Energy Evaluation and Processing Cost Reduction in Agudu Maize Processing Industry

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ABSTRACT

This study evaluated energy consumption by Agudu Farms Limited (AFL) that processes maize and cassava into flour for human consumption. The objectives of study included to determine energy contribution to processing cost, to minimize the processing cost and to propose a new selling price per unit of sale of the product. The study materials included; a multi-meter, stopwatch, electrical appliances' nameplates and bills, fuel purchased receipts, and production records. Data was collected through detailed energy audits and measurements of present electricity consumption. This data was converted into energy intensities, rates and costs, and analyzed. The monthly energy intensity plotted on bar charts using Microsoft excel and the results showed that diesel had the highest consumption variation of 3500 kWh/t, electricity 200kWh/t and labor 110 kWh/t. The percentage of energy contribution to processing cost was 33%. In monetary terms, the processing cost per hour of operation showed average value of ₦830. Whereas, the minimum production cost per hour using Tora software showed ₦767. The new product price per ten-kilogram (10kg) unit of sale of maize flour, using break-even analysis, showed ₦2864. The study observed that diesel contributed more to production cost than electricity and labor and therefore, recommended the setting up of an energy monitoring team to monitor procurement and control utilization of diesel to reduce production cost.

Keywords-- Agudu Farms Limited, Cost Reduction, Evaluation, Energy, Unit Price Reduction

I. INTRODUCTION

Energy consumption is unavoidable in any processing activities and its cost constitutes a significant part of total processing costs therefore; using minimum amount of energy resources to achieve the desired production level should be the key to sustainable growth. To reduce cost, entails effective energy management, which traces all causes of wastes, evaluates and analyzes them with a view to eliminating them [1]

Agudu farms limited (AFL), is an agro-crop processing industry that processes maize and cassava into flour for human consumption. Like any other industry in Nigeria it faces many challenges that make effective energy management appear difficult. For instance, poor infrastructures, epileptic and low electric power supply, high cost of fuels, inadequate loan facilities, poor quality farms produce etc [2][3]. These factors are among the impediments that directly or indirectly affect the operations of this industry, which in turn may influence increased energy consumption and processing cost. However, by setting up an industry, investors should perform feasibility studies and determined the prevailing technical, economic, social and environmental problems, and worked out ways to handle them as they arise [4], and should be done before set up and not after.

Similarly, AFL like any other processing industry, depends on inputs like; capital, land, energy, labor, raw materials etc, for processing but the major recurrent inputs been energy, labor and raw materials. The most acceptable option worldwide is minimizing the use of the recurrent variables or reverting to renewable energy sources, which are less costly, and environmentally benign[5]. Moreover, the issue of cost reduction through effective energy management has become a global subject because the developments of nations depend on energy consumption, which informs its ever-increasing costs. It is important to follow the global trend in energy management to reduce production cost and its other negative effects.

Towards this end, the developed economies of the world standardized the use of energy in their policy frameworks. These standards are set for everything including; domestic and industrial energy utilizations, farms produce, labor utilization [6]. However, Nigeria, as a nation has no policy or standards concerning energy consumption domestically or industrially [2][7]. However, researchers in energy managements have advocated for reduced energy consumption in industries [8][9].

Although, researches have been carried out in some industries to evaluate energy consumption, however, no study has been carried out on AFL to evaluate its energy consumption with a view to reduce its processing cost. Energy consumption is location dependent and based

on the type and quality of raw crop, effectiveness of the processing machinery, extent of processing required, proficiency of labor involved etc [8]. Therefore, energy audit of one industry in a location does not confer same solution on other industries even within the same vicinity. Therefore, the previous studies did not offer solution to energy consumption problems of AFL.

The problem in view was the high selling price of a unit of maize flour produced by AFL compared to those brought from elsewhere, and blamed on high production cost. The cost of energy consumed in processing influences production cost, which is one of the major determinants of the selling prices of products [10][11]. Therefore, the specific objectives of this work are to determine the contribution of energy sources to production cost, to determine the minimum cost of energy necessary for processing a unit of output and lastly, to suggest a new price per unit of sale for the product.

This study contributes significantly to both practical and intellectual knowledge. Firstly, assessment of energy aimed at reducing processing cost from AFL is carried out for the first time. Secondly, the results obtained can assist the industry to predict future energy consumption. Lastly, product will be priced based on actual costs involved in production and remove the drudgery of arbitrariness. For the intellectual contribution, other researchers with little modifications to suit other industries can replicate the procedures outlined herein. The study is beneficial to managers whose responsibility is to plan, manage energy for production and priced output product, the study will remove the drudgery of guesswork.

II.   MATERIALS AND METHODS

The study used the following materials: multi-meter for electricity instrument, stopwatch, electric utilities nameplates, electricity bills, production record books and fuels purchased receipts. These materials obtained from the industry were considered adequate for the study because an expert from the industry validated them. The multi-meter had the following specifications; (*Suoer SD 9208A version* 2010, maximum voltage (700 VAC); accuracy AC voltage for 700V ($\pm$ 1.2%) while, for AC current 20A ($\pm$ 3.0%).The stopwatch had the following specifications; An *Accu split Pro Survivor-A601X* stopwatch, specification 0.01 of a second. The methods of data gathering were through detailed energy audit that included present electricity consumption measurement.

The data gathering was done personally within a period of one-month of work in the industry. The industry attached a qualified staff that guided the data collection process throughout this period. The choice of these methods based on the level of accuracy of information required. The importance of these techniques was to maximize the quality of the data and reduce the chances of bias. The period of data collection was the last twelve months. The study chose this period to coincide with the budget-planning period of the industry. Moreover, the study hopes to provide models to aid annual energy planning for the industry to reduce arbitrariness in its energy planning. The annual information on energy, time and production outputs collected on monthly bases, were converted in intensities and rates of consumption, and organized on monthly bases together with the costs incurred. The analyses energy intensities, rates and costs formats addressed the specific objective posed in the study.

III.   PRIOR APPROACH

The test of average working temperature of electric motors and load balance between electric motors and the mechanical driven equipment, The methods used by [3] to test for percentage unbalanced voltage (PUV) and the power factor (PF) was used in the present study:

$$PUV = \frac{MV - AV}{AV} \text{ x } 100\% \qquad (1)$$

Where,
MV is maximum phase voltage and
AV is the average phase voltage.

$$PF \text{ was tested using } = \frac{Ative\ Power}{Apparent\ Power} \qquad (2)$$

Similarly, optimization, in linear programming was used to address the problem of minimum energy consumption by the industry. The problem was to determine the rate of product output required at each production unit, so that the overall cost of energy involved per hour of processing would be a minimum. The linear programming method presented by [13][14] was used in this study. The following steps outlined were followed to problem formulation were:

i.   The identification of the objective function and decision variables from the problem,

ii.   The identification of the problem parameters and constraints, and

iii.   The non-negativity constraints

The linear model for minimization of the problem was given by [13][14]:

$$\text{Minimize} \quad Z = \sum_{i=1}^{n} C_{i,}\ x_{j,} \qquad (3)$$

Subject to:

$$\sum_{j=1}^{m} a_{i,j}\ x_j \geq b_i \qquad (4)$$

Nonnegative constraint

$$x_i \geq 0 \qquad (5)$$

Therefore, (3) to (5) expanded to;

Minimize $(Z) = C_1 x_1 + C_2 x_2 + C_3 x_3$ (6)

Subject to the constraints;

$a_{11} x_1 + a_{12}\ x_2 + a_{13} x_3 \geq b_1$ (7)

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 \geq b_2 \qquad (8)$$
$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 \geq b_3 \qquad (9)$$

Non-negativity constraints;

$$x_1 \geq 0, \ x_2 \geq 0, \ x_3 \geq 0 \qquad (10)$$

Z= the overall measure of performance called the objective function,

x_j = decision variables, in the level of activity j   (for j = 1, 2, 3...n)

b_i = the total amount of energy resources i that is available for allocation to activities (i= 1, 2, 3...m),

C_i = unit cost of energy source Z that would result from each unit increase in level of activity j

$a_{i,j}$ = amount of energy resourceiused in unit j.

The parameters; $a_{j,i}$, b_i and C_i, were required for optimization.

The third objective in this study was a proposal for new selling price per unit of sale of the product. The method used by previous researchers to address this type of problem was the breakeven analysis. The tool allows the review of all fixed and variable costs to establish if any of them can be removed at any point without serious effect on production. This tool helps to narrow the breakeven point, with higher assurances of making profit from sales [10][11]. It is used in this work with the following assumptions made [11]:

i.   The quantity of output during the previous output was the break-even quantity,

ii.   The value of the fixed cost (F) was based on the problem parameters (not the actual fix cost of industry),

iii.   The unit selling price of product   remained constant during last year,

iv.   The processing had only two costs: fixed and variable costs, and

v.   The quantity of output produced were sol

Therefore, the total production costs (TPC) was given as the fixed cost (F) plus the variable costs (x) multiply by the output (Q) [10] [11]:

$$TPC = F + x Q_1 \qquad (11)$$

Where;

TPC = total production cost recoverable from total sales ($y_i Q_1$) at breakeven point

F= fixed cost,

x = variable costs used to produce output products Q_1

Q_1= quantity produced at break-even point

y_1 = the unit selling price of products at breakeven point .

IV.   PRESENT APPROACH

AFL uses only three energy sources namely; electricity, diesel for local power generation and manual labor supplied by human beings. Information on the consumptions of these sources was collected from walkthrough and detailed energy audit and present electricity measurements. Electricity consumption was considered for utilities that have direct bearing to production while, consumption by allied departments were collected but removed as none process consumption.

Table 1: Basic Energy Requirements per Unit of Operation

Operation Units	Elect power (kW)	Machine Time (h)	No. of Workers (N)	Labor-hours (h)	Material Inputs (ton)	Installed Production Capacity (t/h)
						2
CLU	12.50	4.7	6	12.22	10	
MLU	12.27	8.0	5	0.96	9.5	
GSU	54.26	8.4	6	6.00	6.0	

Table 2: Information from detailed Energy Audit

Months	Product Output (t)	Admin Elect (kWh)	Process Elect (kWh)	Diesel (liters)	Time (h)	Labor (N)
1	59.16	323.64	1131.00	1084.59	348	26
2	6.96	323.64	720.36	1145.68	348	26
3	81.12	290.16	954.72	1073.21	312	27
4	33.00	279.00	717.00	1024.45	300	26
5	40.56	290.16	645.84	1155.67	312	25
6	49.92	290.16	698.88	1043.24	312	27
7	6.96	323.64	1071.84	1135.67	348	26
8	59.16	323.64	664.68	1034.56	348	27
9	57.80	316.20	1026.8	1025.67	340	26
10	51.00	316.20	663.00	1157.45	340	25
11	59.28	290.16	1170.00	1088.45	312	25
12	90.48	323.64	1030.08	1035.35	348	25

Table 3: Units Costs of Energy Types, Raw Materials and Impurity Ratings

Elect (₦/KWh)	Diesel (₦/liter)	Average Labor (₦/h)	Product Selling Price (₦)	Unit Cost of Raw Material (₦ /kg)	Raw material Type	Raw Mats. impurity Ratings (%/ton)
46.25	165.00	6.50	3000	50	Maize/cassava	6 - 14

Table 4: Information on Electricity Measurements based on Operation Units

Days	CLU (kVA)	MLU (kVA)	GSU (kVA)
1	20.45	21.32	94.41
2	21.56	20.56	90.63
3	20.21	20.54	91.45
4	22.79	19.56	91.56
5	21.54	20.67	90.73
6	20.55	20.98	91.75
7	22.67	21.56	91.67
8	21.91	20.89	92.69
9	20.95	20.59	90.88
10	22.83	21.56	92.22
11	22.69	20.48	92.59
12	22.89	20.65	92.64

Note: Total Apparent power = 134.52 kVA
Total PI   = 96.42 kW
Total PR   = 79.03 kW (Table 1)

Detailed Energy Audit and Conversion

Table 1 showed information gathered from the first phase of the detailed energy audit from the industry. While, Table 2, represent information from the second phase of the detailed energy audit, collected from nameplates of all electric power equipment including; air conditioners, refrigerators, lighting points, computers, etc used by the industry. From inventory, information obtained included annual amounts of electricity consumption and bills paid, receipts of fuel purchased and amounts of money paid. Similarly, the unit selling price of product output and the cost per unit of raw material collected from records for the past twelve months shown in Table 3. For the raw material flow diagram, refer to Appendix A, Figure 1a. Electric power supplied and used by appliances was measured through voltage, current and time. Electricity energy consumption by departments like; administration, accounts, security, etc collectively tagged 'elect admin'; this quantity was deducted from the monthly consumption because it did not have direct contribution to output. The first column in Table 4 showed the number of days measurements were conducted, the other columns showed consumption by each operation unit. Electric motors were the dominant electric appliances driving the mechanical equipment for processing, therefore, measurements of centered on them. The data collect from this method was used to test the average working temperature of the electric motors, using the percentage-unbalanced voltage (PUV), and the power match between electric motors and the driven equipment using power factor (PF).

Information collected on energy sources was converted into energy consumption units (kWh) per ton of output (Appendix A, Table 1a), using standard energy conversion factors (Appendix A, Table 1c). Then monthly output and corresponding energy units consumed (Appendix A, Table 1b) tabulated. The rate of energy consumption and cost incurred for each month (Appendix A, Table 1d). It provided indication of the monthly variations of energy consumed to produce a ton of output during the period under review. This data was analyzed using Microsoft excel, which drew bar charts and determined the consumption variation during the period. The amount of money expended on energy per hour (₦/h) to produce per hour (t/h) was also presented on bar charts using Microsoft excel.

Minimization of the Processing Cost

Energy sources consumed within the period were converted into monetary values in Naira, using unit values in Table 4. For the problem formulation, the industry has three production units that consume different amounts of energy for production. The amounts of different energy sources available from previous year's processing activities represented the basic amount of energy resources used by each processing unit. The problem therefore, was to determine the product output at each production unit, so that the overall cost of energy involved per hour of processing would be a minimum.

The descriptions and dimensions of the parameters used for optimization. From (3) to (5), the parameters $C_1 - C_3$ represent the cost of each energy source i used in unit j while, $x_1 - x_3$ represent the variables (product output per hour - t/h) from each processing unit. The parameters $a_{11} - a_{43}$ are the basic values of energy sources required by each of the operation units. The parameters b_1-b_4 represents energy sources consumed per hour of processing during the previous year's production. The constraints (4) represent the impediments preventing effective energy consumption for production. The dimension units for these parameters were also tested to ensure consistency. From the objective function (3), the symbol Z has two components; C_i and x_i. the label C_i, represents the cost (₦) of a particular energy type, i, consumed to process one ton (t) of output (₦/t). The variable (x_i) represent the rate of output per hour (t/h). Therefore combining the units of these two parameters, the dimension unit for Z became:

$$₦/t * t/h = (₦/h) \qquad (12)$$

The symbol Z therefore, represents the minimum cost of energy required to process raw material per hour. From the constraints (4), dimension units for the symbol $a_{i,j}$, which is the basic amount, a, of a primary energy source, i consumed for production in unit j. x_j represents the output from production unit j, combining the two parameters yielded, $a_{i,j} x_j$. The dimension unit for each constraint becomes:

$$kWh/t * t/h = kWh/h, \qquad (13)$$
$$liter/t * t/h = liter/h, \qquad (14)$$
$$kg/t * t/h = kg/h \qquad (15)$$

The dimension unit for b_i, (4), been an energy source consumed during the year reviewed, to produce per hour represented as kWh/h, liter/h, kg/h etc. Therefore, the left hand side (LHS) and right hand side (RHS) of (3) and (4) are dimensionally consistent.

The actual model for the industry was derived according to industry's expected output and energy requirements. The objective of the problem was to minimize the cost of energy that meets the consumption requirements of the production units. Therefore, applying (6) and (10):

$$Min(Z) = 1405.23x_1+1712.20x_2+3604.21x_3 \qquad (16)$$
Subject to;

$$5.88x_1+3.38x_2+16.28x_3 \geq 2.65 \qquad (17)$$

$$5.16x_1 + 9.23x_2 + 15.39x_3 \geq 3.28 \qquad (18)$$

$$5.50x_1 + 0.36x_2 + 3.60x_3 \geq 1.95 \qquad (19)$$

The non-negativity constraint;
$$x_1 \geq 0,\ x_2 \geq 0\ \text{and}\ x_3 \geq 0 \qquad (20)$$

The Proposed Selling Price Per Unit of Sale

      The third objective in this study was the proposal for a new product-selling price per unit of sale. The data for this analysis was obtained from Table 3 and optimization results. From (11), the following equation was derived to find the fixed cost in the problem:

$$F = y_1 Q_1 - x Q_1 \qquad (21)$$
Where;
y_1 = the selling price per unit of sale,
$y_1 Q_1$ = the total revenue from sales
$x Q_1$ = total variable costs based on production,
x = total variable cost (energy resources and raw materials etc.)
$$x = u + m + \omega \qquad (22)$$

Where;
u = average unit cost of energy resources used, and
m = the unit cost of raw material processed ω = other variable costs not identified like lubricants, (in this study these are constant)

Therefore, the amount of energy contributed to processing cost = $Q_1 u$
Therefore, the percentage energy cost contribution to processing cost = $\dfrac{Q_1 u}{TPC}$ (23)

From (21) and (22), the unit selling price of the product was derived as:,,
$$y = \frac{F}{Q_i} + u + m + \omega \qquad (24)$$

Where
Q_i = the quantity of output from operation unit (i= 1, 2).
1 = the average output from previous operation
2 = average quantity of output obtained from proper planning
For detailed numerical calculations, refer to Appendix C.

V. RESULTS AND DISCUSSIONS

      The results obtained are presented and discussed in this section, based on the data collected to address the objectives of the study, which included the percentage energy contribution to processing cost, the minimization of processing cost and a suggestion for a new product selling price per unit of sale.
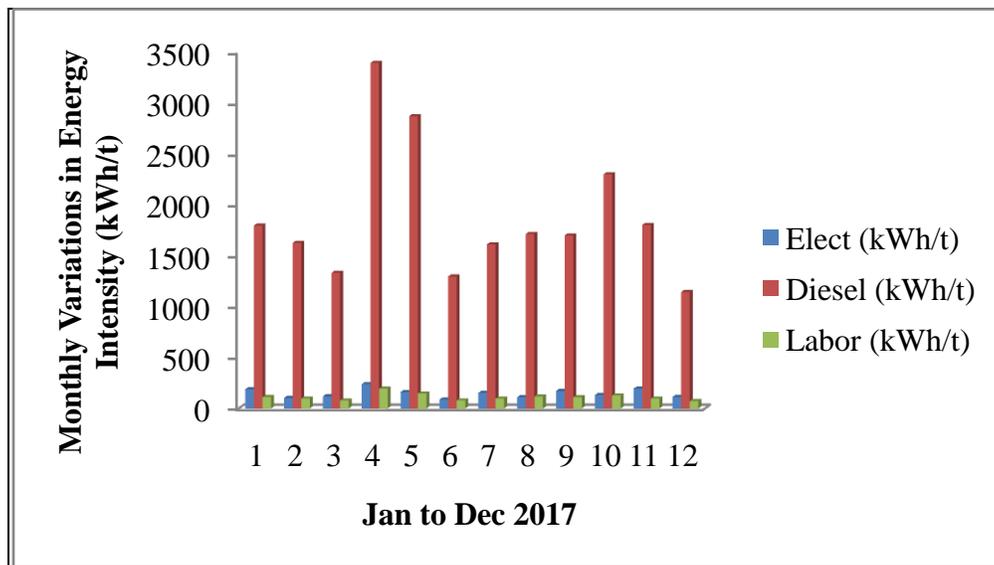

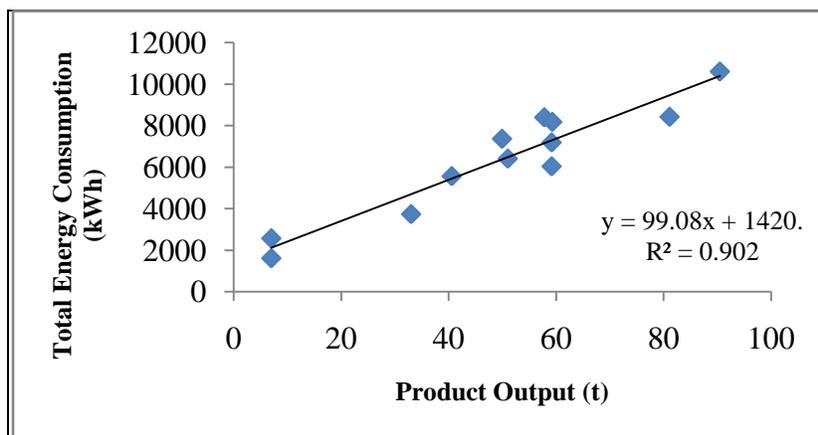**Figure 1:** Energy Contributions to Processing

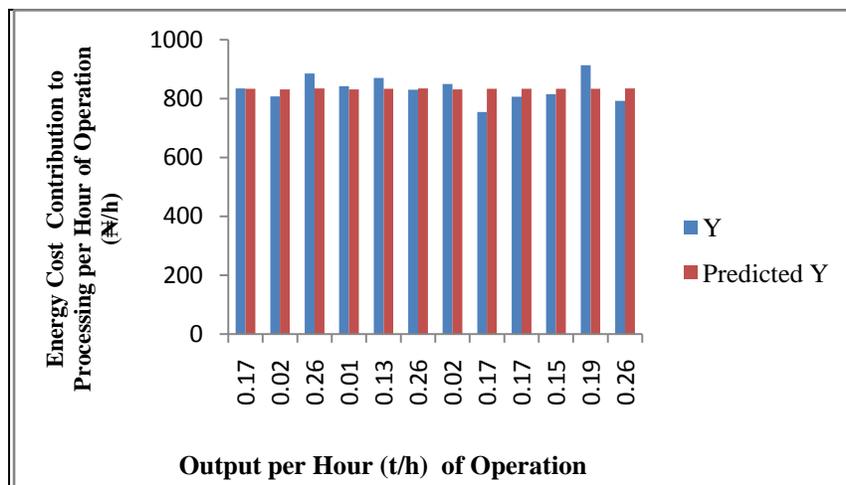**Figure 2:** Relationship between Total Energy Consumption and Product Output

Figure 3: Energy Contribution to Processing cost per Hour

Figure 4: The Results of Processing Cost Optimization

Energy Contribution to Processing Cost

Figure 1, showed the variations in energy sources consumed across the months of January to December 2017. The industry used three energy types; electricity, diesel (automotive gas oil –AGO) and labor. Diesel had the highest consumption variation during the period of 3500kWh/t, followed by electricity with 200kWh/t. and lastly labor with 110 kWh/t This was indication of very poor electricity supplied to the industry [2][3] hence, the dependence on local generating plant that consumed diesel to power the production machinery. The figure also showed poor labor utilization. It was observed during data collection that most labor was hired only when an order was placed for production by customers and fired at the end.

Figure 2, showed the relationship between energy consumption and output during the period of January to December 2017. It showed positive and linear relationship, which agreed with literature [7][8]. The intercept on the y-axis showed the value of 1420 kWh/t. The intercept represented the amount of energy consumed during start, cleans up. Comparing Figures 1 and 2, it was observed that this quantity of energy might be contributed mainly by diesel without value addition to the products. However, the present study did not have adequate data to determine the actual energy consumption during start and clean up periods.

Observation of Figure 3 showed the uneven variations of energy cost distribution across the months of the year. Comparing Figure 3 to 1 showed that diesel was responsible for the increased cost. The blue bars in the figure depicted monthly variations of energy cost per hour of operation during the period. The third, fifth and the eleventh months had very high values however, eleventh month had the highest cost variation of ₦910. Whereas, the average value of ₦830 for each month shown in red bar was predicted by the software. Why was energy consumption more in some months and less in others? Observe the output in ton per hours on the x-axis of Figure 3; the output was low compared to installed capacity of 2 t/h (Table 1). The available answer to this researcher is unprofessional practices in energy procurement and utilization. To buttress this point, it was observed during data collection that only energy purchase records were available but no consumption records to compare and contrast what was purchased and actually used. For proper accountability, both purchased and utilized records must be available for comparison[7][8][9].

Electricity supply and utilization by the industry was very low, however, the examination of what was supplied and utilized by the electric motors and the mechanical driven requirements showed that the results of PUV was 4.5% whereas, , the standard value reported was 5% [3][4]. The implication was that the electric motors operated optimally without excessive heat generation. Whereas, the PF, result showed 72%. The standard value for processing industry was reported as 75%-95% [9]. The proximity of the results to the practical values indicated that the industry needs to put measures that are more practical in place for improvements of electricity utilization like installing of smart electric monitors to monitor and dictate .faults for quick ,maintenance.

It was observed from Figure 1 that diesel contributed more to the cost of production than the other two sources. Comparing Figures 1 and 2, the cost distribution across the period showed that the high cost variation was majorly contributed by diesel. The industry should set up energy monitoring team to monitor purchases and consumptions and keep proper records.

Minimization of Processing Cost

Figure 4 presented an objective function solution of ₦767.05 as the minimum energy cost per hour of processing, obtained after six (6) iterations by Tora software. The result of variables (output from each processing unit) showed: CLU (x_1) as 0.339, MLU (x_2) as 0.151, GSU (x_3) as 0.009 in ton per hour (t/h) with average value of 0.166 t/h (166 kg/h). Compare the optimized value with the actual production value during the period under review of 151 kg/h (Appendix A, Table 1d), and the installed production capacity of 2 t/h (Table 1), the industry performed below the installed production capacity. The industry need to improve on its inputs management to produce close to installed capacity. This minimum amount represents the cost incurred on energy sources and the output; represent maximum production if the energy inputs were planned properly. The constraints in the same figure, represent the impediments in energy sources consumed to produce maximally, which included cost, availability and waste. The software showed 0.00 values under the 'surplus column.' The implication was that the values presented for optimization were reasonably authentic.

In the section labeled 'sensitivity analysis' (Figur4 4) under this simplex table, there are five columns headed: variable, current objective coefficient, minimum objective coefficient, maximum objective coefficient and reduced cost. The software showed the values fielded into the software were realistic and this was indicated as 0.00 in the reduced cost column. In a similar way, under this simplex table there were five columns labeled: constraints, current right hand side (RHS), minimum RHS, maximum RHS and the dual price. The software generated the values for the columns labeled: 'minimum RHS', 'maximum RHS' and 'dual price'. The significance of dual price for minimization problem is that energy types with high dual price values needed careful planning, monitoring and controlled consumption to reduce their cost since the consumption of a unit more of such energy source

increased cost equivalent to the dual price value. Observe Figure 4, the energy source with the highest dual price value was diesel; also observe Figure 1, diesel had the highest energy source consumed during the period. The optimized energy cost per hour of operation was ₦767.05 and the output per hour was 0.166 t/h. The implication of this result is that controlled diesel consumption, which has the highest dual price value; will reduce energy consumption significantly and its production cost and improve output.

How optimal will this model and results be if changes occurred in the parameters used? Two hypothetical cases, a 25% decrease in electricity consumption and a 15% increase in all the energy sources consumed by the industry were tested. The first change involved only a single parameter (may be due to electricity consumption changes following a new installation of a *smart* meter). Analysis showed a reduction in the objective function from ₦767.05/h to ₦728.04/h (Appendix B, section 1), without effect on the variables (outputs) because the decrease was within allowable limits (constraint Figure 4). Similarly, a 15% increase in the costs of all energy sources used, the changes also affected only the objective function, it showed increase from ₦767.05/h to ₦851.72/h (Appendix B, section 2), without increase in the variables (output per unit). This also explained that all the increases were within the allowable limits. Therefore, the results showed that changes in the model would not require a new model provided the changes be within the allowable limits. The implication is that the model presented is effective for predicting future energy consumption based on anticipated production level and can accommodate changes if they fall within allowable range.

The Selling Price Per Unit of Sale

Energy cost is one of the major recurrent variables in processing that have significant influence on the selling price of products [10]. Therefore, fixed cost (F) for the industry was generated from the problem parameters using (21) as ₦22754.19. The total production cost, which made up of the fixed costs and the variable costs (energy cost) totaled ₦45299.81. Energy costs alone contributed ₦14995.81 to the total processing cost. Thus, percentage contribution of energy to processing costs was 33.10% (23). The cost per kilogram (kg) of flour was calculated using equation (24) as ₦286.38. For a 10kg bag of processed maize flour, the cost of ₦2863.80/bag was obtained. Comparing this value with the actual price sold per 10 kg bag of maize floor ₦3000 (Table 3), the percentage reduction in selling price achieved was 4.5%. For details of calculations, refer to Appendix C.

VI. CONCLUSION

The study-assessed energy consumed by AFL during the period of January to December of 2017. The objectives of the study were to determine the percentage processing cost, minimum processing cost and a proposal for a new price regime per unit of sale of the product. Data collected through energy audit of the industry covering the period of one year was analyzed and the following conclusions drawn:

i.   Energy contributed 33% to the cost of processing.

ii.   The minimum cost of energy needed per hour of processing was ₦767.05, and

iii.   The proposed product-selling price per 10 kg unit of sale was ₦2863.80.

RECOMMENDATIONS

It was observed during data gathering that the industry did not have an energy monitoring team, this manifested in the manner diesel was utilized. It had the highest consumption variation during the period. It also had the highest dual price value, accounting for high percentage cost contribution to processing cost The study therefore, recommend that:

i.   the industry should create an energy monitoring team to be responsible for; planning, purchases, monitoring, control and documentation of energy utilization,

ii.   the industry to install *smart* electricity monitors to control electric consumption to dictate faulty appliances in time for prompt maintenance, and

iii.   the industry to use systematic approach outlined herein to fix prices to units of sales and avoid arbitrariness. .

Further Study

Assumption was made in the study about the 'fixed cost' in the third objective; further study is needed to establish the true value for the 'fixed costs', so that the true price per unit of sale can be determined.

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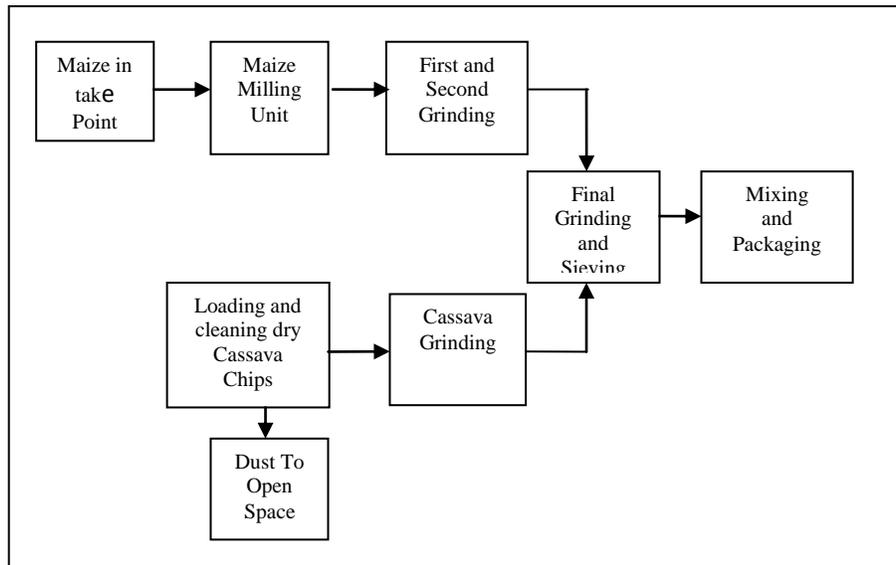
Appendix A

Figure 1a: Material flow Diagram for maize to flour processing

Table 1a: Energy Units consumed Per Ton of Output

Months	Elect (kWh/t)	AGO (kWh/t)	Manual Energy (kWh/t)
1	188.50	1796.80	112.45
2	102.91	1626.88	96.94
3	119.34	1333.45	78.98
4	239.00	3394.31	195.00
5	161.46	2871.86	146.25
6	87.36	1296.28	78.98
7	153.12	1612.65	96.94
8	110.78	1713.92	117.45
9	171.13	1699.19	110.50
10	132.60	2301.01	127.50
11	195.00	1803.20	97.50
12	114.45	1143.49	72.50

Table 1b: Monthly Total Output and Energy Units Consumed

Months	Output(t)	Elect(kWh)	AGO(kWh)	Labor(kWh)	TEC
1	59.16	1131.00	4218.39	678.60	6033.99
2	6.96	720.36	6154.38	678.60	2560.34
3	81.12	954.72	6836.62	631.80	8423.14
4	33.00	717.00	4426.44	585.00	3728.44
5	40.56	645.84	4329.36	585.00	5560.2
6	49.92	698.88	7032.41	631.80	7363.09
7	6.96	1071.84	6850.85	678.60	1601.29
8	59.16	664.68	5817.32	704.70	7186.70
9	57.80	1026.80	6706.02	663.00	8395.82
10	51.00	663.00	5105.87	637.50	6406.37
11	59.28	1170.00	6422.2	585.00	8177.20
12	90.48	1030.08	7925.66	652.50	10608.24

Table 1c: Energy Conversion Factors

S/No.	Parameters	From:	Factor	TO:	Sources:
1.	Diesel fuel	1 liter	35.80	MJ/liter	IRES, (2011)
2.	Air dried Wood	1kg	13.53	MJ/kg	IRES, (2011)
3.	Rice Husk	1kg	13.40	MJ/kg	IRES, (2011)
4.	Nat. gas oil (NGO)	1kg	43.80	MJ/kg	IRES, (2011)
5.	Labor	-	0.075NT	kWh	Oyedepo and Aremu, (2013)
8.	Energy	MJ	3.6	1 kWh	IRES, (2011)

Table 1d: Monthly Output Rates and Energy Cost Contribution

Period (Months)	Product Output (t/h)	Elect (kWh/h)	AGO (liter/h)	Manual Energy (kWh/h)	Avg. Monthly (₦/h)
1	0.17	3.25	3.12	1.95	834.12
2	0.02	2.07	3.29	1.95	807.6
3	0.26	3.06	3.44	2.03	885.07
4	0.01	2.39	3.41	1.95	842.2
5	0.13	2.07	3.70	1.89	870.05
6	0.26	2.24	3.34	2.03	830.64
7	0.02	3.08	3.26	1.95	849.36
8	0.17	1.91	2.97	2.03	754.33
9	0.17	3.02	3.02	1.95	806.99
10	0.15	1.95	3.40	1.89	815.00
1	0.19	3.75	3.49	1.89	913.10
12	0.26	2.96	2.98	1.89	792.41
Avg.	**0.151**	2.65	**3.28**	**1.95**	**833.41**

Appendix B

1. Single parameter change

$\Delta Z = y_i \Delta b_i$

From this same equation:

Change in the electric energy (availability- b_i) = (2.65 x 0.25)   = 0.66

The dual price for the constraint (y_1)   = ₦59.11

Change for this constraint = (59.11x 0.66)   = ₦39.01

The change in the objective function (ΔZ) = (767.05- 39.01)   = ₦728.04/h

This represents about 5.09% reduction in the cost of energy used.

2. For multiple parameter changes

For this industry too, the same treatment applied and for 15% increase in energy consumption Figure 9 shows that the present values will be: electricity = 0.39, diesel= 0.36 and labor = 0.08. Therefore, the allowable increases are;

Electricity = 875.55, diesel = 366.92 and labor = 445.79

Therefore, dividing the increases over the allowable changes (increases);

$\sum r$ = 0.39/875.55 + 0.36/ 366.92 + 0.0.08/445.79

    = 0.0004 + 0.001 + 0.0002

    = 0.002

($\sum r < 1$)=   (0.002 < 1)

$\Delta Z = y_i \Delta b_i$ = 59.11 (0.39) + 162.29 (0.36) + 40.04(0.08)

        = 23.05 + 58.42 + 3.20 = 84.67

New Z   = 767.05 + 84.67 = ₦851.72/h

    1.   The increase in the cost of energy is 84.67/767.05 x100% = 11.04%.

The proposed changes will bring about change in objective function value increasing from (₦767.05/h) to (₦851.72/h). However, these increments will have no effect on the product output because the changes are within the allowable increase range.

Appendix C

$TPC = F + xQ$

From (21) (derivative of breakeven equation, TPC = yQ))

$F = yQ_1 - xQ_1$ (derivative)

The average output (Q_1) (Appendix C, Table 1e) during the previous year was 151 kg/h. Therefore;

$F + xQ1 = yQ1$ (The actual form of breakeven (21))

Substituting (the cost per 10 kg bag of flour ₦3000 (Table 3) was converted to the cost per kilogram (₦300/kg) to be consistent with the units thus, the fixed cost F was:

$F = Q1(y - x) = 151(300 - 149.31) = ₦22754.19$

And from (22) the unit costs of variables x was:

$x = u + m = 99.31 + 50 = ₦149.31$

The unit costs of energy sources and raw material (Table 3)

TPC = 22754.19 + 149.31 (151) = 45299.81

Energy contribution to production cost was (99.31 x151) = 14995.81

The percentage energy cost contribution to production, (23):

$= \frac{14995.81}{45299.81}$ x 100% = 33.10%

From cost optimization conducted output appreciated to (Q_2): 166 kg/h. Thus, the new product-selling price (y_2) based on the new output was calculated using (24), a derivative of breakeven equation as:

$y_2 = \frac{22754.19}{166} + 99.31 + 50 = ₦ 286.38 /kg$

Therefore for a 10 kg bag of maize flour the proposed selling price will be:

₦286.38 x 10 kg = ₦2863.80/bag.

This analysis showed a percentage reduction in price of 4.54%.