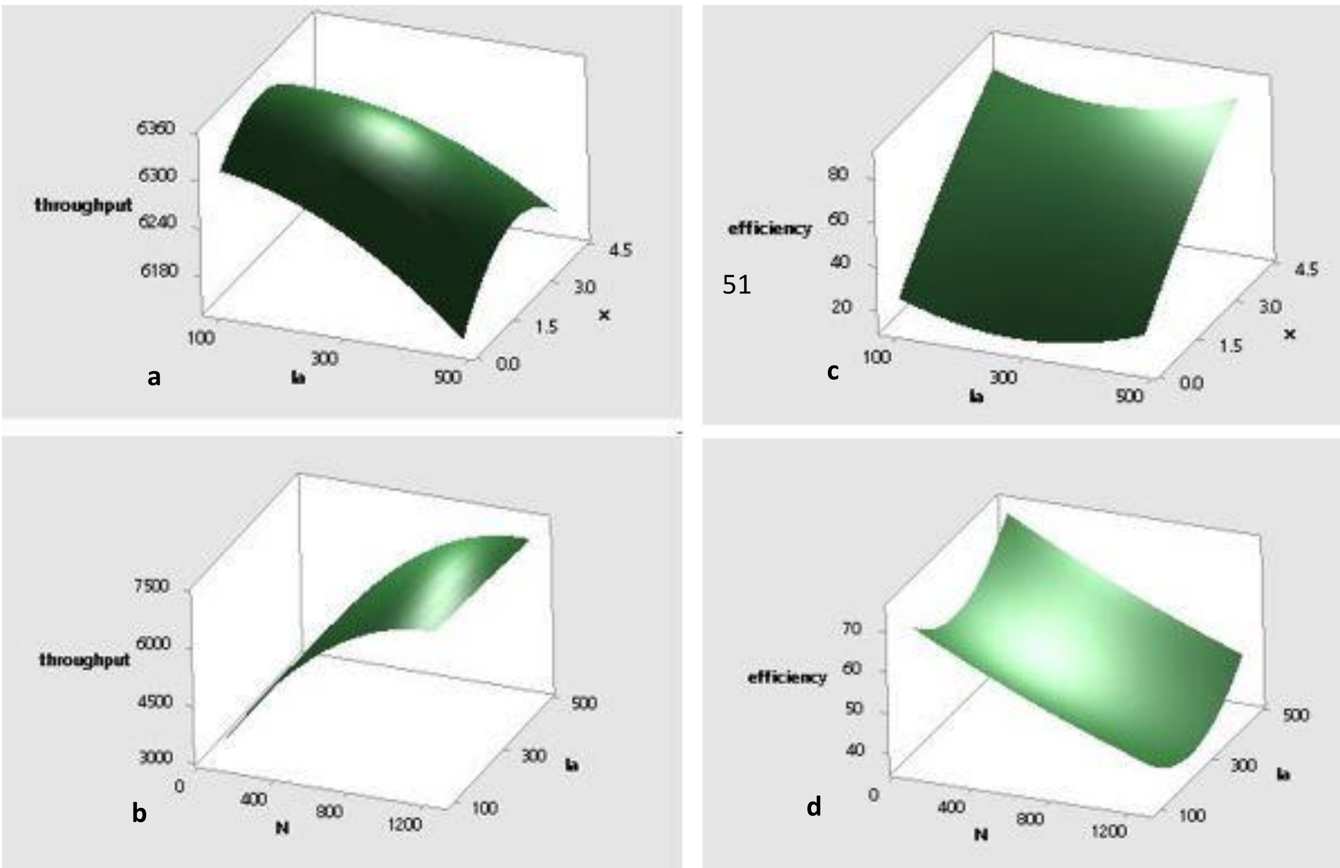

Figure 6: Surface plots of peeling efficiency and throughput vs rotary peeler speed, stationary peeler arc length and clearance

3.1.2 Optimization analysis

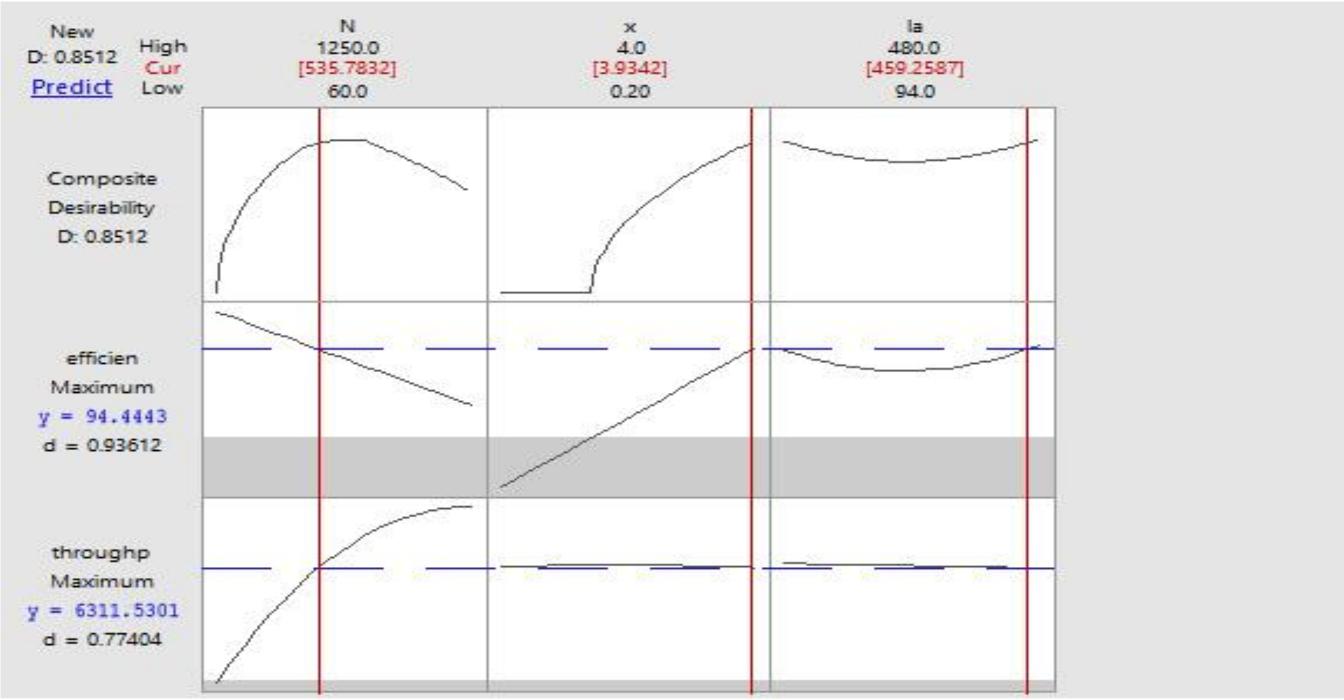

Figure 7: Optimization plot of the developed models

Optimal machine peeling efficiency and throughput of 94% and 6311 bristles/hr were obtained at rotary peeler speed, arc length of stationary peeler and clearance of 536 rpm, 459 mm and 3.9 mm, respectively as seen in the optimal desirability plot in figure 7. Operating this machine at these optimal factor settings confirmed this result with less than 5% error margin. This is an improvement on the initial oil palm broom processing model developed by Onwuka and Nwankwojike (2019) whose throughput and efficiency were 6186 bristles/hr and 89% respectively, hence, ensuring maximum profit is derived.

3.2 Economic analysis

The yearly depreciation of the oil palm broom processing machine was estimated from equation (4) as ₦ 26,525.00, thus the salvage value at the end of each year is presented in table 6 below:

Table 6: Salvage value at the end of each year

Year	Opening balance (₦)	Depreciation (₦)	Salvage value at the end of year (₦)
1	265,250.00	26,525.00	238,725.00
2	238,725.00	26,525.00	212,200.00
3	212,200.00	26,525.00	185,675.00
4	185,675.00	26,525.00	159,150.00
5	159,150.00	26,525.00	132,625.00
6	132,625.00	26,525.00	106,100.00
7	106,100.00	26,525.00	79,575.00
8	79,575.00	26,525.00	53,050.00
9	53,050.00	26,525.00	26,525.00
10	26,525.00	26,525.00	0.00

Analysis of recurring and nonrecurring costs and revenues is presented in table 7 while the net cash flow for each period as well as the present value costs and benefits are shown in tables 8 and 9. While ₦ 656,344.00, ₦ 440,520.00 and ₦ 219,023.79 are required annually for oil palm leaflets, rope and energy respectively, ₦ 19,240.00 is required annually to maintain this machine, thus, an annual initial sum of ₦ 1,816,378.00 is required for investment in this technology. An Average annual cash inflow of ₦ 1,074,248.00, (or ₦ 89,520.68 monthly) can be realized from this investment. The negative cash flow for the first year is due to the purchases of fixed assets, however, positive cash inflow was realized afterwards. The Payback period, Accounting Rate of Return, Net Present Value and Benefit Cost Ratio were estimated as 1.69, 7.89%, ₦ 6,700,123.00, and 1.76 respectively. This means that with an expected rate of return of approximately 8%, an average of one year and seven months is required for recouping investment in this technology. Benefit Cost Ratio of 1.73 implies that for every ₦ 1 invested in this technology, ₦ 1.76 will be realized. A positive Net Present Value further justifies the viability of investment in this technology for broom processing.

According to a local manual broom processor, about ₦ 80,000.00 monthly revenue can be made from sales of broom, which approximates to about ₦ 50,000.00 to ₦ 60,000.00 monthly profit (Omiko, 2015); whereas mechanized broom processing yields ₦ 89,520.68 monthly profit. This shows the huge profit potentials of mechanized oil palm broom processing.

Table 7: Analysis of nonrecurring and recurring annual costs and revenues of oil palm broom processing machine

NONRECURRING COSTS AND REVENUES	**Costs (₦)**	**Revenue(₦)**
1. *Capital Investments*		
Cost of machine	265,250.00	
Installation cost	0,00	
2. *Revenue*		
Sales of equipment after useful period		0.00
Total	265,250.00	0.00

RECURRING ANNUAL COSTS AND REVENUES	**Costs (₦)**	**Revenue(₦)**
1. Operational and Maintenance (O&M) Cost		
(a) Direct costs		
Labor (minimum wage = N18,000 monthly)	216,000.00	
(Only one operator required)		
Material cost		
(i) Oil palm leaflets	656,344.00	
(ii) Rope	440,520.00	
(b) Indirect costs		
Maintenance	19,240.00	
Power	219,023.79	
other cost		
2. *Revenue*		
(a) Sales		2,625,376.00
Total	1,551,128.79	2,625,376.00
Total Annual Initial Investment	1,816,378.79	

Table 8: Before tax net cash flow analysis of oil palm broom processing machine

End of year	**Before Tax Net Cash Flow**
0	-265,250.00
1	1,074,248.21
2	1,074,248.21
3	1,074,248.21
4	1,074,248.21
5	1,074,248.21
6	1,074,248.21
7	1,074,248.21
8	1,074,248.21
9	1,074,248.21
10	1,074,248.21
Total annual cash flow	**10,742,480.10**
Average Annual Cash flow	**1,074,248.21**

Table 9: Analysis of present value costs and benefits of oil palm broom processing machine

Year	**Investment Cost (₦)**	**Operating cost (₦)**	**Total cost (₦)**	**Sales (₦)**	**Salvage Value (₦)**	**Total Benefit (₦)**	**Present Value Cost (₦)**	**Present Value Benefit (₦)**
0	265,250.00	0.00	265,250	0.00	265,250.00	265,250	265,250.00	265,250.00
1		1,551,128	1,551,128	2,625,376	238,725	2,864,101	1,366,632.42	2,523,437.00
2		1,551,128	1,551,128	2,625,376	212,200	2,837,576	1,204,081.42	2,202,702.17
3		1,551,128	1,551,128	2,625,376	185,675	2,811,051	1,060,864.69	1,922,565.48
4		1,551,128	1,551,128	2,625,376	159,150	2,784,526	934,682.55	1,677,906.79
5		1,551,128	1,551,128	2,625,376	132,625	2,758,001	823,508.85	1,464,249.59
6		1,551,128	1,551,128	2,625,376	106,100	2,731,476	725,558.46	1,277,680.36
7		1,551,128	1,551,128	2,625,376	79,575	2,704,951	639,258.55	1,114,777.95
8		1,551,128	1,551,128	2,625,376	53,050	2,678,426	563,223.40	972,551.84
9		1,551,128	1,551,128	2,625,376	26,525	2,651,901	496,232.07	848,388.07
10		1,551,128	1,551,128	2,625,376	0	2,625,376	437,208.87	740,002.00
Total							**8,516,501.28**	**15,009,511.26**

4. Conclusion

Optimization of the oil palm broom processing machine revealed 94% and 6311 bristles/hr as its respective optimal peeling efficiency and throughput when the machine was operated at rotary peeler speed, stationary peeler arc length and peelers clearance of 536 rpm, 459 mm and 3.9 mm respectively. While an annual cash inflow (before tax) of N 1,074,248.00 was realized at optimal condition. Net Present

Value, Benefit Cost ratio, Accounting Rate of Returns and Payback Period were estimated as N 6,700,123.00, 1.76, 7.89 % and 1.69 respectively. Also, an annual initial sum of N 1,816,378.00 is required for investment in this technology whereas N 19,240.00 constitute the annual maintenance cost. This machine is thus recommended in order to increase broom supply as well as boost the profit margin of oil palm processors.

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