Development of Equations for Estimating Energy Requirements in Processing Local Alcoholic Beverage (*Burukutu*) In Nigeria

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ABSTRACT

Determination of the energy consumption in the processing of local alcoholic beverage, *burukutu* in selected commercially viable six (6) local government areas in Benue state of Nigeria was conducted. Eighteen cases were randomly investigated within these locations. Mathematical expression was developed to evaluate the energy requirement for each of the seven (7) readily defined unit operations, namely steeping (St), grinding (Gr), washing (W), mashing (M), filtering (Fl), boiling (B) and re-filtering (Re-Fl). The equations were exploited to compute energy expenditure in the production using measured input data. Empirical equation was developed for each unit operation to relate energy requirement to red sorghum input in kg. The application test of the equations indicated that about 3122.90MJ was averagely needed to process about 150 kg of red sorghum in each location while energy requirement for each unit operation in each location was also estimated. Results showed no significant difference at 95% confidence level of the energy requirements for the 18 cases studied with respect to the identified unit process of production.

Keywords: Beverage, *burukutu*, development, energy equation, requirement, empirical.

I. Introduction

Energy audit is an important management tool required for economic utilization of energy resources in any manufacturing outfit. Inefficient energy utilization could lead to huge economic losses and energy is one of the most critical input resources in the manufacturing industry. Energy cost outweighs the cost of other resources such as raw materials, personnel, depreciation and maintenance. Excessive energy consumption adds to the cost of goods produced especially in energy intensive industries. Energy produced by crude oil has over the past five years contributed average of 13.5% of Nigeria's Gross Domestic Product (GDP), representing the highest contributor after crop production. Consequently, energy in Nigeria serves not only as a tradable commodity for earning of national income, but also as an input to the production of all goods and services as well as an instrument for politics, security and diplomacy.

The major energy issues in Nigeria include inefficient energy utilization and environmental concerns. Therefore, there is a need to understand the mechanisms which degrade the quality of energy and energy systems.

Burukutu production relies on energy to carry out the desired operations and obtain high processing efficiencies. Energy is primarily invested in *Buruku* production in various forms such as mechanical (human-labour), chemical (fossil fuel) and heat (wood fuel). The amount of energy used is significantly high in order to meet the demand for the expanding population, especially with the present high cost of factory manufactured beer.

In Nigeria, *Burukutu* is consumed in various festivals and ceremonies (marriage, birth, dowry and so on) and constitute a source of economic return for the women producers. The raw materials used in manufacturing the drink are produced in the tropical regions of Africa particularly in the Northern Guinea savanna areas of Nigeria [1, 2].

Currently the production of this local beer is increasing because of the high cost of factory beer as compared to the local alcoholic beverage, NGN300.00 to NGN40.00 (2 to 0.27 USD) respectively yet giving the same effect. This *Burukutu* has come to provide a lot of women with jobs, especially those living in rural and semi-urban areas. The annual growth rate in women employment in this enterprise is about 8 percent, while young girls and older women are keen on learning the trade. Many young girls learn it when helping their mothers in the local enterprise. Most Women in the business confirmed that the business is lucrative [3].

Burukutu is an alcoholic beverage drink that contains ethanol (commonly called alcohol). Alcoholic beverages are divided into three (3) general classes: beers, wines and spirits. Alcoholic beverages that have lower alcohol content (beer and wine) are produced by fermentation of sugar- or starch-containing plant materials. Beverages of higher alcohol content (spirits) are produced by fermentation followed by distillation. The major local alcoholic beverages produced in Nigeria are *Burukutu*, palmwine, pito, and Ogogoro. *Burukutu* beer is a traditional cereal-based fermented beverage. Cereals are important in many parts of the world as food sources, and starches from them differ in physicochemical properties and molecular structures

[5]. A majority of African traditional cereal-based food as shown in Table 1 are mainly processed by fermentation. Millet and sorghum are important cereal crops grown in Nigeria. The main chemical component of millet and sorghum grain is starch.

TABLE 1: FERMENTED CEREAL BASED FOODS

Cereal	Food	Class	Location
Sorghum	*Burukutu*	Alcoholic beverage	Northern part of Nigeria, Ghana
	Pito	Alcoholic beverage	Mid-western part of Nigeria
	Obiolor	Non-alcoholic beverage	Igala in Nigeria
	Ogi	Gruel	Nigeria
	Bogobe	Sorghum porridge	Botswana
	Kisra	Sorghum bread	Sudan
	Injera	Sorghum bread	Ethiopia
	Merrisa	Alcoholic drink	Sudan
	Ogi	Gruel	
Maize	*Kenkey*	Solid/dough	Nigeria
	*Burukutu**	Alcoholic beverage	Northern part of Nigeria
Millet	*Kunu-Zaki*	Non-alcoholic beverage	
	Bouza	Alcoholic beverage	Egypt and some
Wheat	*Kishk*	Hamma	Arabian countries
Barley	Beer	Alcoholic drink	Nigeria

Source: Mbajuika *et al.*, (2010)

The basic characteristics of *Burukutu* include a sour taste due to the presence of lactic acid, a pH of 3.3 to 3.5 and an opaque colour because of suspended solids and yeast. It contains vitamins, iron, manganese, magnesium, potassium and calcium and also contains about 26.7g of starch and 5.9g of protein per liter [7, 8]. The local beverage is known as *Techoukoutou* in Benin or Togo, *Dolo* in Burkina-Faso, *Pito* in Ghana, *Burukutu* or *Otika* in Nigeria, *Bilibili* in Tchad, *Mtama* in Tanzania, *Kigage* in Rwanda [9, 10, 12, and14].

The manufacturing processes are very variable and dependent on the geographical location. Generally the production process of cereals involves, malting, steeping, germination, milling, mashing, boiling, fermentation and maturation [15]. Figure 1 presents the flow sheet for traditional production of *Burukutu.*

In traditional *Burukutu* production, the three stone open fire is used to boil the mash, with fuel wood (from biomass energy). In view of the huge amount of wood fuel required in most cottage industries in Nigeria, the increasing energy demand coupled with the finite energy resources, the rising cost of fossil fuel, deforestation and its attendant environmental impacts necessitate an understanding into energy requirements of *Burukutu* production industry.

There is therefore no known report of any work in the literature on the energy requirement in *Burukutu* production in Nigeria or elsewhere in the world.

The aim of this study is to develop an energy use equation which can assess energy requirements of all processing operations in *Burukutu* production as practiced in the middle belt region of Nigeria with specific study area of Benue State.

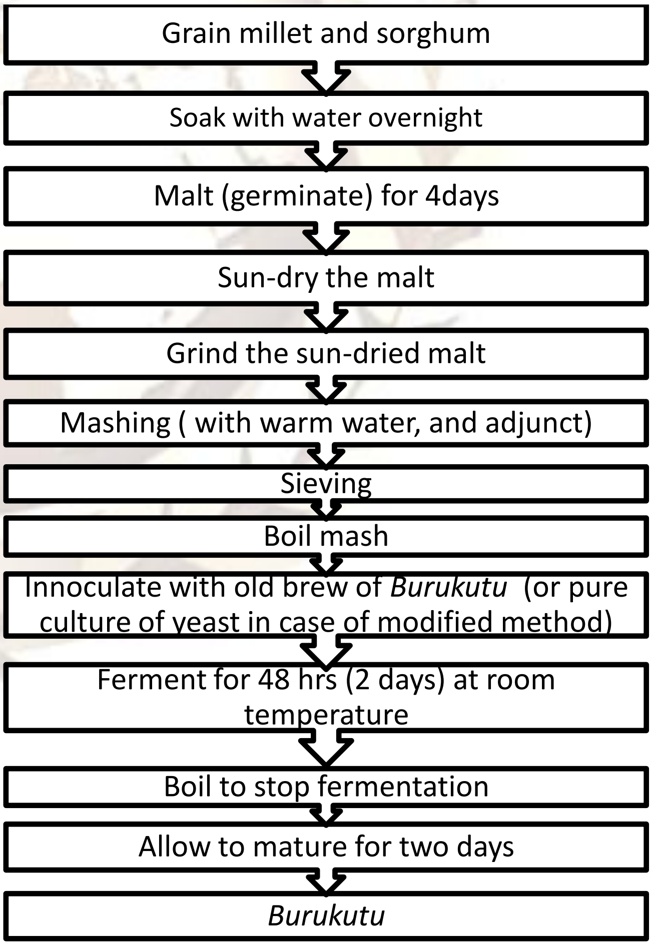

Figure 1: Flow Sheet for the Traditional Production of *Burukutu*, from sorghum grains (red varieties)

II. Study Area and *Burukutu* Production

The study was carried out in Benue state in the middle belt region of Nigeria which is one of the major producers of *Burukutu* beer in Nigeria. Six local governments (locations) were selected randomly for the study. Each local government was made up of three randomly selected case areas (sites) of *Burukutu* processing industries. A total of eighteen sites were used for the study which were Buruku (Abwa, Tyowanye 1, Tyowanye 2); Gboko (Tse-Kucha, Gboko 1, Gboko 2); Makurdi (North bank, Wurukum 1, Wurukum 2); Katsina-Ala (Katssina-Ala 1, Katsina-Ala 2, Katsina-Ala3); Oju (Oju 1, Oju 2, Oju3); Vandeikya (Vandeikya 1, Vandeikya 2, Vandeikya 3).

Burukutu beer was prepared by the skilled producers in each of these 18 sites. The process raw materials input for different sites are presented in Table 2.

TABLE 2: RAW MATERIALS (RED SORGHUM) INPUT FOR DIFFERENT LOCATIONS OF STUDY

Locations	Case 1 Raw Material Input (Kg)	Case 2 Raw Material Input (Kg)	Case 3 Raw Material Input (Kg)
Location 1 Buruku	125	150	150
Location 2 Gboko	150	150	290
Location 3 Makurdi	110	250	100
Location 4 Katsina-Ala	100	125	250
Location 5 Oju	160	95	120
Location 6 Vandeikya	165	285	115

III. Development of Energy Equations

At each stage of unit operation, some level of energy input was required in the form of manual, thermal and fossil fuels. The type and magnitude of the energy input is a function of the technology employed as well as the quantity of *burukutu* being processed. To compute these energy demands, quantitative data on operating conditions for each unit operation were measured (Table 3).

TABLE 3: MEASURED PARAMETERS IN EVALUATING ENERGY INPUT DATA

S/No.	Operations	Required parameters
1	Steeping	Time taken for steeping (h) Number of persons hundred in steeping (N)
2	Washing	Time taken for washing (h) Number of persons involved in washing (N)
3	Grinding	Time taken for grinding (h) Number of persons involved (N) Quantity of fuel used for grinding (L)
4	Mashing	Time taken for washing (h) Number of persons involved in washing (N)
5	Filtering	Time taken for washing (h) Number of persons involved in filtering (N)
6	Boiling	Time taken for boiling (h) Quantity of wood fuel used (kg) Number of persons involved (N)
7	Re-filtering	Number of persons involved in re-filtering(N) Time taken for re-filtering (h)

From the observed operating conditions for all the unit operations in *Burukutu* production, it was concluded that energy demand for operations utilizing fuel to run internal combustion engine, is directly proportional to the quantity of fuel used (W), $E \propto W$, equation 1 [20,21, 22].

$E = C_f W$ (MJ) (1)

Where, C_f, is the constant of proportionality which represents the calorific value (heating value) of fuel used. Similarly fossil fuel energy input was calculated using the expression in equation 2.

$E_{FLD} = 47.8D, (MJ)$ (2)

47.8 = Unit energy value of diesel, MJL^{-1}

D = Amount of diesel fuel consumed per unit operation, (liter)

For Petrol, $MJ\ E_{LLP=} 42.3p\ (MJ$ (3)

Where E_{LLP} = liquid fuel energy input for petrol, MJ 42.3 = Unit value of petrol,

$MJL^{-}P$ = Amount of petrol consumed per unit operation, (liter).

Manual energy estimation can be computed based on the value recommended by Odigboh. For any unit operation the manual energy expenditure is calculated using the expression of equation 4 [25, 26]

$E_{m=} 0.075N.T_a\ (Kw)$ (4)

Where 0.075 = the average power of a normal human labour in kW; N = number of person involved in the operation; and T_a = useful time spent to accomplish a given task (operation), h. To perform any of the unit operation wood fuel, liquid fuel, or manual energy is used. It is possible to use a combination of two. The evaluation method for each unit operation follows:

3.1 Steeping

Manual energy was involved in steeping. The energy required for steeping operation was computed using the expression:

$E_s = 3.6\ (0.075 N_s\ t_s\ )$ (4)

3.2 Washing

Manual Energy was involved in washing. The washing operation was computed using the expression:

$Ew = 3.6(0.075NwTw)$ (2)

3.3 Grinding

Both manual and energy from liquid fuel was involved in grinding operation. The energy required for grinding E_g (MJ) was evaluated from the expression:

$E_g = W_g C_g + 3.6(0.075 N_g T_g)$ (5)

3.4 Mashing

Mashing was done manually with hands. The energy required for mashing was computed from the expression:

$Em = 3.6(0.075 N_m\ T_m)$ (6)

3.5 Filtering

Filtering was done manually. The energy required for filtering operation was evaluated using the expression:

$E_f = 3.6(0.075 N_f T_f)$ (7)

3.6 Boiling

Manual and wood fuel energy was involved in boiling. The energy required for boiling was obtained from the expression:

$E_b = W_b C_b + 3.6(0.075 N_b T_b)$ (8)

3.7 Re-filtering

Manual energy was involved in Re-filtering. The energy required for re-filtering operation was obtained from the expression:

$E_r = 3.6(0.75 T_r T_r)$ (9)

3.8 Total Energy

The total energy expended in producing a given quantity of *Burukutu* evaluated by summing up all the energy components involved in the process.

Thus the total energy, E_T, becomes

$$E_T = E_s + E_w + E_g + E_m + E_i + E_b + E_r \quad (10)$$

Equation (10) was used to determine the total energy required in the industry producing *Burukutu* at a given production rate. For the *Burukutu* mills under study, the determination of energy use was done using Microsoft Excel. The data obtained from the computations were further employed to generate equations relating energy requirement and red sorghum grains input for different unit operations.

IV. Results of Application Test of Equations

Result of Analysis of variation (ANOVA) at 5% significant difference was conducted for the 18 cases which make up the locations of study for the energy requirement and the different unit operations for the production of the local alcoholic beverage as presented in Table 4. There was no significant difference in the energy requirements for all the 18 cases for at 95% confidence level implying that the system has been standardized. The mean values therefore became consequential to be employed for analysis. The results of application tests of the developed equations using mean value of red sorghum input in the study area are presented in Figure 2. Table 5 presents regression equations relating energy consumption to red sorghum input for each unit operation in the study area.

Table 4: ANOVA of *Burukutu* Production Sites

Rows	599483.5	17	35263.74	1.121219	0.344688	1.723833
Columns	1.43E+08	6	23753584	755.2512	3.96E-82	2.188761
Error	3208026	102	31451.24			
Total	1.46E+08	125				

Ho: F ≤ F Critical **α = 0.05**

Ha: F > F Critical

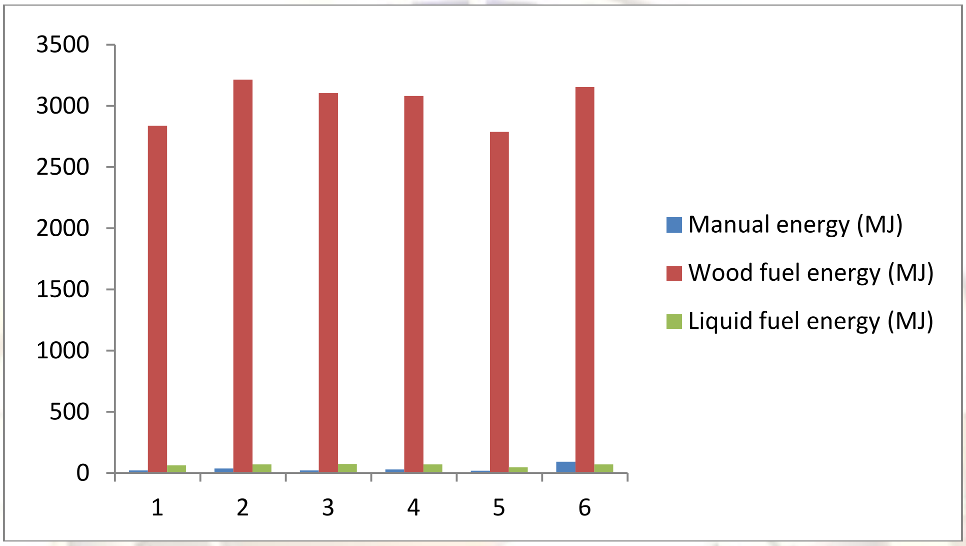

Figure 2: Mean Energy Types and Consumption Levels for *Burukutu* Production in the Study Area

Table 5: Model equations for energy requirements and raw material input for location 4 (mean case material input - 160.53kg)

Energy Requirement (Unit Operations)	Mean Cases	Model Equations	R^2 Value
Steeping	Case 1, 2, 3	$Y = 0.47x - 0.2833$	0.8515
Washing	Case 1, 2 ,3	$Y = 0.46x - 0.3267$	0.7906
Grinding	Case 1, 2, 3	$Y = 43.235x + 10.1$	0.7624
Mashing	Case 1, 2, 3	$Y = 0.3x + 0.32$	0.8242
Filtering	Case 1, 2, 3	$Y = 0.46x + 0.14$	0.8758
Boiling	Case 1, 2, 3	$Y = 585.32x + 1931$	0.8285
Re-filtering	Case 1, 2,	$Y = 0.28x - 0.0667$	0.8906

The R^2 for the estimated regression in all cases considered are greater than 0.7 showing that red sorghum mostly influenced the quantity of energy consumption assuming that all factors are constant. The results so far discussed emphasize the usefulness of the development of energy use profiles in the study area. Figure 2, shows that wood fuel energy was the most used energy source, followed by liquid fuel energy and manual energy.

V. Conclusion

1. A study was conducted in 18 *Burukutu* production areas in the Middle Belt Region of Nigeria to develop a set of spreadsheet equations that were capable of estimating energy requirements in each of the processing operations involved in processing *Burukutu.*
2. The results of application test of the developed equations show an average energy consumption of 3122.MJ.
3. The study has provided the basis upon which optimization of energy consumption of *Burukutu* can be carried out. The equations developed have provided fundamental information for carrying out budgeting and expansion planning, and predicting energy requirement in *Burukutu* production industries.

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