International Journal of Engineering Innovation & Research
Volume 4, Issue 5, ISSN: 2277 – 5668

Energy Analysis of Local Rice Processing in Benue State, Nigeria

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***Abstract* – The study examined the energy required in local rice milling process in three towns within Benue State, Nigeria. Three locations were randomly chosen in each town resulting in nine cases that were considered. Well-designed questionnaires were used for data collection. The types of energy utilization (manual, wood fuel and liquid fuel) as well as unit operations (parboiling, sun drying and milling) were identified. The energy analysis was evaluated for 1000 kg of processed rice. Result of the ANOVA showed no significant difference at 95% confidence level of all the nine cases studied. The mean value of the total energy requirement was 6639.87 MJ. The most intensive operation was parboiling, which accounts for 89.86% of the total energy required. The highest energy intensity of 8.0 MJ/kg was recorded in Otukpo. The average energy per unit product was 6.8 MJ/kg. The average productivity per unit energy is 0.15 kg/MJ.**

***Keywords* – Average Productivity, Energy Analysis, Energy Efficiency, Energy Requirement, Local Rice Processing, Questionnaires, Unit Operations.**

I. Introduction

Rice is the second most important cereal in the world after wheat in terms of production [1], [2]. Nigeria ranks the highest as both producer and consumer of rice in the West Africa sub-region [1]. In recent years, there has been an evolution of mechanized farm operations in Nigeria. Small-scale cottage agro based industries are springing up [2]. Some of these agro based industries include; rice mills, feed mills hatcheries and modern poultry. These establishments make use of energy in various forms for their operations. However, for these systems to obtain maximum performance, the production cost must be reduced. This can only be achieved by continuously monitoring the management of energy inputs and making sure that wastage is minimized or eliminated entirely [3].

Energy is an essential input in the growth and development of the various sectors of an economy. Rice mill consumes large amount of energy in form of manual, thermal and electrical. Rice milling in Nigeria is mainly carried out by small-scale machines with an average hourly capacity of 200 kg [4]. According to [3], data on energy use in rice milling in Nigeria are not enough. Few researchers have conducted studies on energy consumption in rice milling operation:

A study of energy utilization and environmental aspects of the rice processing industries in Bangladesh [5] showed that rice husk, a milling by-product of rice, is used as a source of thermal energy to produce steam for parboiling of raw rice. The demand of energy for rice processing increases every year, they concluded that energy conservation in rice processing industries would be a viable option to reduce the intensity of energy by increasing the efficiency of rice processing systems which leads to a reduction in emissions and an increased supply of rice husk energy to other sectors as well.

The energy used for milling rice in Lafia, Nigeria was examined using a sample of 50 randomly selected rice mills [3]. Simple descriptive statistics, production function analysis and correlation analysis were used for data analysis. The result shows that the average total energy used daily for rice milling was 2427.44 MJ/mill with diesel energy having the largest share (54.66%) of the average total daily energy used. Furthermore, to mill a bag of paddy about 211.06 MJ of energy was required. The energy productivity was 0.37 MJ/mill. Diesel and paddy were the most significant inputs that influenced the output of milled rice. Rice milling in the research area was observed to be dependent on direct and non-renewable energy forms especially diesel. He recommended the development of cleaner and safer energy forms such as solar energy for rice milling in the study area.

Energy use pattern in medium- and small-scale rice parboiling outfits was studied using five set of parboilers in the upper Benue River basin in Adamawa State, Nigeria [6]. Three small rural parboilers and two medium-scale suburban parboilers were used for the study. Questionnaire was used to gather data, along with inspection of the firewood sizes and the stove used. Data gathering from the two medium-scale suburban parboilers involved on-site study. Two energy parameters involved in rice parboiling are human energy and thermal energy. Thermal energy comes entirely from firewood. The human energy use per kilogram of parboiled paddy was higher for the rural small-scale parboiling process than for the medium-scale parboilers. Energy use of the medium-scale parboilers was higher if they did not make use of the charcoal left after the complete combustion of the firewood. One of the reasons for this was the energy losses to the atmosphere, which were apparently very high for the medium-scale parboilers. The convection current through the stove was much higher for the small rural parboilers, leading to higher convection losses. The study reveals the need for optimized energy use for rice parboiling and it shows that in order for rural rice processing to be sustainable, energy sources must be carefully considered and the concept of recycling of fuel biomass should be integrated into the process. The objectives of this work were to determine the energy use pattern in rice processing industries and energy requirement of each and the entire study and the productivity of energy input in the processing mills.

II. Materials and Methods

The main materials used for the study were well-designed questionnaires, stopwatch for measuring the production time, 20 liters tank used for measuring the quantity of fuel consumed in the mill and weighing bridge machine used for measuring the weight of firewood. The study was conducted in Makurdi, Aliade and Otukpo rice mills in Benue state, Nigeria. Three cases were selected for each town, making a total of 9 cases. The three main unit operations in rice mill processing considered were parboiling, spreading for sun drying and the milling. Fig. 1 shows the flowchart of the unit processes for rice milling operation generally.

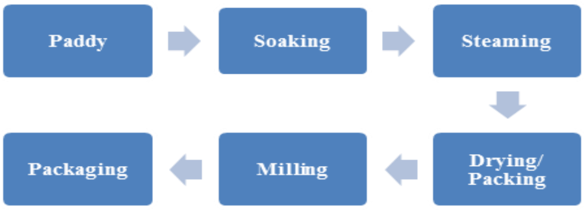

Fig.1. Flow chart showing the unit process for rice milling operation

The parboiling process is the partial boiling of rough rice (paddy) using wood fuel energy. The quantity of the wood fuel fed into the local stove specially constructed for parboiling purposes was measured directly by a weighing balance. The quantity of the paddy parboiled in a batch was recorded from the register of the rice mill.

Drying is the removal of moisture from parboiled paddy. The drying operation is mainly done on the floor under direct sunlight radiation for a period of 2 (two) days in the dry season which runs from 10:00-16:00hrs. And in the raining season an estimation of three to four days interval which also through the same time interval.. The drying process requires appreciable amount of manual energy for the reduction of moisture from the paddy through continuous spreading. The initial moisture content after parboiling was 32% and after drying the moisture content runs down to about14%. The number of persons involved in the operation was noted.

After drying, the paddy is milled to get rice grains using a Huller Miller ZS1110NM Techno for rice milling in all the locations. The amount of rice husk obtained is termed negligible in weight and otherwise. The energy used in the operation is either a fuel (diesel) or electrical energy in the part of the milling machine and manual energy in the part of the operator. Though some milling machines do combine both the diesel fuel and electrical energy, but in the course of our case studies, only the diesel fuel milling machines were in operation. The time taken to complete the milling of 1000 kg of paddy was noted, and the number of personnel involved in the milling operation was equally noted. The quantity of fuel used was recorded accordingly.

The data was analyzed to determine the efficiency of energy use in each location. Energy indicators employed include Energy Intensity (EI) and Energy Productivity (EP). The data was collected through a well-structured questionnaire. Types of energy sources used in the plants were identified to be manual, wood fuel and liquid fuel, and the amount consumed was recorded for each section. The energy type total consumption in relation to their percentage breakdown was also calculated.

Manual, wood fuel and liquid fuel were estimated during rice processing. The manual was estimated based on the time spent on working on the process. The wood fuel was estimated by measuring the amount of log (wood) in kg that was consumed by the process. While liquid fuel was estimated by measuring the amount of fuel in liters that was consumed by the process. The different unit operations of local rice processing were critically analyzed to determine the energy consumption from different sources.

The energy components (wood fuel, manual, liquid fuel) for the processing of each unit operation in local rice processing were calculated for the processing of 1000 kg paddy. The wood fuel energy E_W is estimated from W the amount of wood fuel used and C_w the heating value of log wood using the following relationship as given in equations 1 and 2 [8], [9].

$$E \propto W \qquad (1)$$

$$E_W = W C_w \ (MJ) \qquad (2)$$

where heat capacity of wood fuel C_w = 1720 J/kg [7], [8].

Manual energy was estimated using estimated using the values recommended by [7], [8], [10]. Normal human labour in the tropical climates is approximately 0.075 kW sustained for 8-10 hours workday with a continuous energy consumption rate of 0.3 kW and conversion efficiency of 25%. All other factors affecting manual energy expenditure were found insignificant and therefore neglected. Mathematically, this is given in equation 3 [8], [9].

$$E_m = 0.075NT \ (kWh) \qquad (3)$$

Energy consumed from fossil fuel (diesel) was estimated by multiplying the quantity of fuel consumed by its lower calorific value, mathematically as given in equation 4 [10].

$$E_f = 4.8D \ (MJ) \qquad (4)$$

where E_f = liquid fuel energy input for diesel **(**MJ**)** and D= quantity of liquid fuel consumed per unit operation **(**l**)**.

All the experimental procedure was carried out repeatedly. The mean values in respect to the various unit energies were recorded. The data for the energies of the three cases were subjected to two way analysis of variance (ANOVA) to test for significant difference.

III. Results and Discussion

Analysis of variance (ANOVA) at 5% significant difference was conducted for the 9 cases of local rice paddy processing in three towns of Benue State of Nigeria. There was no significant difference in the energy requirement for all the cases at 95% confidence level implying that the system has been standardized as shown in Table 1. The mean values of the cases were then considered for energy analysis.

The mean energy requirement at different stages of rice processing is presented in Table 2 and represented in energy flow diagram in Fig. 2. While the mean energy types and consumption level is shown in Fig. 3. The wood fuel energy took the lead in energy consumption throughout the nine (9) cases studied.

As in Table 2 and Fig. 2 the energy requirement data obtained provides useful information on the sources of energy needed for each processing unit. The mean energy required for processing 1000kg of paddy is (6639.87 MJ), wood fuel energy was extensively used (5955.56 MJ) 89.69%, followed by liquid fuel (654.22 MJ) 9.85% while manual energy consumed (30.09 MJ) 0.45%. Finally, 6639.87 MJ is the mean energy input required to process a paddy into rice grain output of 1000 kg. Since wood fuel energy consumed above 80% of the average required energy in a local rice mill, it implies that majority of the work is being done in the parboiling unit by the wood fuel. The indicator gives the energy consumption per unit product. The highest energy intensity of 8.0 MJ/kg was recorded in Otukpo, followed by 7.4 MJ/kg in Makurdi and 7.2 MJ/kg in Aliade as represented in Table 3. The variation was because the system is localized. The average energy per unit product was 6.8 MJ/kg.

IV. Conclusion

The energy analysis for processing of local rice in Benue State, Nigeria suggested that 3 unit operations were required for processing local rice paddy. Wood fuel was the major energy input in the processing process. The most extensive process was parboiling which accounted for 89.86% of the total energy required for processing of rice. The use of rice husks and incorporation of charcoal as fuel would minimize the amount of charcoal used. Efficient milling machines should be used to reduce the high consumption of liquid fuel. Too much time should not be wasted on a unit operation. However, optimization of the entire process is suggested to make the entire process more energy efficient.

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Table 1: ANOVA for Energy Requirement of Local Rice Processing

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Rows	1361306	8	170163.3	1.495229	0.234517	2.591096
Columns	1.91E+08	2	95407227	838.3456	6.37E-17	3.633723
Error	1820867	16	113804.2			
Total	1.94E+08	26				
Ho: F ≤ F Critical; Ha: F > F Critical; α = 0.05						

Table 2: Mean Time and Energy Requirement for the Processing of *Rice* in the Entire Study

S/N	**Process**	**Mean Time (h)**	**Mean Manual Energy (MJ)**	**Mean Liquid fuel (MJ)**	**Mean Wood fuel (MJ)**	**Total energy (MJ)**	**Percentage**
1	Parboiling	11.40	11.07		5955.56	5966.63	89.86
2	Spreading	17.10	16.38			16.38	0.25
3	Milling	9.80	2.64	654.22		656.86	9.89
	Total	**38.30**	**30.09**	**654.22**	**5955.56**	**6639.87**	**100.00**
	Total %		**0.45**	**9.85**	**89.69**	**100.00**	

Table 3: Mean Energy Variation in the Operating Units of Rice Processing

LOCATION	Cases	Total	Parboiling Energy	Spreading Energy	Milling Energy
Makurdi	1	7121.86	6409.74	19.44	692.70
	2	6720.24	6010.80	17.28	692.16
	3	7350.24	6410.80	16.20	923.24
MEAN (MJ)			**6277.11**	**17.64**	**769.37**
Aliade	1	6175.76	5608.64	12.96	554.16
	2	6182.51	5612.15	16.20	554.16
	3	6092.40	5612.96	17.28	462.16
Mean (MJ)			**5611.25**	**15.48**	**523.49**
Otukpo	1	8014.40	7210.80	17.28	786.32
	2	5922.94	5212.96	17.28	692.70
	3	6178.46	5610.80	13.50	554.16
Mean (MJ)			**6011.52**	**16.02**	**677.73**
Total Mean (MJ)			**5966.63**	**15.90**	**656.86**

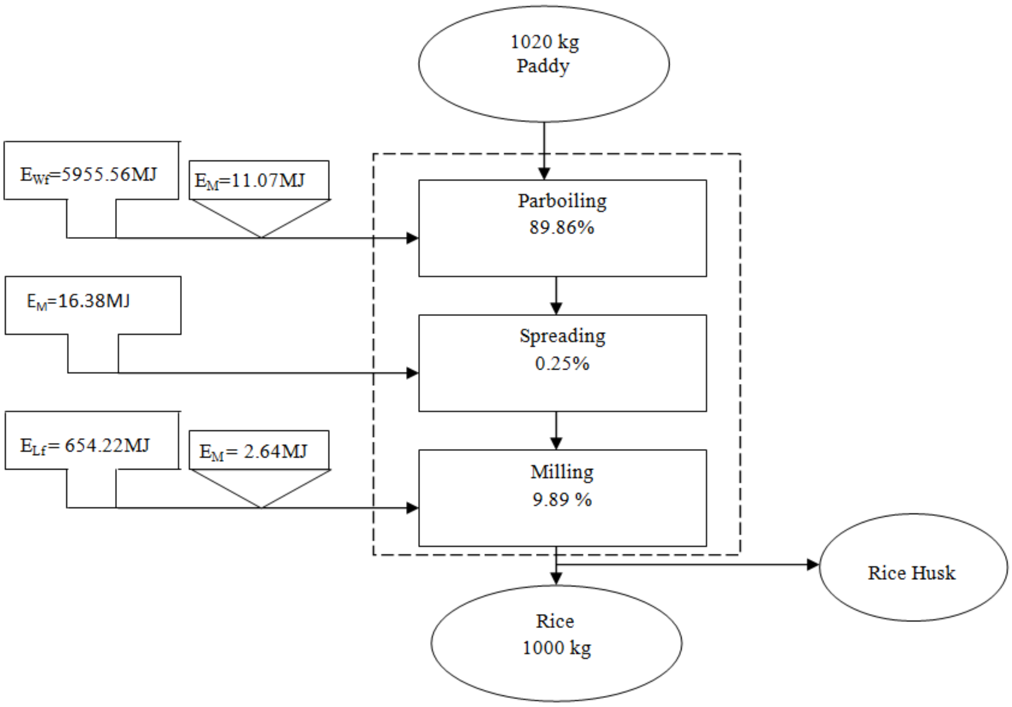

Fig. 2: The Mean Mass/Energy Flow Diagram for the Entire Case Study

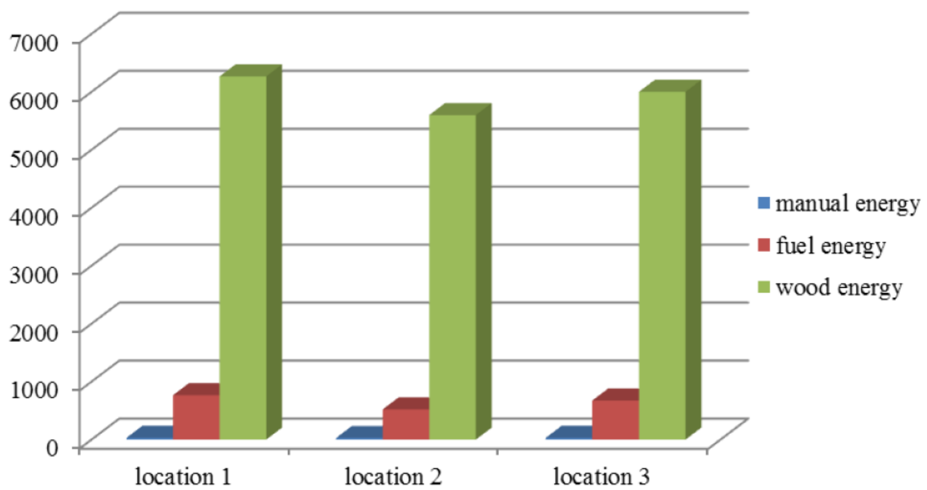

Fig.3. The Mean Energy Types and Consumption Levels for Rice Production in the Study Area

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was born in 1960 at Ogori in Nigeria. He obtained a BSc degree in Mechanical Engineering from University of Ife, Nigeria in 1984. He also holds an MEng. degree in Production and Design Engineering from Ahmadu Bello University, Zaria in 1995. He is a PhD degree holder in Thermo-fluids obtained from University of Agriculture, Makurdi in 2007.

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