Assessment of Energy and Cost Optimization of Seraph Nigeria Limited for sustainable Growth

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Abstract

The study aimed at assessment of energy and processing cost optimization of Seraph Nigeria Limited (SNL), producer of soya oil, for cost reduction. The objectives of the study include; determining the contributions of energy sources to production, and secondly, to minimize processing cost. The materials used for study were; utilities nameplates, fuel receipts, electricity bills and raw material purchase receipts and output records. Data was collected through detailed energy audit that covered a period of twelve months, January to December, 2017. Conversion of individual energy sources to energy unit per unit of output (kWh/t) enabled evaluation through plot on bar charts using Microsoft excel. The result showed that natural gas oil (NGO) had the highest contribution variation of 1400 kWh/t, followed by diesel, 390kWh/t; electricity 380kWh/t, labor 50 kWh/t to produce at 0.198 t/h, contributing ₦5114.42 to processing cost per hour. The minimized energy requirement per hour of processing, using Tora software showed ₦5028 with an output of 0.205 t/h. It was observed that NGO contributed more to processing cost than electricity, diesel and labor. The study found that absence of an energy monitoring team in the industry was responsible for the unethical handling of this energy source. Thus, recommended the setting up of an energy monitoring team to monitor purchases, utilization, documentation and the installation of smart electricity gadgets for regulating consumption to reduce processing cost and enable sustainable growth of the industry.

Key words: *Assessment, Energy, Cost optimization, Monitoring team, Seraph Nigeria limited and Sustainable growth*

I. Introduction

Seraph Nigeria Limited (SNL), Makurdi, is an agro processing industry that produces soya oil from soya beans for human consumption and the chaff (*meal*) used as animal feeds. The industry consumes inputs like; energy, labor, raw materials, capital and land for processing with energy as the major recurrent variable. Energy costs, availability and effect of consumption on the environment are the major impediments in energy utilization [1], [2]. Unprofessional utilization of energy inputs increases avoidable cost and impair sustainable growth of an industry [3], [4]. The acceptable practice globally is the reduction of energy cost through application of minimum energy consumption standards [5], [6]. Alternatively, reverting to renewable energy sources that cost less and are harmless [7], [9], [10], [11].

However, SNL operates in an environment with challenges that affect processing cost adversely like; bad road network, poor electricity supply, poor infrastructure and high cost fuels [7], [8], [10], [11]. Despite these problems, the industry still has important advantages; raw material is available locally because it is grown in the State, transportation cost is less because of short distances from farm sites and the industry has the choice to buy from the farmers themselves. What the industry need is effective energy management to reduce cost of processing. Reduced energy cost is synonymous with effective planning and demand careful monitoring, controlled utilization and analysis to identify waste and losses, rectify them promptly and to keep the processing machinery in optimal working condition [10], [11], [12]. Reducing energy consumption is a prerequisite for achieving minimum processing cost that leads to sustainable growth of the industry [11], [13], [14], [15].

Although, energy evaluation in some agro-crop processing industries in Makurdi have been carried out, however, no study has been carried out on Seraph Nigeria limited, Makurdi, aimed at minimizing energy consumption and cost for sustainable growth of the industry. This study is significant because it developed a model that will assist managers of the industry to predict future energy consumption based on output requirements and this will encourage sustainable growth of the industry.

II. Materials and Methods

The study materials came from the industry and included; nameplates of utilities, fuel receipts, electricity bills and product output records. Data was collected through detailed energy audit of the industry. This method provided the quality of information needed for the study. The analytical tools used in this study made up of Microsoft excel, for bar charts contraction and optimization, in linear programming.

The preliminary phase of energy audit enabled familiarization with staff and work procedures in the industry. In addition, identification and collection of general information regarding processing activities including types of utilities in use; energy resources used, raw material type, energy and raw material flow sequence. Also identified were the, operating units of the industry, electric power ratings of operation units and the number of workers per operation unit, for numerical details, refer to Appendix A, Table 1a.

In the second phase of energy audit, information collected through detailed energy audit comprised of inventory taken from records. Data collection duration was a period of twelve months from January to December of 2017. The period rhymed with annual budget planning period of the industry and intended to provide a model to assist annual energy and output planning. The study duration was one month of work in the industry that enabled this data collection. The study considered only the primary energy sources consumed by the industry namely; electricity, diesel, natural gas oil (NGO) and labor that have cost attached to them. The secondary energy forms like compressed air, steam and hot water etc, were not considered in this study because they do not have direct cost attached to them, their usage are enabled by the application of the primary energy sources. This industry uses a single electric energy-billing meter therefore, data collected from nameplates of utilities like; air conditioners, refrigerators, computers, fans, lighting bulbs etc, that did not have direct contribution to processing was computed for twelve months and subtracted from total to obtain electricity used for processing. The data on primary energy sources; electricity, diesel, NGO and labor were collected from inventory. For numerical details refer, to Appendix A, Table 1b. The units' cost of energy types, labor, and raw material were also collected, for details, refer to Appendix A, Table 1c. From literature, energy conversion factors were gathered, refer to Appendix A, Table 1d. For the material flow diagram for soya oil extraction, refer to Appendix A, Figure 1a. The primary energy types consumed were converted to energy consumption unit of kilowatt-hour (kWh) using standard conversion factors (Appendix A, Table 1d). These were further converted into monthly energy consumption per unit of output (kWh/t) to verify consumption variation, for details, refer Appendix A, Table 1e. Thus, the monthly energy consumption intensities (kWh/t) were plotted on the bar chart, using Microsoft excel, and determined consumption variation of each energy source during the period. In addition, bar charts showing cost variations per hour of operation across the months were also plotted using Microsoft excel tool, for numerical values refer, to Appendix A, Table 1f.

For processing cost optimization, Tora Software, a linear programming tool was used to determine the minimum processing cost per hour of operation. Seraph Nigeria Limited (SNL) has four operation units identified as; preparatory units (PPU), solvent extraction unit (SEU), refining unit (RFU) and filling and bottling unit (FBU). The industry uses four primary energy resources namely; electricity, diesel, natural gas oil (NGO) and labor. To formulate the problem for optimization, the procedures adapted were those used by [5], [9], [12]:

i. The identification of the objective function,

ii. The identification of decision variables,

iii. The identification of the problem parameters and constraints,

iv. Non-negativity constraints.

The objective function is to minimize the cost of processing whereas; the constraints represent the limited amounts of energy sources required by each production unit. Thus:

$$Min\ (Z) = C_1x_1 + C_2x_2 + C_3x_3 + C_4x_4 \quad (1)$$

Subject to:

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + a_{14}x_4 \geq b_1 \quad (2)$$

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + a_{24}x_4 \geq b_2 \quad (3)$$

$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + a_{34}x_4 \geq b_3 \quad (4)$$

$$a_{41}x_1 + a_{42}x_2 + a_{43}x_3 + a_{44}x_4 \geq b_4 \quad (5)$$

Non-negativity constraints: $x_i \geq 0$ (6)

Where;

Ci = the total cost of energy source i per ton (₦/t) used for processing,

xi = the variables representing amount of product output per hour of operation (t/h),

aij = the basic energy source i consumed from operation in unit j,

i = energy sources consumed (i= 1,2,3 and 4),

j = operation units, (j = 1,2,3,and 4), and

bi = represent averages of energy sources consumed per hour of operation during the year under review.

The constraints in the problem represent the cost of energy sources and availabilities. The dimensional units for the parameters of problem formulated are consistent with standard. For test of dimensional units' consistency, refer to Appendix B, section 1. Equations (1) to (6) formed the optimization model for this industry. Thus, substitution of values shows:

$$Minimize(Z)\ 5302.34x_1+10946.88x_2+6923.78x_3+260.35x_4 \quad (7)$$

Subject to;

$$25.07x_1+45.20x_2+38.42x_3+9.00x_4 \geq 20.25 \quad (8)$$

$$3.03x_1+2.30x_2+3.95x_3+4.54x_4 \geq 3.17 \quad (9)$$

$$5.33x_1+35.67x_2+15.67x_3+15.33x_4 \geq 11.65 \quad (10)$$

$$3.40x_1+2.00x_2+0.67x_3+4.58x_4 \geq 2.31 \quad (11)$$

The non-negativity constraint:

$$x_1 \geq 0,\ x_2 \geq 0,\ x_3 \geq 0 \text{ and } x_4 \geq 0 \quad (12)$$

For detailed generation of these values, refer to Appendix B, section 2. The values for these calculations were derived using basic values from first phase of energy audit (Appendix A, Table 1a). Equation (7) represents the objective function whereas; equations (8) to (12) represent the constraints, which entered into Tora Software interface for analysis**.** For numerical details, refer to Appendix B, Table 1g.

III. Results Presentation

Fig. 1 presents bar charts been the results of monthly energy intensity variations across the months of January to December 2017. Fig. 2 also presents char charts, been the results of energy cost contribution to processing per hour of operation during the same period. Whereas, Fig. 3 presents simplex tables; these are the results of minimum processing cost for the industry obtained from optimization.

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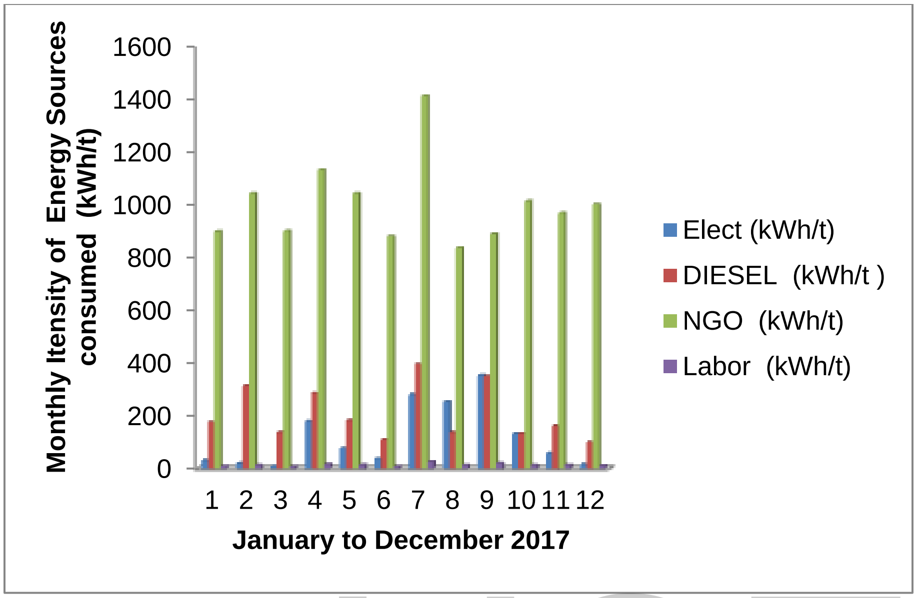


Fig. 1: Monthly Variations of Energy Sources consumed

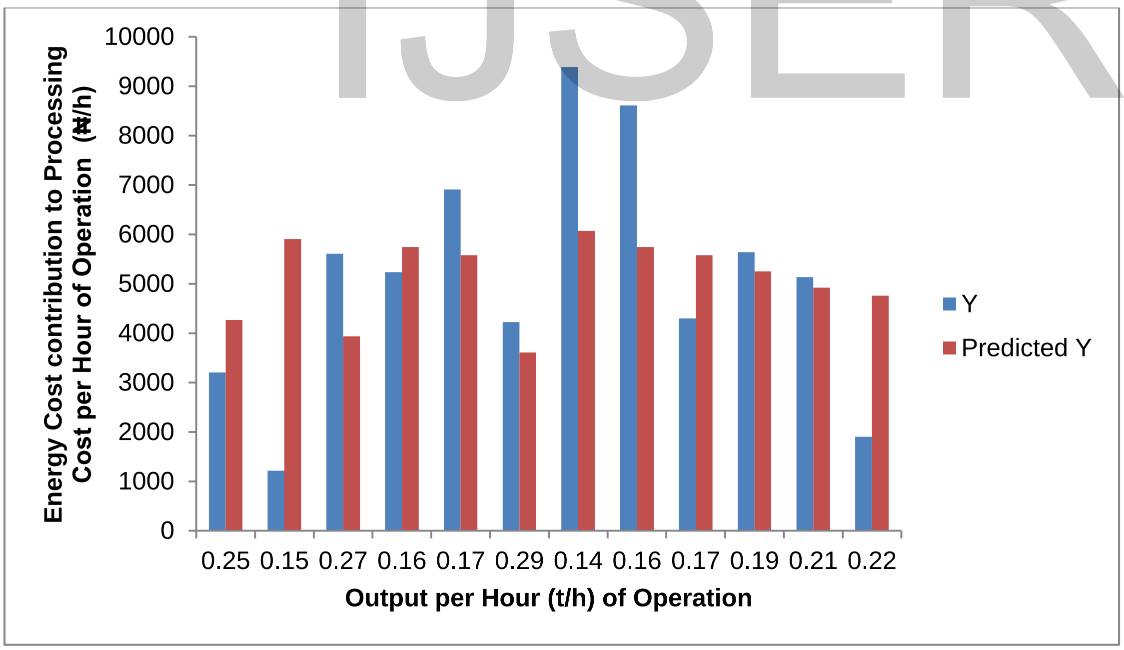
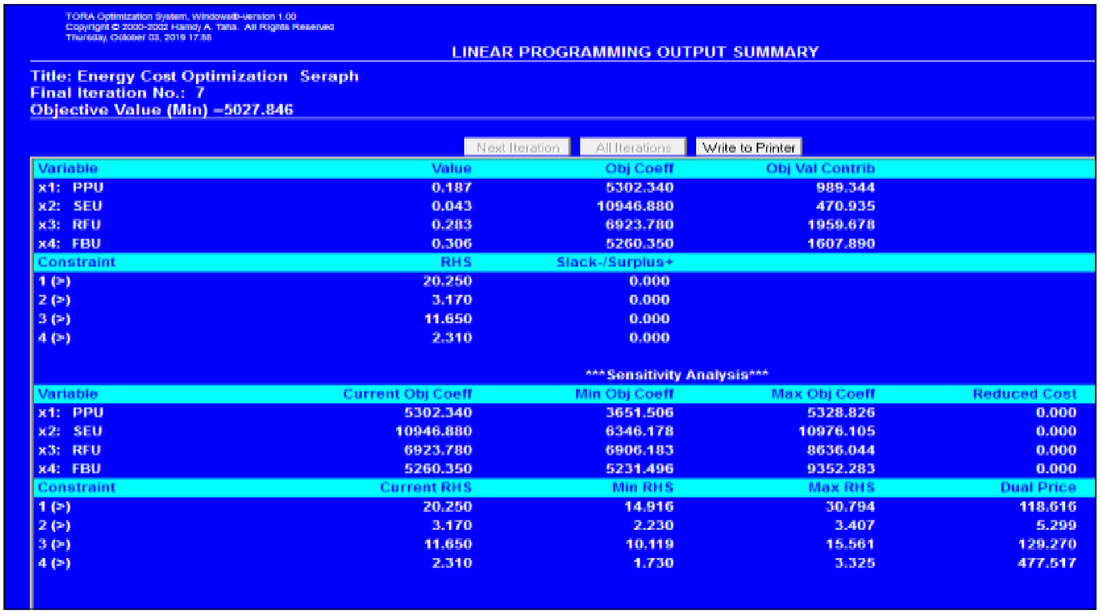


Fig. 2: Energy Cost Contribution to Processing per Hour of Operation



TORA Optimization System, Windows®-version 1.00
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Thursday, October 03, 2019 17:55

LINEAR PROGRAMMING OUTPUT SUMMARY

Title: Energy Cost Optimization Seraph
Final Iteration No.: 7
Objective Value (Min) =5027.846

Next Iteration | All Iterations | Write to Printer

Variable	Value	Obj Coeff	Obj Val Contrib
x1: PPU	0.187	5302.340	989.344
x2: SEU	0.043	10946.880	470.935
x3: RFU	0.283	6923.780	1959.678
x4: FBU	0.306	5260.350	1607.890

Constraint	RHS	Slack-/Surplus+
1 (>)	20.250	0.000
2 (>)	3.170	0.000
3 (>)	11.650	0.000
4 (>)	2.310	0.000

Sensitivity Analysis

Variable	Current Obj Coeff	Min Obj Coeff	Max Obj Coeff	Reduced Cost
x1: PPU	5302.340	3651.506	5328.826	0.000
x2: SEU	10946.880	6346.178	10976.105	0.000
x3: RFU	6923.780	6906.183	8636.044	0.000
x4: FBU	5260.350	5231.496	9352.283	0.000

Constraint	Current RHS	Min RHS	Max RHS	Dual Price
1 (>)	20.250	14.916	30.794	118.616
2 (>)	3.170	2.230	3.407	5.299
3 (>)	11.650	10.119	15.561	129.270
4 (>)	2.310	1.730	3.325	477.517

Fig. 3: Output from Tora software

IV. Discussion

The energy consumption variation (Fig. 1), during the period of study showed that natural gas oil (NGO) had the highest monthly consumption variation of 1400 kWh/t, followed by diesel 390kWh/t; electricity 380kWh/t and labor 50 kWh/t. It will be observed that NGO, with the highest market price value of ₦230/kg (Appendix A, Table 1c) was consumed more during the period. However, researchers have argued that the boiler units normally worked continuously for most hours of the day for steam generation as the reason to justify high consumption [4], [5]. However, in the present study, consideration was limited to one hour of processing therefore; many hours of operation were not considered. Thus, there are no justifiable reasons for this high consumption variation for this energy source especially the month of July. Again, it will be observed that diesel and electricity have nearly equal consumption variations in most months of the year, however, April, July, September and October witnessed equal electricity and diesel consumption. Diesel was only used as fuel to power the local plant for electricity generation in case of power failure from public power supply [11]. Therefore, ranking electricity from public supply and diesel equal in consumption, as in April, July, September and October indicate that something was amiss. To support this point, it was observed during energy audit that the industry did not have an energy monitoring team to monitor energy procurements, usage and documentation. Secondly, records of procurements were available but no consumption records, indicating presence of wrong practices [2], [4], [13]. Labor utilization in the industry was very poor during the period and contributed much less to processing cost.

Fig. 2 showed the results of monthly consumption cost variations for the period. The highest variation was ₦9100/h during the month of July and the least value in second month as ₦1000/h. However, the average cost incurred during the period showed ₦5114.42 shown in red bars. The average production cost, located on the bottom of the bars showed average value of 0.198 t/h during the significantly by NGO. However, the cost considered in the study was that of production per hour, so variation ought to be even. However, Fig.2 showed uneven costs variations per hour of operation, showing in blue bars, across the period. This is an indication that unprofessional practices might be responsible for this action. To support the allegation, during data gathering it was observed that the industry had only energy procurement records but no consumption records to compare purchases and consumption. It was observed too that the industry did not have energy monitoring team in place to monitor procurement, utilization and documentation. Therefore, one vital aspect of effective energy management was defeated and in absence of supervision many unwholesome practices prevail [1], [13].

Fig. 3, presented the minimum processing cost per hour of operation as ₦5028 with average output rate of 0.205 t/h obtained from optimization. However, the installed production capacity was 3.5 t/h (Appendix A, Table 1a), which showed that even with this results the industry still needs effective management of inputs resources to achieve target production. Effective energy management and production planning would ensure elimination of waste and losses, to achieve maximum output [4]. It will be observed that, with optimization, which entails effective planning, the output appreciated to average value of 0.205 t/h (Fig. 3). Fig. 3 also indicated that among the four energy sources used, labor had the highest dual price value however, the industry had very low labor utilization therefore, it added only minimal cost to production cost period. Comparing Figs.1 and 2, it will be observed that this high production cost was contributed (Fig. 1). NGO followed with high dual price value and had the highest consumption rate, which implied that it contribution more to processing cost (Fig. 1) than the other sources put together. Electricity came third in the ranking of high dual price value but has low utilization and therefore, contributed marginally (Fig. 1). Diesel had the lowest dual price value and low consumption therefore contributed the least to processing cost (Fig. 1). The implication of 'dual price' is that the consumption of one more unit of an energy source increases production cost equivalent to its dual price value [10], [13]. This informs the necessity of optimizing energy consumption by the industry to ascertain energy sources that might require more monitoring and control or outright substitution for new ones to reduce cost influence in production.

V. Conclusion

The following conclusions were drawn from the study;

i. The contribution of primary energy sources to processing showed NGO 1400 kWh/t, diesel 390kWh/t; electricity 380kWh/t and labor 50 kWh/t with NGO having the highest contribution,

ii. The minimized processing cost per hour of operation was ₦5028, with output of 0.205 t/h.

VI. Recommendations

The analysis carried out in this study showed that lack of energy monitoring and control by the industry was responsible for uncontrolled consumption of natural gas oil (NGO). Secondly, the high dual price values of labor, NGO and electricity made them candidates for close monitoring therefore, recommend that, for sustainable growth, the industry should;

i. Set up an energy monitoring team to monitor procurement and utilization of energy sources especially NGO, Install *smart* electricity monitoring gadgets to monitor electricity consumption to dictate faulty utilities in time for ratification.

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Appendix A

Table 1a: Basic Energy Information from first phase of Energy Audit

Operation Units	Elect power (kW)	Machine Time (h)	Thermal Fuel Type	No. of Workers (N)	Labor-hours (h)	Material Inputs (ton)	Installed Production Capacity (t/h)
							3.5
PPU	96.70	7.78	NGO	9	5.00	30	
SEU	135.18	11.72	"	8	3.50	35	
RFU	129.67	4.18	"	5	1.8	20	
FBU	40.50	2.00	"	8	7.63	9	
	402.05						

i. AGO consumption rate = 48 liters/h
ii. NGO consumption rate = 75 kg/h,

Table 1b: Primary Energy and Output from second phase of Energy Audit

Period (Months)	Admin Elect (kWh)	Process Elect (kWh)	AGO (liter)	NGO (kg)	Labor (N)	Time (h)	Output (t)
1	3594.70	4066.30	2299.92	3798.13	34	518	129.50
2	4318.00	1866.00	1946.86	598.66	27	622	93.30
3	3620.40	1200.60	1686.06	10419.74	30	522	140.94
4	3890.80	12862.20	2060.4	6653.23	32	510	81.60
5	3815.23	6817.77	1600.56	7466.45	34	513	87.21
6	3546.79	5677.21	1640.31	6196.25	31	511	148.19
7	3830.79	12005.21	1199.73	7091.35	27	591	82.74
8	4186.79	24373.21	1298.16	14846.21	31	601	96.16
9	3792.68	22584.32	2246.64	1371.46	34	552	93.84
10	3826.35	13857.65	1349.95	8715.60	35	551	104.69
11	8613.60	7466.40	2093.04	9392.01	38	612	128.52
12	3872.88	2845.12	1468.8	924.54	34	544	119.68
Avg.	42909.01	115622	20890.43	77473.61	32	6647	108.86

Table 1c: Units Cost of Energy, Product and Raw Material

Elect (₦/kWh)	Diesel (₦/liter)	NGO (₦/kg)	Average Labor (₦/h)	Product Selling Price (₦/liter)	Unit Cost of Raw Material (₦ /kg)
46.25	165.00	230	12.50	760.87	75

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Table 1d: Energy Conversion Factors

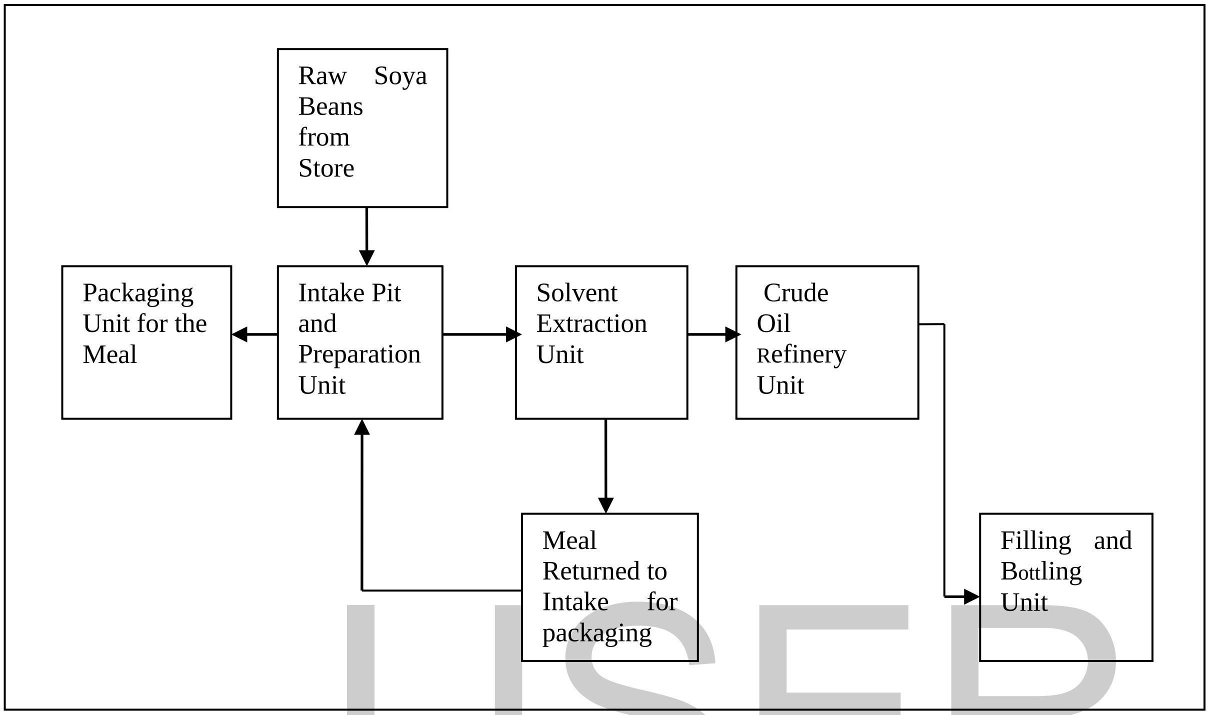

Fig. 1a: Material flow Diagram for soya Oil Processing

Table 1e: Monthly Energy Consumption Intensity

Months	Elect (kWh/t)	AGO (kWh/t)	NGO (kWh/t)	Labor (kWh/t)
1	31.4	176.53	897.45	9.72
2	20	314.60	1042.68	12.87
3	8.52	137.31	899.73	7.94
4	179.64	286.05	1130.86	16.30
5	78.18	182.43	1041.92	14.30
6	38.3	110.02	880.00	7.64
7	280.89	395.94	1410.90	26.69
8	253.47	137.12	836.10	13.85
9	353.76	349.83	888.01	21.20
10	132.37	132.37	1013.14	13.17
11	58.10	161.88	968.85	12.94
12	15.88	100.27	1000.98	11.05

Table 1f: Energy Sources consumed and Costs per Hour

Period Months	Output Rate (t/h)	Elect (kWh/h)	AGO liter/h	NGO kg/h	Manual kWh/h	TEC Cost (₦/h)
1	0.25	7.85	4.44	7.33	2.42	3204.65
2	0.15	3.00	3.13	0.96	1.94	1215.17
3	0.27	2.30	3.23	19.96	2.16	5607.76
4	0.16	25.22	4.04	13.04	2.31	5236.09
5	0.17	13.29	3.12	14.55	2.45	6909.29
6	0.29	11.11	3.21	12.13	2.25	4226.76
7	0.14	42.31	2.03	12.00	1.92	9387.46
8	0.16	47.21	2.16	24.70	2.23	8610.73
9	0.17	48.16	4.07	2.48	2.46	4299.43
10	0.19	25.15	2.45	15.82	2.48	5639.62
11	0.21	12.20	3.42	15.35	2.72	5134.59
12	0.22	5.23	2.7	1.70	2.42	1901.48
Avg.	0.198	20.25	3.17	11.65	2.31	5114.42

Appendix B

1. Determination of Dimension Units for Optimization Parameters

This section outlines the dimension units to the objective function and constraints for the model. The condensed form of objective function equation (1) page 6 is;

Min (Z)= $\sum_{i=1}^{n} C_i \, x_i$

The symbol Z has two components; C_i *and* x_i, the label C_i, represents the cost of energy source, i, consumed per ton of output and has the dimension unit of (₦/t). This is the amount of money incurred on energy for producing one ton of output. The variables (x_i) represent the output from a processing units and has the unit of ton per hour (t/h). This represents the hourly rate of output of production. Therefore, combining the units of these two components, the dimension unit for Z (₦/t * t/h) becomes (₦/h). Z, Represents the minimum cost of energy required per hour of processing.

Whereas, the condensed form of the constraint equations (2) to (6) is:

$\sum_{i=1}^{m} a_{i,j} \, x_i \geq b_i$, The symbol $a_{i,j}$ represents the basic quantity of primary energy sources i required to process a ton of output in unit j. Therefore, combining these two parameters $a_{ij}x_i$ the left hand side of equation (5) gives the dimension unit for each constraint. Thus, the rate of: consumption per hour for electricity (kWh/t x t/h) equal to kWh/h, for diesel (liter/t x t/h) equal to liter/h, for NGO the (kg/t x t/h) equal to kg/h. The dimension units for b_i, which represent the previous year's primary energy sources consumption rates, have the units of kWh/h, liter/h, kg/h etc. This showed that both the left hand side (LHS) and right hand side (RHS) of (2) to (5) are consistent dimensionally. For the dimension units for all parameters in model, refer to Appendix A, Table 1d, and the format entered into optimization interface of Tora software.

In the answer displayed, the dimension units for the 'dual price' values in the solution sheet equals the objective function units divide by the units of constraint and thus, the units of 'dual price values' equals: ₦118.62/kWh, ₦5.30/liter, ₦129.27/kg and ₦477.52/kWh for electricity, diesel, NGO and labor respectively. That is the unit cost to be paid for consuming one more unit of any of the energy sources by the industry.

2 Calculation details for optimization parameter values

PPU (values for parameters obtained from, Appendix A, Table 1a)

1. Elect $= \frac{96.90\ kW x\ 7.8h}{30\ t}$ = 25.07 kWh/t
2. AGO $= \frac{48\frac{liters}{h} x\ 1.89\ h}{30\ t}$ = 3.03 liters/t
3. NGO = 75 kg/h x 2.13 h)/30t = 5.33 kg/t
4. Labor (kWh/t) = 9workers x 5 h x .075kW) =3.40 kWh

SEU

1. Elect $= \frac{135.18\ kW\ x\ 11.72h}{35t}$ = 45.26 kWh/t
2. AGO $= \frac{48\frac{liters\ x\ 1.7\ h}{h}}{35t}$ = 2.30 liters/t
3. NGO $= \frac{75\frac{kg}{h}\ x\ 16.65\ h}{35\ t}$ = 35.67 kg/t
4. Labor (kWh/t)= 8workers x 3.50 h x 0.075kW) =2.0 kWh

RFU

Elect $= \frac{129.67\ kW\ x\ 6.5\ h}{20\ t}$ = 40.00 kWh/t

1. AGO $= \frac{48\frac{liters}{h} x\ 1.6\ h}{20\ t}$ = 3.95 liters/h
2. NGO $= \frac{75\frac{kh}{h}\ x\ 4.18\ h}{20\ t}$ = 15.67 kg/t
3. Labor (kWh/t)= 5 workers x 1.8 h x 0.075 = 0.67 kWh

FBU

1. Elect $= \frac{40.50\ kW\ x\ 2h}{9t}$ = 9 kWh/t
2. AGO $= \frac{48\frac{liters}{h} x\ 0.85\ h}{9t}$ = 4.54 liters/h
3. NGO $= \frac{75\frac{kg}{h}\ x\ 1.84h}{9t}$ = 15.33 kg/t
4. Labor (kWh/t) = 8 workers x 7.63 h x .075kW) = 4.58 kWh

These values are entered into Table 1g.

Table 1g: Data entered into Tora Software

Energy Sources (kWh)	PPU (t/h)	SEU (t/h)	RFU (t/h)	FBU (t/h)	Availability
Elect (kWh /t)	25.07	45.26	38.42	9.00	20.25 kWh/h
AGO (Lt/t)	3.03	2.30	3.95	4.54	3.17 Lt/h
NGO (kg/t)	5.33	35.67	15.67	15.33	11.65 kg/h
Labor (kWh/t)	3.40	2.00	0.67	4.58	2.31 kWh/h

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