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Energy Use Patterns of Local Gari Production Industries in North Central Nigeria

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ABSTRACT: A study on the energy use pattern of local gari production process was carried out in some states of North Central Nigeria. Nine cases were randomly investigated within three locations. Three types energy utilization (manual, liquid fuel and wood fuel energy) in addition to unit operations were identified. Energy, time, and number of persons and mass/material data were collected and computed. The energy consumption pattern of the unit operations were evaluated for the production of 1000kg gari. It was observed that six unit operations were required for gari production process. The ANOVA showed no significant difference at 95% confidence level of the energy requirements for all the 9 cases studied with respect to the identified unit process of production. The mean total energy consumption was found to be 1853.82 MJ. The most intensive operation was frying, which accounts for 82.8 % of the total energy for the gari production process. An improved local stove for energy conservation is recommended. Energy conservation and optimization of the process is therefore suggested.

KEYWORDS: Energy, Pattern, local, Gari, Industries, Unit process, Nigeria.

I INTRODUCTION

The food industry is one of the energy-intensive industries and lacks information on energy conservation and conversion technologies (Wang, 2009). Economic growth and development of any nation relies greatly on energy availability, management and conservation (Jesuleye 1999 and Ibrahim *et al*., 2013). Energy efficiency practices and products will reduce cost of production and consequently results in lower selling prices of the products (Akinoso and Olatoye 2013). Energy efficiencies in food processing facilities vary with end users and production lines. Procedural and behavioural changes that include avoiding wastages can save about 30% energy without capital investment (Fischer *et al*., 2007).

Energy efficiency and environmental protection have attracted increasing attention in the food industry. Effective energy utilization and energy source management in food processing facilities are desirable for reducing processing costs, conserving non-renewable energy resources, and reducing environmental impact. In recent time, there has been a greater awareness of the energy problems facing the world than at any other period in history (Wang, 2009). It is now widely accepted that the current rate of energy generation and supply cannot match the rapid growth in energy consumption rate (Aiyedun *et al*., 2008). The importance of energy in sustained economic development is a well accepted fact. Energy of different forms and quantity are required to carry out each unit operation involved in *Gari* production. These include liquid fuel, wood fuel, and manual (human) energies. Profiling energy utilization data and developing energy conservation processing methods will improve sustainability in the food processing industry (Mohammed, 2009).

Available literature on estimation of energy input in food processing include some reported work on energy utilization in food industry such as bread baking (Jekayinfa, 2007), cassava products processing operations (Jekayinfa and Olajide, 2007), palm-kernel oil processing operations (Jekayinfa and Bamgboye, 2007), bread making processes (Le-bail *et al*., 2010), sugar production factory (Abubakar *et al*., 2010), and cashew nut processing mills (Atul *et al*., 2010). Conversion of cassava tubers into *gari* requires quantifiable magnitudes and different forms of energy that includes

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wood fuel, fossil fuel and manual energies Therefore, the objective of this study was to determine energy use pattern of the established three local cassava *gari* processing methods.

II MATERIALS AND METHODS

2.1 Survey areas

Nine processing mills used for this survey are located in three Local Government Areas situated in Niger and Nassarawa States in Nigeria. These States are located in the North Central of Nigeria. The mills were randomly selected for the conduction of the study because they are commercially viable.

2.2 Data collection

Data was collected by on-site study of all unit operations in the industries, and oral interview of processors and their workers. An inventory of number of persons involved (N), time required for production (h), quantity of fuel used (L), and quantity of wood fuel used (kg) and material flow for the seven readily defined unit operations was made. Data of required parameters for the evaluation the energy input in Gari production was then compiled for all the cases. The calorific value of wood fuel used was 16.6MJ/Kg (air dry, dry zone) while the calorific value of fuel used was 47.8 MJ/L for diesel for the processing of 1000Kg of cassava tubers. Other relevant information was also sought at the sites.

2.3 Data Analysis

From the data collected, the following procedural steps were taken to get them analyzed and presented in the required forms:

- Energy types (manual, liquid fuel and wood fuel) were identified and collated
- The percentage breakdown of total consumption of energy type was calculated.
- Tables were prepared for each section showing total consumption for each energy type.

2.4 Energy consumption

The energy components from each source were calculated for 1,000 kg of cassava tubers by using the following procedure:

2.4.1 Manual energy input

Manual energy estimation can be computed based on the value recommended by Odigboh (1999). According to Odigboh (1999) at the maximum continuous energy consumption rate 0.30KW and conversion efficiency of 25% the physical power output of a normal human labour in the tropical climates is approximately 0.075KW sustained for an 8 – 10 hour working day; all other factors affecting manual energy expenditure were found insignificantly and therefore neglected. To determine the manual energy for a given operation, the time spent by the worker on ach operation was recorded. These include the intermittent resting periods. For any unit operation the manual energy expenditure is as in equation 1 (Odigboh 1999).

$$E_{m} = 0.075N.T_a \quad (Kwh) \qquad (1)$$

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.

2.4.2 Wood Fuel Energy Input

The wood fuel energy was estimated by measuring the amount of log that was consumed by the process, The wood fuel energy consumption E_w is estimated from W, the amount of firewood used and C_k, the heating value of the wood using the following relationship: $E_w \alpha W$, (Odigboh, 1997)

$$E_w = C_f W \quad (MJ) \qquad (2)$$

where, C_f, is the constant of proportionality which represents the calorific value (heating value) of fuel used.

2.4.3 Fossil fuel energy input

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The total quantity of energy consumed from fossil fuel (diesel and petrol) was estimated by multiplying the quantity of fuel consumed by its lower heating value, thus, (Rajput, 2001)

$$E_{FLD} = 47.8D, (MJ) \qquad (3)$$

Where E_{FLD} = liquid fuel energy input for diesel, MJ 47.8 = Unit energy value of diesel, MJL^{-1}
D = Amount of diesel fuel consumed per unit operation, (liter) (Pimentel, 1992)

For Petrol, MJ $E_{LLP} = 42.3p\ (MJ)$ (4)

Where E_{LLP} = liquid fuel energy input for petrol, MJ 42.3 = Unit value of petrol,
P = Amount of petrol consumed per unit operation, (liter).

2.4.4 Total Energy input

The total energy expended in producing Gari locally in each mill was evaluated by summing up all the energy components involved in the process.
Thus the total energy was computed using the following expression

$$E_T = E_p + E_w + E_g + E_d + E_s + E_f + E_r$$

III RESULT

3.1 Energy Requirement for Production of *Gari*

The average energy requirement at different stages of *Gari*, production process in all the three locations investigated is presented in Table 1. These represent the energy consumption pattern for the production of *Gari*. From this study in all the three locations investigated, wood fuel energy was the most used energy source, followed by liquid fuel energy and manual energy. This shows that all the mills extensively use wood fuel for operation. Almost 82.50% of the average total average in all the three locations was obtained from wood fuel source, followed by 14.40% and 3.10% from fuel and manual energy sources respectively. This clearly indicates that most of the tedious operation involved in *Gari* production were performed by heating and use of liquid fuel, with over 80% of the energy consumption attributed to the use wood fuel combustion, over 14% of the energy consumption attributed to the use of internal combustion engine powered grinding mill.

The average energy source for frying (1536.32MJ) was the highest accounting for 82.8% of the total energy consumption. This was followed by grating (268.81MJ, 14.5%), peeling (27.67MJ, 1.4%), washing (9.48MJ, 0.5%), sieving (7.96MJ, 0.43%), re-sieving (2.56MJ, 0.08%), dewatering (1.69MJ, 0.08%). Conclusively the average energy required for processing 1000kg mean raw material input into *Gari* was 1853.82MJ to get an average of 255Kg of gari. This is shown energy flow diagram in figure 1. The predictive model equation energy requirement and unit process for the production of *Gari* is given in table 2.

Table 1: Mean Time and Energy Requirement for the Production of *Gari* in North Central Region of Nigeria

S/N	Process	Time (h)	Manual (MJ)	Liquid fuel (MJ)	Wood fuel (MJ)	Total energy (MJ)	Percentage
1	Peeling	19.01	27.67			27.67	1.40
2	Washing	8.70	9.48			9.48	0.50
3	Grating	1.57	0.83	267.98		268.81	14.50
4	Dewatering	2.25	1.69			1.69	0.08
5	Sieving	2.83	7.96			7.96	0.43
6	Frying	4.0	9.93		1526.39	1536.32	82.80
7	Re-sieving	3.02	2.56			2.56	0.13
	Total	**41.31**	**59.45**	**267.98**	**1526.39**	**1853.82**	**100.0**
	Total %		**3.10**	**14.40**	**82.50**	**100.0**	

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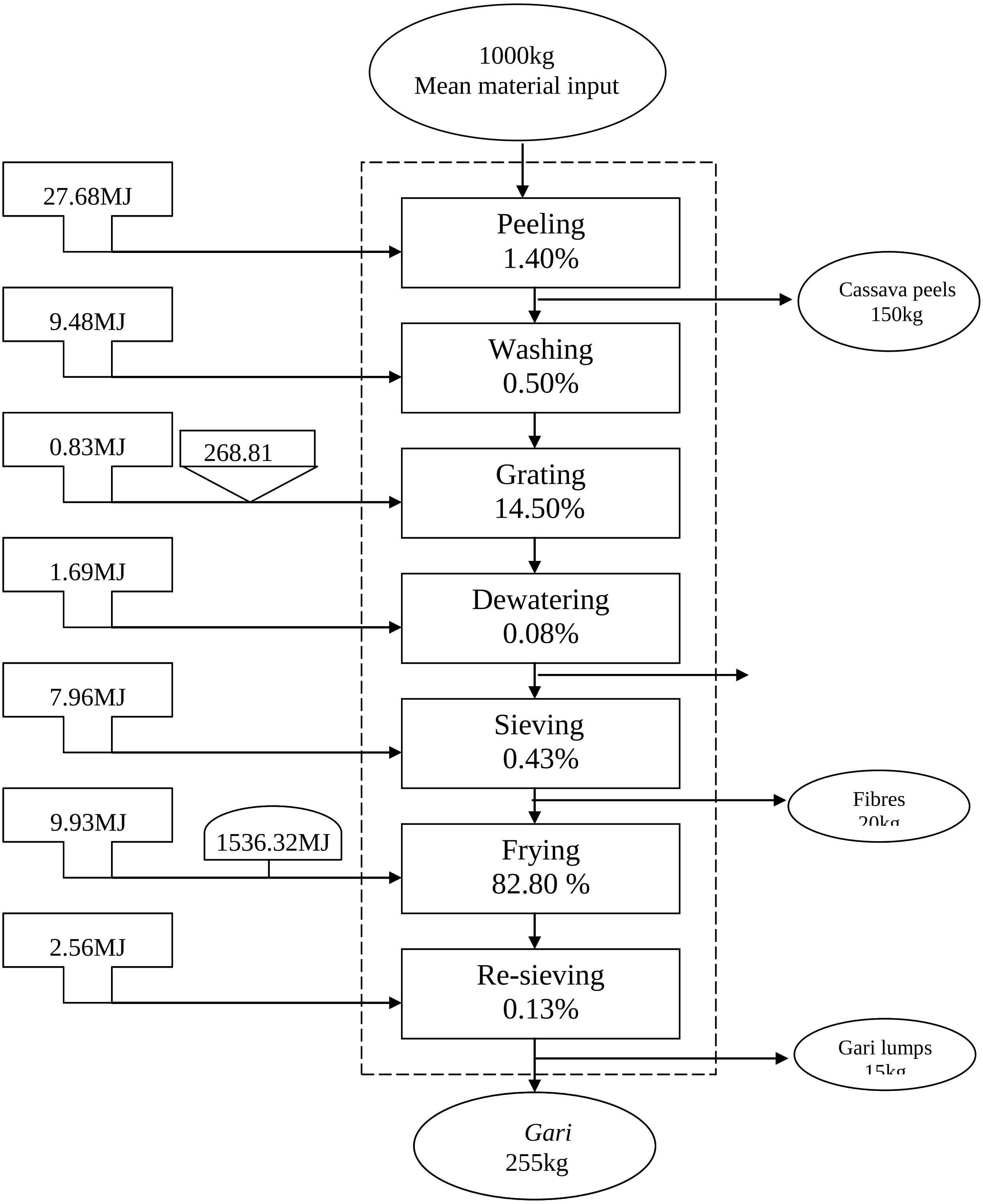

Figure 1: Energy flow Diagram in the local *Gari* Producing mill

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TABLE 2: PREDICTIVE MODEL EQUATIONS FOR ENERGY REQUIREMENTS AND UNIT PROCESS FOR THE PRODUCTION OF *GARI*

Unit Operation and Energy Model Equations	R^2
$T.E = -165.933 + (10.911 * P) - (113.229 * W) + (0.961 * G) + (238.653 * D) - (47.126 * S) + (1.375 * F) + (173.405 * R)$	0.99

Source: Regression Analysis output of Microsoft excel 2007 (Monday, July 22, 2013, 8:46:00 PM (Appendix V).
Where;
$T.E.$ = Total Energy Requirement in MJ;
P = Peeling (MJ);
W = Washing;
G = Grating;
D = Dewatering;
S = Sieving;
F = Frying;
R = Re-sieving;

IV CONCLUSION

The energy consumption pattern of local processing methods of cassava *Gari* in North Central Nigeria was examined. Seven defined unit operations were established for the production of cassava *Gari*. Manual, wood fuel and liquid fuel energy were the main source of energy input in local *Gari* industries. The main source of energy input for *Gari* processing operations done locally was wood fuel which accounted for 82.50% (1526.39MJ) of the total energy.
The study suggested that methods for improving the sustainability of the overall process should be investigated these include: the incorporation of improved local stove or the use of charcoal as fuel which would minimize the amount of firewood used. Insulating the frying pot in order to reduce the thermal losses to the atmosphere through convection is another method of energy saving strategy.

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