Trends and Effective Use of Energy Input in the Palm Kernel Oil Mills

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Summary

This work aims at studying the importance and the efficiency of energy use in a few palm kernel oil mills selected for their representativity. Pattern of energy use, the cost of energy per unit product, energy intensity and normalized performance indicator (NPI) were determined. Results show that the medium and the large mills depend largely on fossil fuel; while the small mill depends on electricity. It was found out that the large mill has the most effective use of energy with high energy intensity. The annual cost of energy per unit product of ₦8,360,000 ($64,307.69); ₦12,262,250 ($94,325) and ₦13,353,870 ($102, 722.08) were obtained for small, medium and large mills respectively. The NPI results show that there was no wastage of energy through space heating in energy supplied for production within the factory site.

Résumé

Tendances et efficacité d'utilisation de l'énergie dans les moulins à huile de palmiste

Ce travail vise à évaluer l'importance et l'efficacité de l'utilisation des apports d'énergie chez un petit nombre d'unités de production d'huile de palmiste choisies pour leur représentativité. Le mode d'utilisation de l'énergie, le coût de l'énergie par unité produite, l'intensité de l'énergie nécessaire et l'indicateur normalisé de performance ont été déterminés. Les résultats obtenus montrent que les moulins de grande et de moyenne capacités fonctionnent essentiellement à partir de combustible fossile; tandis que les petits moulins marchent à l'électricité. On a trouvé aussi que les grands moulins utilisaient plus efficacement une quantité d'énergie plus élevée. Les coûts annuels de l'énergie par unité produite étaient respectivement de ₦8.360.000 ($64.307,69); ₦12.262.250 ($94.325) et ₦13.353.870 ($102.722,.08) pour les unités de petite, de moyenne et de grande capacités. Les résultats obtenus pour l'indicateur de performance normalisé montrent de plus qu'il y a peu de gaspillage d'énergie sous forme de déperdition de chaleur dans l'environnement de production.

Introduction

A fundamental requirement for human development is energy, and it is capable of transforming communities. Energy exists in many forms and can be classified as renewable and non-renewable. Renewable energy includes solar (sunlight, wind, hydroelectric and biomass), tidal and geothermal energy. Non-renewable energy includes fossil fuels (natural gas, oil, coal and peat) and nuclear energy. A high percentage of the world's total energy output is generated from fossil fuels such as oil and coal (11). It is universally conceded that fossil fuels are finite. It is only a matter of time before fossil fuels reserves will be depleted.

For over a hundred years, engineers have taken a close interest in the energy consumption of the machines they have developed. However, in recent years, energy analysis has been expanded to encompass not only the actual manufacturing process but also ancillary operations and services that are required for studying present-day industry. This is as a result of gradual appreciation of the finite quantities of conventional fossil fuels available from the earth and the rapidly increasing cost of energy. For instance, in Nigeria, the prices of petroleum products have been increased six times in the last eight years while the electricity tariff has also been increased thrice in the same period.

The level and pattern of a country's use of energy from different sources often serve as an index of its agro-industrial development and standard of living. Because commercial energy inputs are an indispensable part of transitional and modern agriculture, a slight increase in the energy inflow often results in a significant response in food production.

Three methods for determining the energy sequestered in goods and services were been reviewed and analysed to determine its input (4). The first method reported is the statistical analysis, which entails the determination of the energy used per unit of output from statistical data collected from production records. The second method, which was termed 'Input-Output analysis' is a square matrix of a production economy that presents the quantities of each commodity (in energy units or monetary units) required to produce every commodity. In this method, materials flow can be traced backwards to eventually the primary energies upon which they depend. The third method is termed 'Process Analysis'. It involves the identification of the networks or processes required to make a final product. Each is analysed to determine its inputs and each input is assigned an energy requirement so that the total energy requirement can be summed.

In a further work, some researchers demonstrated how the process analysis method can be combined with input-output analysis method to obtain the best estimate of energy intensity or embodied energy with least effort (3). They suggested that input-output analysis is better for aggregated, nationwide problems and that process analysis is more suited to specific processes, products or manufacturing chains for which physical flows of goods and services are easy to trace.

Several researchers reported the use of regression analysis in estimating the energy consumption of each product from data on the total consumption of each energy source in the processing of food products (5, 7). Results of these analyses had been used for forecasting energy requirement in crop/food processing plants. Because such analyses can be performed using statistical programmes on computers and programmable calculators, it would cost much less

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than studies based on metering consumption of fuels and electricity for specific unit operations.

In 1987, the Federal Government of Nigeria introduced the Structural Adjustment Programme (SAP) which led to the prohibition of importation of some essential products (including soap, cooking oil and body/hair cream) as policy measures to revive the economy, minimize the dependence on importation and to build a non-oil export based economy.

These policy measures rekindled an interest in agriculture on the part of many Nigerians and Nigerian organizations. The government (federal, state and local) through different agencies such as Agricultural Development Projects (ADPs), Directorate of Foods, Road and Rural Infrastructure (DFFRI) and Federal Institute of Industrial Research Oshodi (FIIRO) made efforts to increase local production of these essential commodities through incentives given to farmers and organizations. This led to the establishment of some cottage industries such as those for soap making, production of cooking oil and body/hair cream (1, 8, 10).

These industries make use of palm kernel oil as the basic raw materials. As a result, demands for palm-kernel oil have been on the increase without any appreciable profit margin to the producers due to high input energy. Hence, the dwindling production of palm-kernel oil in recent time. To be able to maintain economically sustainable level of production of palm-kernel oil, the industry will need to substantially reduce the cost of production. In view of this, attempts should be made for higher efficiency of utilization of fuel, electricity and labour, these being the three major components of manufacturing cost.

A comprehensive study on the energy consumption in the processing operations of palm kernel is vital to enable the management of palm kernel processing mills to develop strategies for better control of their production operations. It will also enable them to modify areas of waste and to properly appraise their energy consumption in planning their production and marketing activities.

Material and methods

The study methodology

The study of energy requirement and consumption patterns in the production of palm-kernel oil were conducted in some selected processing mills located in Osogbo, Ejigbo, Iwo, Ilobu, Ikirun in Osun State and Ibadan, Ogbomoso, Oyo, Iseyin, and Igbeti, in Oyo State of Nigeria.

Analysis of Secondary Energy and Production Data

The historical data collected from all the 40 PKO mills were analysed to determine the efficiency to energy use in each mill. Energy use efficiency-measuring indicators employed include; Normalised Performance Indicator (NPI,) Energy Intensity (EI) and Energy Cost per Unit Product (EC/P). The indicators are discussed as follows:

(i) Normalised Performance Indicator (NPI)

The total energy consumed for production purpose divided by the total floor area of the factory multiplied by the hours of use factor was used to obtain NPI. For each mill, the calculated NPI value was compared to the standard NPI value quoted by the Energy Efficiency Office (ECO).

NPI = {Total Energy Consumed x use factor} / floor area …… 1
(Energy Audit for Industry, 1993)

(ii) Energy Intensity (EI)

This indicator gives the amount of energy consumed in producing a unit of the product. It is the sum total of all the energies divided by the output or production index.

EI= {Sum total of all energies} / {Output or production Index} (MJ/litre) ……………………………………………………………. 2

(iii) **Energy Cost per Unit Product (EC/P)**

This is represented mathematically as,

EC/P= {Total Energy Cost x Energy Intensity} / {Total Energy} (#/litre) ……………………………………………………………….. 3

Total Energy Cost was calculated for the different energy sources based on their respective rates and summed together. From the historical energy data collected, the calculated specific energy (that is, intensity) data for the mills were subjected to analysis of variance and Duncan's Multiple Range Test to ascertain significant differences in the specific energy consumption within the same mill and across the mills. This is done with a view to selecting few PKO mills for the experimental aspect of this study.

(IV) The mills were categorized into:

Small Mills: Mills with total production output less that 300,000 litres of PKO per annum.

Medium Mills: Mills with total production output between 300,000 and 500,000 litres of PKO per annum.

Large Mills: Mills with total production output greater than 500,000 litres of PKO per annum.

Results and discussions

Tables 1 to 3 show the results of the energy use pattern in the palm kernel mill. The ratio of electricity consumption to fuel consumption was 5:1 between 1996 and 1999.

However, a gradual decrease in electrical energy consumption was observed from 1996 to 2002; while the amount of fossil fuel consumption increases in the small mill. However, in the medium mill, there was no appreciable difference in the energy consumption of electricity and fossil fuel. The total average contribution of thermal energy to the total energy consumption was 50.5%. In the large mill, the percentage contribution of fossil fuel was 61.4%. It was evident that both the medium mill and the large mill depend largely on fuel for production. This will likely affect production cost, since more money will be spent on fuel. It has been reported that under the condition of the prevailing fuel cost similar to when this study was carried out, about 30% of the production cost would have been avoided or diverted to other profitable areas of production cost if electricity had been the only source of energy supply (2, 9).

The highest energy cost per unit product of ₦61.1 ($0.47) was recorded in the year 2002, while the lowest of ₦24 ($0.18) was in the year 1996 in the small mill. However, in the medium mill, the highest cost per unit product of ₦36.8 ($0.28) was in the year 2000, while the lowest cost per unit product of ₦16.43 ($0.13) was in the year 1997. In the large mill, the cost of energy input per unit product varies from ₦11.41 ($0.09) in the year 1996 to ₦19.52 ($0.15) in the year 1999. This gave a fairly good cost of energy input. However, the energy input per unit product increases to ₦44.79 ($0.35) in 2000 and reduced to ₦35.42 ($0.27) and ₦38.42 ($0.30) in 2001 and 2002 respectively. All these are still on the high side.

This is due to the sudden increase in the price of fossil fuel by 150% and 300% in 2000 and 2002 respectively in Nigeria. A sharp decline in the supply of electricity from the national grid was also observed. This forced PKO production to rely more on fuel for production; thereby increasing the cost of energy per unit product.

The average cost of energy input per unit product was ₦25.73 ($ 0.20) in the large mill, this cost is lower than the average cost of energy input per unit product in the medium and the small mills respectively; the average cost of energy input per unit product in the medium and small mills are ₦31.85 ($0.25) and ₦38.0 ($0.29) respectively. This indicates that the large mills have the least average energy input per production, an indication of effective use of energy; while the small mills have the highest average

Table 1
Average yearly energy uses characteristics and production in the small PKO mills studied (1996 - 2002)

Year	Annual Production Output ('000)L	Electricity (GJ)	Fuel (GJ)	Total Energy (GJ)	% Share of Electricity	% Share of Fuel	Energy Cost Per Unit Output (N/'000l of PKO)	Energy Intensity (MJ/'000l of PKO)	Normalised Performance Indicator (GJ/m³ floor area)
1996	295	133.0	29.0	162.0	82.1	17.9	240	549	0.85
1997	285	110.0	46.2	156.2	70.4	29.6	250	548	0.84
1998	282	86.0	46.5	132.5	64.9	35.1	266	470	0.82
1999	242	62.0	60.1	122.1	50.8	49.2	267	500	0.85
2000	108	33.0	64.5	97.5	33.8	66.2	463	900	0.92
2001	155	50.0	65.8	115.8	43.2	56.8	563	750	1.05
2002	170	65.0	41.9	106.9	60.8	39.2	611	630	1.06
Average Annual	220	77.0	50.6	127.6	60.3	39.7	380	621	0.90

Table 2
Average yearly energy uses characteristics and production in the medium PKO mills studied (1996 - 2002)

Year	Annual Production Output ('000)L	Electricity (GJ)	Fuel (GJ)	Total Energy (GJ)	% Share of Electricity	% Share of Fuel	Energy Cost Per Unit Output (N/'000l of PKO)	Energy Intensity (MJ/'000l of PKO)	Normalised Performance Indicator (GJ/m³ (GJ/m² floor area)
1996	477	135.0	100.0	235.0	57.4	42.6	169.6	493	0.65
1997	471	114.5	98.0	212.5	54.0	46.0	164.3	451	0.75
1998	435	118.0	97.5	215.5	54.8	45.2	201.8	495	0.88
1999	387	83.6	103.0	186.6	44.8	55.2	248.0	482	0.94
2000	264	53.0	133.7	186.7	28.4	71.6	368.6	707	0.97
2001	300	110.0	85.5	195.5	56.3	43.7	553.0	652	0.87
2002	360	94.3	105.4	199.7	47.2	52.8	524.0	555	0.52
Average Annual	385	101.2	103.3	204.5	49.5	50.5	318.5	548	0.80

Table 3
Average yearly energy uses characteristics and production in the large PKO mills studied (1996 - 2002)

Year	Annual Production Output ('000)L	Electricity (GJ)	Fuel (GJ)	Total Energy (GJ)	% Share of Electricity	% Share of Fuel	Energy Cost Per Unit Output (N/'000l of PKO)	Energy Intensity (MJ/'000l of PKO)	Normalised Performance Indicator (GJ/m³ floor area)
1996	829	185	280	465	39.8	60.2	114.14	561	0.55
1997	694	149	260	409	36.4	63.6	114.88	589	1.05
1998	515	129	230	359	35.9	64.1	185.64	697	0.95
1999	434	120	194	314	38.2	61.8	195.15	724	0.87
2000	249	56	385	441	12.7	87.3	447.85	1771	1.06
2001	371	160	135	295	54.2	45.8	359.11	795	0.93
2002	542	218	194	412	52.9	47.1	384.23	760	0.95
Average Annual	519	145.3	239.7	385	38.6	61.4	257.29	842	0.95

energy input per production, indicating increase in the cost of production. In the small mill, the annual production was 220,000 litres and the total cost of energy input annually was ₦8,360,000.00 ($64,307.69). This value increased in the medium mill with the annual production capacity of 385,000 litres, to ₦12,262,250.00 ($94,325); and the cost of energy input per year was ₦13,353,870.00 ($102,722.08) for the annual production of 519,000 litres of oil per year. Though the amount of money spent on energy was high in the large mill with the highest quantity of material processed, yet it was obvious that it was more efficient than the other mills in terms of energy utilization.

As the energy intensity increases, a decline in the production index was observed in all the mills. This is an indication of inefficient domestic energy utilization in the mills. The energy intensity used varied over the seven-year period under review. It varies from 0.47MJ/l in 1998 to 0.9MJ/l in 2000 in the small mills (Table 1); 0.45MJ/l in 1997 to 0.71MJ/l in 2000 in the medium mills (Table 2); and 0.56MJ/l in 1996 to 1.77MJ/l in 2000 in the large mills (Table 3). It is evident that the highest energy intensity recorded was in the year 2000 for all the category of mills. This is due to the unsteady supply of electricity from the national grid, and the upward review of prices of petroleum products in Nigeria between 2000 and 2002. This explains the increase in energy intensity in all the mills from year 2000 to 2002 compared with the preceding years. The average energy intensity of 0.62MJ/l was obtained in the small mill, 0.55MJ/l in the medium mill and 0.84MJ/l in the large mill. This clearly shows that the large mills have the highest energy intensity,

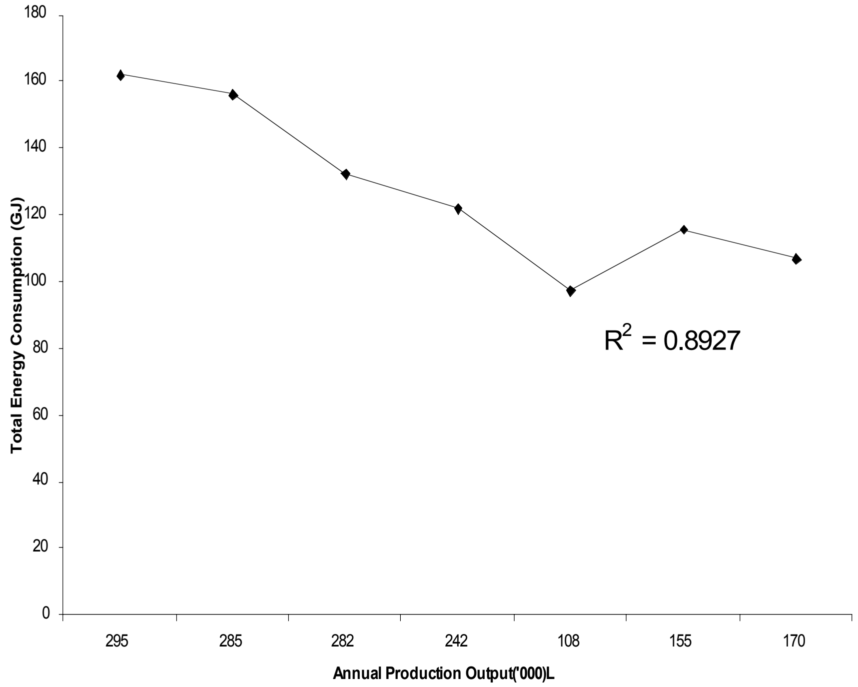

Figure 1: Relationship between Total Energy Consumption per Year and Annual Production from 1996-2002 in the small mills.

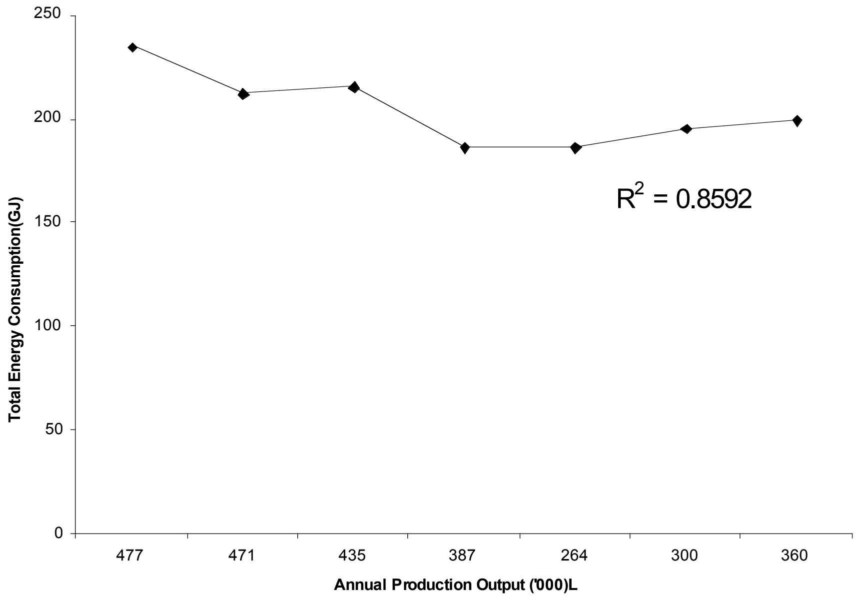

Figure 2: Relationship between Total Energy Consumption per year and Total Annual Production of PKO in the medium mills.

while the medium mills have the least.

The average seven-year NPI values in all the PKO mills ranged from 0.80GJ/m^2 to 0.94GJ/m^2. These values fall below the standard NPI fair range of 0.94 GJ/m^2 to 1.33GJ/m^2 (11). This indicates that the assessment of energy use in all the categories of mills were good. This also shows that there was no wastage through space heating in energy supplied for production within the factory buildings.

During the seven production years under review, it was observed that the energy consumption per year can be predicted by the quantity of PKO production from the small and the medium mills (Figures 1 and 2). The coefficient of determination (R^2= 0.89 and 0.85) obtained for small and the medium mills respectively indicated that the total energy used could to some extent explain the variation in PKO production output. However, other factors such as maintenance, management skill, and attitude of the mill's operators were observed to also affect energy consumption in PKO production. Generally in the small and medium mills, a decline in the quantity of PKO produced was observed with a decrease in the energy consumption between 1996 and 2000. This may be attributed to the instability in the energy supply in the country with a steady rise in the price of petrol. However, from Figure 3, there is no clear pattern in the relationship between energy consumption and the quantity produced in the large mills. The coefficient of determination (R^2 = 0.39) obtained further indicated that the quantity of PKO output cannot be used alone to predict the total energy input. This suggests the presence of other factors such as the age of mills, maintenance, type of equipment, and level of mechanization that may account for the effective use of energy other than the quantity of PKO being produced.

Conclusion

The mills depend largely on fossil fuel for energy input in the PKO mills. The large mill was observed to have the best energy utilization of all the mills, followed by the medium and small mill respectively. In all the mills, energy cost per unit product was highest in the year 2002; and the large mill gave the least average cost of energy input per unit product. The energy intensity was highest in the year 2000 for all the category of mills; and the large mill recorded the highest energy intensity, while the medium mills have the least. An estimate cost of energy input in the small mill with the annual production of 220,000 litres was ₦8,360,000.00 ($64,307.69); the medium mill with the annual production of 385,000 litres was ₦12,262,250.00 ($94,325); and for the large mill, the cost of energy input for the annual production of 519,000 litres was ₦13,353,870.00 ($102,722.08).

Literature

1. Aina O.I., 2002, Technological assimilation in small enterprises owned by women in Nigeria. Technology Policy and Practice in Africa. Chapter, 13, 1-15.
2. Akinbami J.F.K., Ilori M.O., Adeniyi A.A. & Sanni A.A., 2001, Improving efficiency of energy use in Nigeria's industrial sector. a case study of a beverage plant: Nigerian Journal of Engineering Management, **2**, 2, 1-8.
3. Bullard C.W., Penner P.S. & Pilati D.A., 1996, Energy analysis handbook. CHC Doc. N°. 214, Centre for advanced computation, University of Illinois, Urbana.
4. Chapman P.F., 1994, Energy costs: a review of methods. Energy policy, **2**, 2, 91-103.
5. Dash S.K. & Das D.D., 2000, Optimal energy requirements for groundnut cultivation in Orisa, India. Journal of Agricultural Mechanization in Asia, Africa and Latin America, **3**, 1, 41-43.
6. Energy efficiency office, 1982, CIBSE building energy code. Measurement of energy consumption and comparison with target for existing building and services. Part 4, England.
7. Jacobs W.P., 1991, Forecasting energy requirements. Chemical engineering, **85**, 5, 97-99.
8. Jekayinfa S.O., 2001, Energy accounting in industrialized agriculture: a review. Journal of Applied Science, **4**,1, 1562-1577.
9. Megbonwon I.O. & Adewusi S.O., 2002, Effect of failure of NEPA electricity on the finance of small and medium scale industries: case study of two agro-allied industries in Ondo state. Nigerian Journal of Industrial Safety and Systems, **1**,1, 28-31.
10. Olajide J.O. & Oyelade O.J., 2002, Performance evaluation of the strategic grain reserve storage programme (SGRSP) in Nigeria. Technovation, 22, 463-468.
11. Sambo A.S., 1997, Renewable energy technology in Nigeria: resource availability, and potential for application to agriculture. Journal of Agricultural Technology, **3**, 1, 1-4.

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