TRENDS OF ENERGY INPUT IN SOME NIGERIAN PALM OIL MILLS

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ABSTRACT

Energy audit was conducted using the energy accounting method in seven palm oil processing mills. The mills were stratified into small, medium and large categories based on the levels of mechanization and daily production capacity. The production process in three mill categories was divided into eight defined unit operations: bunch transportation, detachment and plucking, bunch sterilization, fruit digestion, pulp pressing, oil clarification, oil drying and oil packing. The energy (electricity, thermal and labour) consumption in each unit operation for processing 1,500 kg of fresh fruit bunch was evaluated. Results showed that the total energy intensity in the palm oil processing plants reduced with increase in levels of mechanization and daily production capacity from 344.98 MJ/tones in the small-scale plants to 252.43 MJ/tones in the large-scale plants. Percentage share of electrical energy in the total energy reduced from 96.73 to 95.06, while the thermal energy reduced from 3.27 to 1.84%. The two identified energy intensive operations in palm oil processing are bunch transportation and fruit digestion, which accounted for over 90% of the total energy consumption in all the three mill categories. The use of fiber sludge as alternate source of energy for the boiler was recommended to reduce the cost of energy.

Keywords: Palm oil processing, energy consumption, manufacturing,

1.0 INTRODUCTION

Energy cost has been one of the major factors driving the cost of agricultural products and manufactured goods. Over the past two decades, Nigeria's commercial energy demand has grown at a rapid rate of over 13% per year, as a result of high population growth rates, increased urbanization, rapid industrialization efforts and rising living standards (Adegbulugbe, 1991). The overall energy consumption per capita in Nigeria (13.4 GJ) is very low compared to that of the developed countries such as UK and Germany respective values of 144.7 and 164.1 GJ and a developing country such as South Africa with a value of 182.6 GJ (Adenikinju, 1995; Akinbami, et al. 2001).

The protracted energy crisis with associated increase in electricity tariff, skyrocketing fuel cost and erratic power supply has continued to plaque the industrial sector of Nigeria economy. This has made energy cost of manufactured products a predominant component of the production cost, such that cost of energy accounts for about two-third of the total production cost (Waheed, 2008). This in effect, has led to increase in cost of production and lack of global competitiveness of goods produced in Nigeria. Hence, the Nigerian manufacturers are seeking opportunities to reduce manufacturing costs through the use of cost-effective energy saving technologies and practices that will reduce operating costs while maintaining or increasing product quality and quantity. To this effect, there is need for proper auditing for efficient management of energy resources. In recent times, the need for cost-effective energy saving technologies or practices is being recognized by many governments and manufacturing industries, hence enforcing the review of energy policies. This accounts for the extensive energy-related research work that has been done on many industrial systems with the aim of analyzing, improving the design and optimizing the performance of energy systems. Such industrial systems include rice processing (Ezeike, 1981), sunflower oil expression (Farsaie and Singh, 1985), palm-kernel oil processing foods (Jekayinfa and Bamgboye, 2004; 2007), cashew nut processing (Jekayinfa and Bamgboye, 2006), poultry processing (Jekayinfa, 2007), cassava-based foods ((Jekayinfa and Olajide, 2007), organic fertilizer production (Fadare et al, 2010), etc.

Although, considerable volume of energy-related study of industrial processes exists in literature, limited work has been reported on energy analysis of palm processing operations. Optimization of energy utilization in palm oil processing operations for Malaysian palm-oil mills has been reported by Chua (1991). At present, Malaysia has being the largest producer of oil-palm produces, while Nigeria is the third largest producer after Indonesia. The percentage share of Nigeria in world production of palm kernel and palm oil for 1996, 1997 and 1998 were 0.27 and 0.59%, 0.26 and 0.60%, and 0.25 and 0.59%, respectively (USAD, 1998). However, the Nigerian production capability has continued to dwindle, while other major producers like Malaysia and Indonesia have continued to strive, due in part to use of obsolete and energy-inefficient processing operations (Jekayinfa and Bamgboye, 2004; 2006). This in effect, has led to increase in energy cost with attendant increase in total cost production and hence lack of global competitiveness of oil-palm produces in Nigeria. Historical decline of the Nigerian palm-oil industry and the associated economic implications has been reported by Anyaegbu (1978) and Meshack–Hart (1990). To maintain economically sustainable production level, the palm-oil industry in Nigeria needs to substantially reduce their production cost by reducing their energy consumption through efficient utilization of fuel, electricity and labour, these being three major components of manufacturing cost. To this effect, Jekayinfa and Bamgboye (2006) has studied the energy requirement for palm kernel oil processing operations in Nigeria and reported an average energy intensity of 181.77, 230.00 and 350.00 MJ/kg for small, medium and large scale mill, respectively, with fuel (thermal) energy accounting for the largest (over 80%) of the total energy requirement. However, it appears that little has done to determine the energy consumption in the processing operations of palm-oil in Nigeria. The work Odior and Fadare (2009) was based on the application of neuro-fuzzy model for performance evaluation of palm oil production process without energy analysis of the process. Therefore, the aim of this study was to analyze the energy requirement as related to the unit operations in the palm oil processing industry in Nigeria in order to identify the amount, type and quality of energy required in view of identifying possible energy saving compatible to respective cost-benefit analysis. This information is vital for palm-oil mill operators in Nigeria to enable them to develop strategies for effective and efficient management of their energies consumption.

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1.1 Palm oil processing operation in Nigeria

Palm oil processing is an ancient agricultural practice in Nigeria, which has evolved into opportunity for small, medium and large-scale fully mechanized processing designed for extraction of edible oil from the palm fruits, with acceptable quality for international oil trade. The palm oil processing operation as practice in Nigeria involves variety of operations: collection and transportation of fresh fruit bunches from plantation to processing mill, detachment and plucking, sterilizing, fruit digestion, pulp pressing, oil clarification, oil drying and storage or packing. The processing is done both in continuous production in mechanized mills, while the batch process is used in traditional processing in small and medium scale mills. The defined unit operations required in the production process are shown in Figure 1.

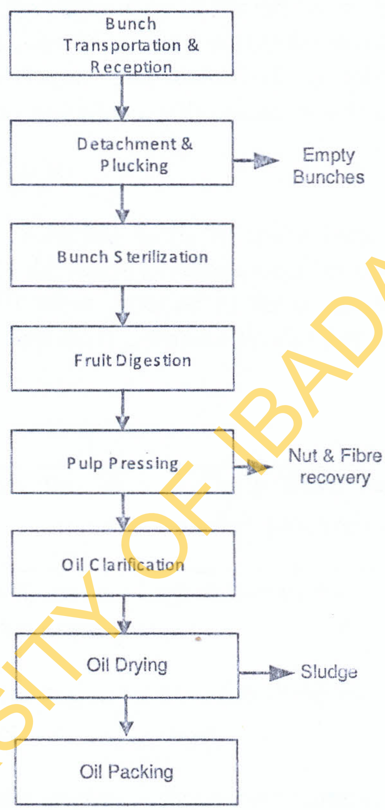

Fig. 1: Process flow chart for production of palm oil

Fresh fruit bunches are harvested from the plantation and transported with truck or carried manually with basket to the processing mill. Fruit bunches are normally emptied into wooden boxes, sorted and weighed. Processing operations begin after two days of storage to allow for fermentation of the fruits. Detachment and plucking of the fruits from the bunch is done either

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manually or mechanically. Sterilization of the fruits involves application of high temperature wet hat on the fruit to soften it. Bunch sterilization serves several purposes, which include: destroying oil splitting enzymes and termination of hydrolysis and auto-oxidation, breakdown of gums and resins, which cause oil to foam during drying, softening of the pulp, which makes extraction of oil easier during digestion and separation of fibrous materials. Fruit digestion involves the removal of palm oil in the fruit by breaking down the oil-bearing cells either by pounding or mashing. The process is more effective (high yield) when carried out under a well-insulated container to retain a high temperature, which reduces the viscosity of oil, destroy the epicarp and completes the disruption of oil cells already begun in the sterilization stage. Pulp pressing involves extraction of palm oil from the digested material. There are two system, which are wet (uses hot water to leach out the oil) and dry method (uses mechanical presses to squeeze out the oil). Clarification of oil involves the separating of the oil from its entrained impurities, oil drying process involves re-heating the decanted oil and carefully skimming off the dried oil from any engrained dirt and residual moisture. The dried oil is stored normally with temperature maintained around 50°C to prevent oxidation, solidification and fractionation of the oil.

2.0 MATERIAL AND METHOD

Energy study in some randomly selected palm-oil mills located in Osun State, southwestern, Nigeria was conducted to evaluate the energy requirement for processing of 1500 kg of fresh fruit bunches into edible oil. The mills were grouped in three categories (small, medium and large) based on levels of mechanization and daily palm-oil production output as shown in Table 1.

Table 1: Classification of plants

Plant category	Level of mechanization	Daily fresh fruit bunches processing rate	No. of mills in each category
Small	more than 50% of their operations performed manually	up to two tones	3
Medium	more than 50% of their major operation mechanized	between three and four tones	2
Large	more than 75% of their major operations mechanized	more than seven tones	2

The processing operations of all categories of plant are very similar and include eight defined unit operations such as: (1) transportation and reception of fresh fruit bunches; (2) detachment and plucking; (3) sterilizing; (4) fruit digestion; (5) pulp pressing; (6) oil clarification; (7) oil drying; and (8) oil packing. The type and make of equipment use and their level of sophistication may vary in each category. All the mills were evaluated for 10 days within the same period in the month of March 2009. Since they were evaluated for over the same period of time, the error of seasonal changes was eliminated. The major instruments used in the study are stop watch used

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for recording time required to carry out a given operation, weighing machine for measuring of the weight material processed, fuel (diesel or gasoline) consumed and product produced during each operation.

2.1. Data collection

The energy requirement for each unit operation was determined using the energy accounting method. The three types of energy input employed in all categories palm oil processing operations are: thermal, electrical and human energy.

2.1.1. Evaluation of electrical energy

The electrical energy input was obtained by multiplying the rated power of the electric motor by the corresponding hours of operation. Motor efficiency of 80% was assumed (Waheed, 2008; Fadare et al, 2010). The electrical energy input can be expressed mathematically as (Waheed, 2008):

$$E_p = \eta P t \qquad (1)$$

Where E_p is the electrical energy consumed (kW h), P is the rated power of motor (kW), t is the hours of operation (h) and η is the efficiency (assumed to be 0.8)

2.1.2. Evaluation of thermal energy

Thermal energy input was calculated based on quantity of fuel (diesel and gasoline) used during each operation. The quantity of fuel used was converted to energy (J) by multiplying the quantity consumed by the corresponding calorific value (lower heating value) of the fuel as (Waheed, 2008):

$$E_F = C_f W \qquad (2)$$

Where E_F is the thermal energy consumed (J), C_f is the calorific value of diesel fuel (J/kg) and W is the quantity of diesel fuel consumed (kg)

2.1.3. Evaluation of manual energy

Manual energy was estimated based on the value recommended by Odigboh (1997). According to him, at maximum continuous energy consumption rate of 0.30 kW and conversion efficiency of 25%, the physical power output of a normal human labour in tropical climates is approximately 0.075 kW sustained for an 8-10 hour workday. The manual energy was calculated mathematically as (Waheed, 2008)::

$$E_m = 0.075 N t \quad \text{(kW h)} \qquad (3)$$

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Where 0.075 is the average power of a normal human labour in kW, N is the number of persons involved in the operation and t is the useful time spent to accomplish a given task (operation) in hours.

2.1.4. Evaluation of energy intensity

Energy intensity reflects the amount of the energy required per unit weight of the processed palm fruits. It was evaluated as the ratio of energy input and the weight of palm fruits processed (Waheed, 2008):

$$E_i = \frac{E_T}{W_p} \quad (4)$$

Where E_i is the energy intensity (MJ/kg), E_T is the total energy input (MJ) and W_p is the weight of palm fruits processed (kg)

3.0 RESULTS AND DISCUSSION

The energy consumption patterns for processing of 1500 kg of fresh fruit bunches in small, medium and large scale plants are shown in Tables 2-4, respectively. Energy requirement of the mills were thermal (fuel), electricity and human labour. The total energy requirements and average energy intensities in the small, medium and large mills were 517.47, 499.35 and 378.64 MJ and 344.98, 332.90 and 252.43 MJ/tones, respectively. These values allow comparison to be made between the energy consumption in the three categories of mills. The energy requirement of the small scale mills was higher than that of the medium scale mills followed by that of the large scale mills. This trend of energy variation may be attributed to the economy of scale, which is a clear indication that the bigger the better in terms of output and energy efficiency. Other factors that may be responsible for this variation may be due to differences in the degree of sophistication, mechanization and ages of processing equipment used in each category of the mills. The same trend in energy consumption of small, medium and large scale of respective values of 350.89, 230.70 and 181.74 MJ/tonnes for palm kernel oil processing mills has been reported by Jekayinfa and Bamgboye (2004; 2006).

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Table 2: Time and energy consumption pattern in small-scale palm oil processing mills

Unit Operation	Time (h)	Thermal Energy (MJ)	Electrical Energy (MJ)	Manual Energy (MJ)	Total Energy (MJ)	% of Total
Transportation & Reception	6.00	274.56	-	4.86	279.42	54.00
Detachment & Plucking	3.00	-	-	4.05	4.05	0.78
Bunch Sterilization	2.00	18.61	-	1.62	20.23	3.91
Fruit Digestion	2.50	188.76	-	1.08	189.84	36.69
Pulp Pressing	3.00	-	-	3.24	3.24	0.63
Oil Clarification	2.00	11.16	-	1.08	12.24	2.37
Oil Drying	1.50	7.44	-	0.81	8.25	1.59
Oil Packing	0.75	-	-	0.20	0.20	0.03
Total	20.75	500.53	-	16.94	517.47	100.00
Percentage of Total		96.73	-	3.27		

Thermal energy accounted for the largest portion (over 95%) of the total energy input in all the mills. Fuel and electricity are predominantly used for the running of the process operations and equipment. In all the mills, over 54% of the thermal energy input was used as fuel (diesel) for running vehicles used for transporting fresh fruit bunches to the mills. Therefore, the transportation and reception of fruit bunch was identified as most energy intensive unit operation. It accounted for 54.00, 55.96 and 55.35% of the total energy consumption in the small, medium and large scale mills followed by the fruit digestion operation with corresponding shares of 36.69, 34.58 and 36.54%, respectively. The electrical energy consumption in all the three mill categories was lower than 4% of the total energy consumption. The low electrical input may be associated with limited accessibility to the national grid particularly in the rural areas where some of these mills are located. Where there is accessibility, the epileptic supply of electricity from the national grid usually results in acute shortage of electrical energy supply. Consequently, most manufacturing industries now rely mainly on the use of heavy-duty generating sets for alternative supply of electrical energy.

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Table 3: Time and energy consumption pattern in medium-scale palm oil processing mills

Unit Operation	Time (h)	Thermal Energy (MJ)	Electrical Energy (MJ)	Manual Energy (MJ)	Total Energy (MJ)	% of Total
Transportation & Reception	6.00	274.56	-	4.86	279.42	55.96
Detachment & Plucking	1.00	-	5.40	0.27	5.67	1.14
Bunch Sterilization	2.00	18.61	-	1.62	20.23	4.05
Fruit Digestion	2.00	171.60	-	1.08	172.68	34.58
Pulp Pressing	1.25	-	-	0.68	0.68	0.14
Oil Clarification	2.00	11.16	-	1.08	12.24	2.45
Oil Drying	1.50	7.44	-	0.81	8.25	1.65
Oil Packing	0.67	-	-	0.18	0.18	0.03
Total	16.42	483.37	5.40	10.58	499.35	100.00
Percentage of Total		96.80	1.08	2.12		

Table 4: Time and energy consumption pattern in large-scale palm oil processing mills

Unit Operation	Time (h)	Thermal Energy (MJ)	Electrica l Energy (MJ)	Manual Energy (MJ)	Total Energ y (MJ)	% of Total
Transportation & Reception	4.50	205.92	-	3.65	209.57	55.35
Detachment & Plucking	0.75	-	4.05	0.20	4.25	1.12
Bunch Sterilization	0.75	-	4.05	0.20	4.25	1.12
Fruit Digestion	2.00	137.28	-	1.08	138.36	36.54
Pulp Pressing	0.67	-	3.62	0.36	3.98	1.05
Oil Clarification	1.50	9.30	-	0.81	10.11	2.67
Oil Drying	1.00	7.44	-	0.54	7.98	2.11
Oil Packing	0.50	-	-	0.14	0.14	0.04
Total	11.67	359.94	11.72	6.98	378.64	100.00
Percentage		95.06	3.10	1.84		

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Transportation and reception of fresh fruit bunch was the most energy intensive operation in palm oil processing operations, accounting for 54.00, 55.96 and 55.35% of the total energy consumption in small, medium and large mills respectively. Fruit digestion process was next energy intensive operation. It accounted for 36.69, 34.58 and 36.54% of the energy consumption in small, medium and large plants respectively. The energy consumed for this operations were 189.84, 172.68 and 138.36 MJ respectively. Detachment and plucking operation required 4.05, 5.67 and 4.25 MJ in small, medium and large plants respectively, corresponding to 0.78, 1.14 and 1.12% of the total energy consumption in small, medium and large mills. For bunch sterilization process, 20.23, 20.23 and 4.25 MJ, respectively were consumed in the three mill categories, accounting for 3.91, 4.05 and 1.12% of total consumption in small, medium and large mills respectively. The energy consumed in pulp pressing operation in small, medium and large plants were 3.24, 0.68 and 3.98 MJ, corresponding to 0.63, 0.14 and 1.05% of the energy consumption in small, medium and large plants respectively. The energy consumed in oil clarification operation in small, medium and large plants were 12.24, 12.24 and 10.11 MJ, respectively. This accounted for 2.37, 2.45 and 2.67% of the energy consumption in the three categories of plants. Likewise, oil drying which required 8.25, 8.25 and 7.98 MJ of the total energy consumed in the three mill categories.

Figures 1-3 show energy and material balance diagrams for each unit operation in the three mill categories. The trends in energy consumption observed in this study can be a useful tool in the development of energy policy and optimization of energy utilization in palm oil processing mills. There is need for an improved technology that will reduce energy input and production time in order to reduce production cost.

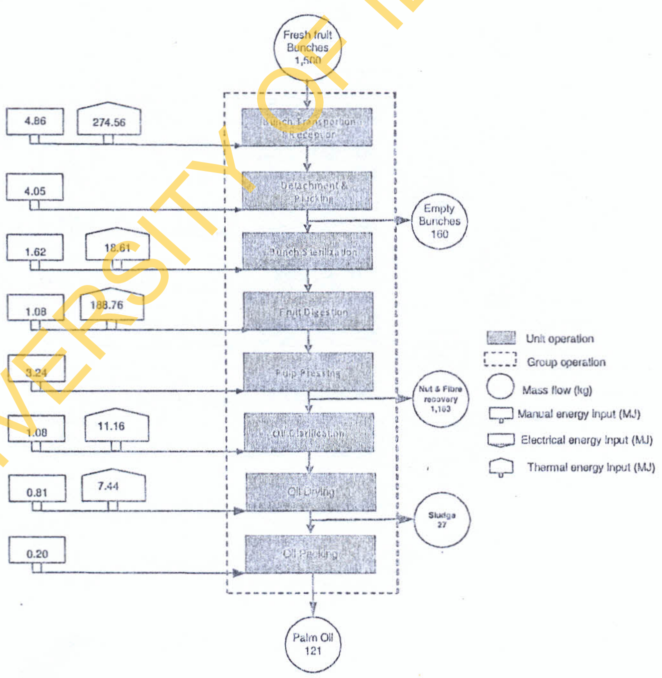

Fig. 1: Energy and material balance diagram for production of palm oil in small processing plants

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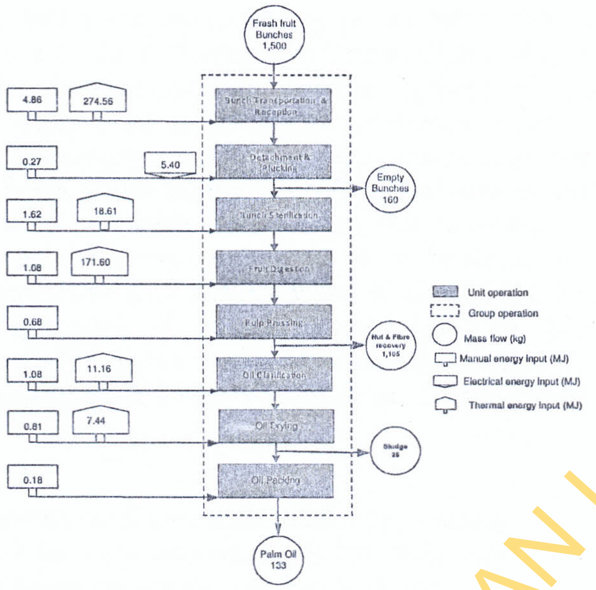

Fig. 2: Energy and material balance diagram for production of palm oil in medium processing plants

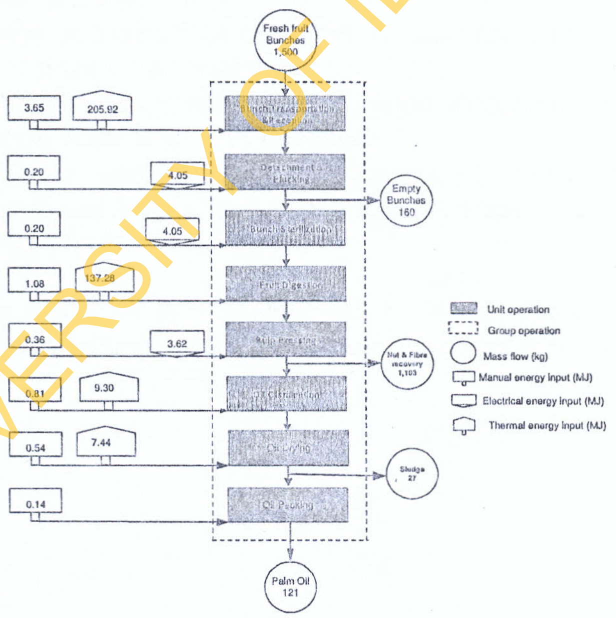

Fig. 2: Energy and material balance diagram for production of palm oil in large processing plants

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The concern to curb the inefficient use of energy in the palm oil industry in Nigeria has not received sufficient attention of the mill operators. The available of energy contents of the fiber sludge and empty fruit bunch have not been properly explored. Fiber sludge generated by the palm oil mills is traditionally used as solid fuel for domestic heating and cooking in rural community, this can be particularly used for generating thermal energy for bunch sterilization, fruit digestion, oil clarification and drying. Yosoff (2004) has estimated the average energy content of fiber sludge to be 14.0 GJ/ton. The empty fruit branch can also be used to generate thermal energy. To make it more easily combustible, it can be shredded and dehydrated to reduce the moisture content below 50% with heating value of about 1950 kcal/kg (Jorgensen, 1985). These renewable energy resources can serve as complement to the thermal energy requirement, thus reducing the energy cost. Another way to improve the energy efficiency of the mills is by using modern and energy-efficient machinery in the palm oil processing mills.

4.0 CONCLUSION

Energy audit of small, medium and large scale palm oil processing mills in Nigeria for processing of 1.5 tones of fresh fruit bunches into edible oil has been conducted. Based on the trends of energy consumption, the following conclusions can be drawn:

- The results showed that the major types of energy sources used in the palm oil processing mills were thermal energy and electrical energy.
- The total energy consumed in small, medium and large palm oil mills were 517.47, 499.35 and 378.64MJ, respectively.
- The thermal energy accounted for over 95% of the total energy consumption in all the three categories of palm oil processing mills.
- The fresh fruit bunch transportation and reception accounted for over 54% of the total energy consumption in the three mill categories.
- The energy utilization pattern of the palm oil industry in Nigeria can be improved by the use of fiber sludge and empty fruit bunch as alternative fuels for heating and use of modern and energy-efficient machinery.

The results of this study may serve as a baseline data for further studies with aims of optimizing energy consumption and reduction in the green house gas emissions of palm oil processing industry in Nigeria.

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