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Energy Cost Optimazation in the Production of Local Alcoholic Drink (*Burukutu*) Benue State of Nigeria

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ABSTRACT: *Optimization of the cost of energy in the production of local alcoholic beverage (Burukutu) in the sub Sahara region of Nigeria was carried out with the view conserving energy and maximizing profit. Data were obtained from six commercially viable Burukutu producing local government areas in Benue State of Nigeria. Minimization linear programming simplex method was used in evaluating cost of energy used in the production of the local beverage using TORA software and simplex algorithm written in visual basic language allocation to constraint with a view to reducing wastages and setting allocation limits within the available scarce energy resources in the study area. The optimal solutions were obtained after eleven iterations. It was observed that the minimum (optimal) value of energy required for production of Burukutu was 8.6MJ per 160.53 kg of Burukutu produced. Total observed thermal and liquid fuel energy was 3096.39MJ. Total reduction in the two energies was 3086.33MJ, resulting to 99.7%. The optimal value for the cost (minimum) was N5540.47, yielding a cost reduction of 67%. The result obtained in this work could form working tool for the Burukutu producers*
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KEYWORDS*: Cost, energy, drink, local beverage (Burukutu), optimization, sahara*

NOTATION

AVG. TIME = Average time for unit operations (Hour) C_{wf} = Cost of wood fuel consumed for a week (N/week)

C_{lfe} = Cost of liquid fuel per week (N/week) C_{we} = cost of wood fuel energy per week $\left(\frac{N}{week}\right)$

C_m = cost of manual labour (N/person/hour) C_{total} = total cost of energy for unit operation per week (N/week)

C_{lf} = cost of liquid fuel consumed for a week $\left(\frac{N}{week}\right)$

C_{me} = cost of manual energy for a week $\left(\frac{N}{week}\right)$

W_f = quantity of wood fuel consumed for a week $\left(\frac{Kg}{week}\right)$ L_f = quantity of liquid fuel consumed for a week (L /week)

N_p= number of persons required for unit operations x_4= Mashing (M)

x_1 = Steeping (st) x_5 = Filtering (Fl)

x_2 = Washing (W) x_6= Boiling (B)

x_3 = Grinding (Gr) x_7= Re-filtering (Re-Fl)

I. INTRODUCTION

Energy is an integral part of a society and plays a pivotal role in its socio-economic development by raising the standard of living and the quality of life. The state of economy of industry can be accessed from the pattern and consumption quality of its energy. Thus, energy is one of the most critical input resources in the manufacturing industries [1]. *Burukutu* production relies on energy to carry out the desired operations and obtain high processing efficiencies. Energy is primarily invested in various forms such as mechanical (human-labour), chemical (fossil fuel) and thermal (heat). The amount of energy used in *Burukutu* production is significantly high. The rising fuel cost and supply limitations plague every sector of Nigerian industry and these industries are now, more than ever before sensing the need for energy related research to reduce costs through energy conservation and prevent possible shut down consequent to reduced availability of energy resources [2]

Optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function [3]. Optimization has become a common phenomenon in almost all organizations and establishments. In developed countries managerial decisions are mostly based on the use of optimization techniques. In a profit seeking organizations, the Board of Directors has many things to tackle which may include, problem of other competitors in the same business, availability of funds for new capital projects, reduction of operational cost, high level of output and ultimately maximization of profit as explained by [4]. Optimization therefore is the process of seeking the best value, condition or solution to a problem subject to the given constraint. In optimization, a given system is described in terms of a mathematical model of the form of equation 1 [5].

Minimize $Z = \sum_{j=1}^{5} \sum_{i=1}^{4} c_{ij}\ x_{ij}$ (1)

Subject to the constraints as presented in equation 2:

$\sum a_{ij} x_{ij} \geq b$ (2)

Where: $c_{ij},\ a_{ij}$, are coefficients

x_i, that quantity of the variable i that produce the optimium value for the criterion,

b = the given limits or restrictions; i = the subareas and j = the sectorial allocations.

Linear Programming is a mathematical technique for generating and selecting the optimal or the best solution for a given objective function. It may be defined as a method of optimizing (i.e maximizing or minimizing) a linear function for a number of constraints stated in the form of linear equations. Let *m* denote the number of different kinds of resources that can be used and *n* denote the number of activities being considered, then, the mathematical model for the general problem of allocating resources to activities can be formulated as follows in equations 3, 4, 5, and 6 [6].

Maximize $Z = c_1 x_1 + c_2 x_2 + \cdots \ldots \ldots \ldots \ldots + c_n x_n$ (3)

Subject to the restrictions: $a_{11} x_1 + x_{12} \ldots \ldots \ldots \ldots \leq b_1$ (4)

$a_{12}\, x_2\, a_{22}\, x_2 + \ldots \ldots \ldots \ldots\, a_{2n}\, x_2 \leq b_2$ (5)

$x_1, x_2, x_n \geq 0$ (6)

The function being maximized $Z = c_1 x_1 + c_2 x_2 + \cdots + c_{nx}$ is called the objective function. The restrictions are normally referred to as constraints. The *m* constraints with function of all variables $a_{j1}\ x_1 + a_{2j}\ x_2 + \ldots \ldots \ldots\ a_{nj}\ x_n$ on the left hand side are called functional constraints, $x_j \geq 0$, j= 1, 2, 3… n, restrictions are called the non-negativity constraints [7].

In an attempt to address these problems there are two techniques of operation, the quantitative and the qualitative techniques that may be applied. Quantitative technique which is preferred involves modeling of a 'real form' problem into a mathematical form which can be solved to arrive at a solution that would aid the decision makers. Linear programming (LP) technique is such a quantitative technique which is a widely used mathematical modeling technique concerned with the efficient allocation of limited resources to known activities with the objective of meeting the desired goal [8]. A limited number of studies have been reported on the development of energy use models, [9, 10, 11, 12, 13, 14]. The computation of energy use were done using the spread sheet program on Microsoft Excel while optimization models were developed to minimize the total energy input into each production line. There is no known report of any work in the literature on the energy cost requirement in *Burukutu* production in Nigeria or elsewhere in the world. This study was undertaken to find the optimal energy cost required for the production of *Burukutu.*

II. MATERIALS AND METHOD

TORA Optimization System Windows version 2.00, 2007 was used in this study. The optimization problem is one requiring the determination of the optimal (minimum) value of a given function called the objective function, subject to a set of stated restrictions or constraints placed on the variables concerned.

2.1 Development of energy optimization model

The problem was formulated as a linear program problem. Only one program was considered. The program was based on total energy (T.E.) as the dependent variable and the seven unit operations of *Burukutu* production (steeping (St), grinding (Gr), washing (W), mashing (M), filtering (Fl), boiling (B) and re-filtering) as independent variables. The developed predictive model for production of *Burukutu* with respect to unit operations was used as the objective function.

Predictive model from regression for the production of *burukutu* is presented in equation 7:

$T.E. = -17.180 - (5.40 * St) + (11.523 * W) + (0.879 * Gr) - (9.818 * M) - (2.444 *) + (1.013 * B) - (0.150 * Re_{Fl})$

$(R^2 = 1.00)$ (7)

The coefficients of the predictive model were substituted in equation (7) to obtain the minimization linear program model. The formulated model was used to solve optimization problem in the study. The maximum available parameters were noted. This include: time, labour, manual energy, thermal energy, and liquid fuel energy which represent the constraints.
The Model Solutions stands as presented in equations 8, 9, 10, 11 and 12.
Minimize:

$$T.E. = 5.40x_1 + 11.523x_2 + 0.879x_3 + 9.818x_4 + 2.444x_5 + 1.013x_6 + 0.15x_7 \quad (8)$$

(8)

Subject to,

S/NO	Unit Operation	AVG. TIME	C_m	N_p	L_f	C_{lf}	W_f	C_{wf}	C_{me}	C_{lfe}	C_{we}	C_{total}
1	Steeping	1.28	100	2					256.00			256.00

Subject to,

1. $1.28x_1 + 1.50x_2 + 1.55x_3 + 1.54x_4 + 1.77x_5 + 27.36x_6 + 0.72x_7 \geq 40$ (9)
2. $2x_1 + x_2 + 2x_3 + 3x_4 + 2x_5 + 2x_6 + 2x_7 \geq 10$ (10)
3. $3030.94x_6 \geq 3035.02$ (11)
4. $65.45x_3 \geq 68.50$ (12)

And $x_1, x_2, x_3, x_4, x_5, x_6, x_7 \geq 0$

Where the respective constraints are as follows:

1. Time constraint: 40 hours available (8 hours/day in 5 days)
2. Labour constraint: 10 persons available (in 5 days)
3. Manual energy constraint: 167.40MJ available (in 5 days)
4. Thermal energy constraint: 3035.02MJ available (in 5 days)
5. Liquid fuel energy constraint: 68.50MJ available (in 5 days)

The cost optimization model was developed for the study. The model was based on the minimization of cost as an objective function and time required per hour for unit operations as decision variables. The cost required/ hour for each unit operation was used as the coefficient for the objective function. The constraints considered were, number of persons involved/hour $\left(\frac{N_i}{hr}\right)$, energy requirement in each unit operation per hour $\left(\frac{E}{hr}\right)$, liquid fuel per hour $\left(\frac{L}{hr}\right)$, wood fuel consumed per hour $\left(\frac{W}{hr}\right)$. For each of the constraints the maximum available number was stated. The data for this study is presented in Table 1 below.

Table 1: *Burukutu* production cost for the study

Source: Field Survey
The formulated cost model is given as
Minimize $100x_1 + 106.67x_2 + 248.06x_3 + 108.33x_4 + 95.83x_5 + 322.07x_6$
Subject to

1. $x_1 + x_2 + x_3 + 2x_4 + 2x_5 + 2x_6 + 2x_7 \geq 10$
2. $0.41x_1 + 0.39x_2 + 43.42x_3 + 0.64x_4 + 0.66x_5 + 111.55x_6 + 0.63x_7 \geq 8.86$
3. $0.97x_3 \geq 1.50$
4. $6.87x_6 \geq 110.0$

$x_1, x_2, x_3, x_4, x_5, x_6, x_7$

III. RESULTS AND ANALYSIS

The problem was solved using Tora Optimization system, windows version 2.00 and simplex algorithm software. Result of optimal solution of linear programming model for energy optimization energy for production of *Burukutu* is presented Table 2 and result of Sensitivity analysis are presented in Table 3. Mean result of production cost for the entire study is presented in Table 4.

Table 1 shows the energy optimal solution of the problem for the entire study. The optimal solution was achieved with 11 iterations or pivots and the solution given thus,

$x_1 = 0.0, x_2 = 0.0, x_3 = 1.05, x_4 = 0.0, x_5 = 0.0, x_6 = 7.84, x_7 = 0.0$

Therefore the final solution is

Minimize Z = 5.407(0.0) + 11.523(0.0) + 0.879(1.05) + 9.818(0.0) + 2.444(0.0) + 1.013(7.84) + 0.15 (0.0) = 8.86

The summary of the result is given in Table 2 below

TABLE 2: The Optimal Solution of Linear Programming Model for Energy Optimization of (*Burukutu*) Production

Variables	Solution Value	Objective Coefficient	Objective Value Contribution
x_1	0.0'0	5.41	0.00
x_2	0.00	11.52	0.00
x_3	1.05	0.88	0.92
x_4	0.00	9.82	0.00
x_5	0.00	2.44	0.00
x_6	7.84	1.01	7.94
x_7	0.00	0.15	0.00

Constraints	Right Hand Side (RHS)	Slacks-/Surplus+
1 (>)	40.00	176.19+
2 (>)	10.00	7.78+
3 (>)	167.40	0.00
4 (>)	3035.02	20734.77+
5 (>)	68.50	0.00

Source: TORA Optimization Systems Windows version 1.00, 2000-2002 Hamdy A. Taha (Tuesday, June 31, 2012 8:47 A.M.)All variables were greater than or equal to 0. It was observed that the values of ($x_1, x_2, x_3, x_4, x_5, x_6, x_7$) minimized the objective function and satisfied the constraints (1, 2, 3, 4, 5) as well as the default constraints $x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, x_4 \geq 0, x_5, x_6 \geq 0, x_7 \geq 0$. The minimum (optimum) value of the objective function Z was:

Z = 0.0879*(1.05) + 1.013 *(7.84) = 8.86 MJ; the values for ($x_1, x_2, x_3, x_4, x_5, x_6, x_7$) that minimized the objective and satisfied the constraints were;

$x_1 = 0.00, x_2 = 0.00, x_3 = 1.05, x_4 = 0.00, x_5 = 0.00, x_6 = 7.84, x_7 = 0.00.$

This implies that the unit thermal and liquid fuel energy required for the production of *Burukutu* was 7.84MJ and 1.05MJ respectively. The optimal value of thermal energy was therefore 7.94MJ, while that of liquid fuel energy was 0.0923MJ. Amount of thermal energy reduction was 3023.00MJ and that of liquid fuel energy was 65.36MJ of their observed values of 3030.94MJ and 65.45MJ respectively; therefore, total observed thermal and liquid fuel energy was 3096.39MJ. Total reduction in the two energies was3086.33MJ, resulting to 99.7% The non-zero variables x_3, x_5 are called basic variables. The contribution of each variable to the objective function is shown on the last column on the right hand side of the table. Variables x_3, x_6 contribute 0.92MJ and 7.94 MJ respectively. For every constraint, how much more resource was used from the available

resource capacity represented on (Table 2). As shown under title of ‘slack/surplus’, the entire amount of available resource were used over constraints 3 and 5. These two constrained 0.00 slacks/ surplus value indicating that the constraints were binding. Nevertheless, there were surplus resource capacities 176.19, 7.78, and 20734.77, MJ for constraints 1, 2 and 4 respectively. These constraints are non-binding. The values of constraints 1, 2, and 4 shows how close it is to satisfy a constraint as an inequality. Since this is a minimization problem the values are surplus values indicating that the resources were over consumed.
Sensitivity analysis using TORA and the result is given in Table 3 below

TABLE 3: Sensitivity Analysis of Objective Function’s Coefficient

Decision Variable	Current Objective Function	Minimum Objective Function	Maximum Objective Function	Reduced Cost
x_1	5.41	0.03	Infinity	-5.38
x_2	11.52	0.03	Infinity	-11.49
x_3	0.88	0.09	Infinity	0.00
x_4	9.82	0.05	Infinity	-9.77
x_5	2.44	0.06	Infinity	-2.39
x_6	1.01	0.00	7.03	0.00
x_7	0.15	0.02	Infinity	-0.13

Constraint	Current RHS	Minimum RHS	Maximum RHS	Dual Price
1 (>)	40.00	-infinity	216.19	0.00
2 (>)	10.00	-infinity	17.78	0.00
3 (>)	167.40	85.34	infinity	0.05
		-infinity	23769.79	0.00
		0.00	5202.98	0.01
4 (>)	3035.02			
5 (>)	68.50			

Source: TORA Optimization Systems Windows version 1.00, 2000-2002 Hamdy A. Taha (Tuesday, June 31, 2012 8:47 A.M.)Table 3 list the sensitivity analysis results on the change of objective coefficient. The intervals of objective function’s coefficient which do not affect the optimal solution are contained in the (Table 3). Change in optimal objective function value per unit increase of a corresponding variable currently at a value of zero. It is an estimate of how much the objective function will change if a zero-valued variable is made to become non-zero. Objective Coefficients is any coefficient change that is greater or less than these values will change the value of the optimum solution variables The reduced cost is a measure showing whether each individual variable has been exploited economically. For those values with zero values like x_3 *and* x_6 it means that the variables have been exploited to the highest potential while those with non- zero values like x_1, x_2, x_4, x_5, x_7 indicates that the variation is not exploited and that the associated objective function coefficient must be adjusted in order for the variable to be just profitable. For a minimization problem of this nature it means the amount by which the objective function would have to decrease before it would be possible for a corresponding variable to assume a positive value in the optimal solution. Table 3 shows the range of the Right Hand Side (RHS) Coefficients that maintains the current basic solution variables: any RHS change that is greater or less than these values will change the non-zero (basic) variable set. The values of the basic variables will change.The dual price for constraints 3 and 5 indicates the cost of changing the limitation of x_1 to x_7. If either of these limitations is changed by one unit, the total cost will change by 0.05, 0.01, i.e. these are the shadow prices.

TABLE 4: The Optimal Solution of Linear Programming Model for Cost Optimization of *Burukutu* Production

Variables	Solution Value	Objective Coefficient	Objective Value Contribution
x_1	0.0'0	100.00	0.00
x_2	0.00	106.67	0.00
x_3	1.55	248.06	383.60
x_4	0.00	108.33	0.00
x_5	0.00	95.83	0.00
x_6	16.01	322.07	5156.87
$\square_7$	0.00	58.33	0.00

Constraints	Right Hand Side (RHS)	Slacks-/Surplus+
1 (>)	10.00	23,57+
2 (>)	8.86	1844.38+
3 (>)	1.50	0.00
4 (>)	110.00	0.00

Source: TORA Optimization Systems Windows version 1.00, 2000-2002 Hamdy A. Taha (Tuesday, June 31, 2012 8:47 A.M.From Table 4, steeping, washing, mashing, filtering and grinding does not require much time. Grinding requires 1.55 hours while boiling requires 16.01 hours to arrive at the optimal solution (minimized cost of N5, 540.47).The reduced cost shows the amount by which the objective coefficient of the decision variables has to be improved in order to make their optimal values to be nonzero. The reduced cost for grinding and boiling operations was zero because their optimal values were nonzero.The surplus for constraint 1 is 23.57 while that of constraint 2 is 1844.38. This shows that less people may be employed for the production of *Burukutu*. Similarly, too much energy is expended in the production process. The surplus for constraints 3 and 4 is 0. Thus they are all binding.The dual price associated with a constraint is the improvement in the optimal value of the objective function per unit increase in the R.H.S. of the constant. The nonzero dual price N255.73 and N46.88 for constraints 3 and 4 implies that an additional liter of liquid fuel will improve the value of the objective function by N255.73 and additional Kg of wood fuel will improve the value of the objective function by N46.88. Thus, if the liquid fuel was increased by 2 liters, with all other coefficients in the problem remaining the same, the locations cost of production would increase by N255.73 from N5540.47.06 to N5796.20.

Since the number of persons required and the energy requirement both have surplus available, the dual prices of zero shows that additional units of these resources will not improve the value of the objective function.

IV. CONCLUSION AND RECOMMENDATION

Optimization technique was used to find the optimal solution to the linear model for the production of *Burukutu* in order to reduce energy requirement and cost. TORA optimization software was used. It was observed that the minimum (optimal) value of energy required for production of *Burukutu* was 8.6MJ per 160.53 kg of *Burukutu* produced. The optimal value of thermal energy was therefore 7.94MJ, while that of liquid fuel energy was 0.0923MJ. Amount of thermal energy reduction was 3023.00MJ and that of liquid fuel

energy was 65.36MJ of their observed values of 3030.94MJ and 65.45MJ respectively; therefore, total observed thermal and liquid fuel energy was 3096.39MJ. Total reduction in the two energies was3086.33MJ, resulting to 99.7%. The optimal value for the cost (minimum) was N5540.47, yielding a cost reduction of 67%. This implies that steeping, washing, mashing, filtering and grinding does not require much time. Grinding requires 1.55 hours while boiling requires 16.01 hours to arrive at the optimal solution (minimized cost of N5, 540.47)
The study revealed that wood fuel energy and thermal energy contributed to the energy optimal solution. This implies that much energy savings could be achieved reducing the energy consumption from boiling and grinding operations. Optimization of the current process would involve the use of an improved local stove that will effectively minimize the convective and radiative energy losses to the atmosphere. This simple improvement would greatly improve boiling efficiency. To optimize the manual energy consumption, it is recommended that the number of persons involved in the production should be carefully selected based on the work place. Too much time should not be wasted on a unit operation. It is also recommended that efficient grinding machines should be used to reduce the high consumption of liquid fuel.

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