Energy Consumption Pattern in Palm Kernel Oil Processing Operations

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ABSTRACT

The energy consumption pattern in three categories of palm kernel mills was considered in this study. The mills were classified as small, medium and large respectively based on their capacities. Data on PKO production, quantity of fossil fuel used, electrical power used from the state grid, and captive power generated were obtained for each of the seven identified unit operations. Thermal, Electrical and Manual energy were identified to be the main sources of energy input in all the mills.

Thermal energy input varying from 44.9% to 82.4% in the mills was observed to be the mostly used, followed by electrical energy (45.7% - 14.9%) and manual (9.4% - 2.7%) in small, medium and large mills respectively.

Palm nut cracking and oil expression accounted for 73.4% of the energy consumed in both small mill and medium mills respectively and 85.2% in the large mill. This indicates that these two unit operations were the most energy intensive operations in all the mills considered.

Keywords: Energy consumption, palm kernel, mill, energy input, cracking, oil, thermal

1. INTRODUCTION

Energy is the livewire of industries and agricultural production, the fuel for transportation as well as for the generation of electricity in conventional thermal power plants is all energy based. In Nigeria, the rising fuel cost and limitations in supply is affecting virtually every sector of the economy. There is a gradual focus on the need for more energy- related research to reduce costs through energy conservation with a view of preventing possible folding up of the industry due to reduced availability of energy resources. The introduction of a Structural Adjustment Programme (SAP) in Nigeria in 1989 led to the prohibition of the importation of some essential products (such as soap, cooking oil, body/hair cream, etc.) as policy measures to revive the economy, minimize the dependence on importation and build a non-oil export based economy (Aina, 2002). These policy measures rekindled an interest in post-agricultural ventures on the part of many Nigerians. These led to the establishment of some cottage industries such as soap production, cooking oil and body/hair cream (Olajide and Oyelade, 2002).

These industries make use of Palm Kernel Oil (PKO) as the basic raw material. As a result of this, the demand for PKO has been on the increase without any appreciable profit-margin to the producers due to high input energy. This has resulted into the dwindling production of PKO in recent time. To maintain economically sustainable level of production of PKO, 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 labor, these being the three major components of manufacturing cost.

In a study of a cashew-nut processing mill in Ibadan, Nigeria, fuel consumption varied from 92GJ to 136GJ, accounting for 74.93% and 89.42% of the total energy consumed respectively. This shows that the mill depended more on fuel energy than the other two sources of energy (electricity and manual) (Jekayinfa and Bamgboye, 2003). The major commercial sources of energy in the factory are electricity, coal, oil and gas. Electricity consumption varied from 5.56MJ/kg to 13.48MJ/kg of processed cashew nut; while fuel energy varied from 14.9MJ/kg to 63.62MJ/kg. Akinbami et. al. 2001, studied energy consumption pattern and management in a beverage plant in Nigeria and found that there was an increase in energy intensity with a simultaneous decrease in production.

According to Odigboh (Odigboh, 1992), at the maximum continuous energy consumption rate of 0.30kw and conversion efficiency of 25%, the physical power output of normal human labor in tropical climates is approximately 0.075kW sustained for an 8-10 hour workday.

The consumption of direct energy from major sources in tea industry in Asia was studied by Baruah and Bhattacharyya (1996). They found that tea garden required an estimated 18,408 MJ/ha of human energy in the first year; and about 3,653 MJ/ha from the fifth year onwards. Sant and Dixit (2000) observed that energy efficiency is the least-cost way to achieve considerable reduction in cost of production of goods and services and to provide energy services, while at the same time reducing the environmental impacts of these services.

2. MATERIALS AND METHODS

2.1 Plant Description: The PKO Plants randomly selected for case studies were grouped into three categories according to the level of mechanization of their operations and annual PKO production output. In line with this categorization, the selected PKO plants were stratified to include small, medium and large plants as follow:

i. Small plants: These are plants with total production output less than $300m^3$ of PKO per annum.

ii. Medium Plants: These plants with total annual production output between $300m^3$ and $500m^3$ of PKO.

iii. Large plants: These include plants with annual PKO production output greater than $500m^{3.}$

A sample size of 9 PKO plants comprising of 3 small, medium and large plants respectively was used. The processing facilities of all the plants were very similar and include those for palm-nut drying, palm-nut cracking, palm-kernel roasting, Palm-kernel crushing, Palm-kernel Oil expression, PKO sitting and PKO bottling/Pumping. The type and make of equipment vary, as does their level of sophistication in each category. All the plants selected were evaluated over the same period of twenty-four months. All the mills were less than ten years old. This ensured that they were within their useful years.

2.2 Methods Employed

Data on PKO production, quantity of fossil fuel used, the electrical power used from state grid, and captive power generated were obtained for each of the seven readily defined unit operations. The product of the rated horsepower of each motor, efficiency and the time taken was used to determine the electrical energy usage by the equipment. A motor efficiency of 75 percent was assumed to complete the electrical inputs.

Thus,

$$E_e = \eta P t \text{ ---------- (1)}$$

Where; E_e = electrical energy consumed, Kwh

P = rated horse power of motor, Kw

t = hours of operation, h

η = motor efficiency

Using this procedure, an annual electrical bill for each plant was reconstructed within a 10 percent error. Likewise, energy from fossil fuel (diesel and petrol) was assigned to each unit operation according to their level of consumption. The total quantity of energy consumed from fossil fuel was estimated by multiplying the quantity of fuel consumed by its lower heating value [C_f].

Thus,

$$E_f = C_f \,.\, W \text{ ------- (2)}$$

Where ; E_f = fuel energy consumed, J

C_f = Calorific (lower heating) value of fuel, J/ l

W = quantity of fuel used, l

Human energy expenditure was quantified by multiplying the number of persons engaged in an operation by the man-hour requirement and 0.075 kW, being the average power normal human labor can supply [Odigbo,1992].

Thus,

$$E_h = 0.075 \times N \times M_h \text{ ----------- (3)}$$

Where;

E_h = human energy consumed, Kw-h

N = number of persons engaged in the operation

M_h = man-hour requirement, h

0.075 = the physical power output of normal human labour in tropical climates, kW.

3.0 RESULTS AND DISCUSSION

The energy used per unit operation for a typical small, medium and large PKO mills for 1000kg of Palm-nut are as shown in Tables 1 to 3 and Figures 1 to 3. From the Tables and Figures, it was observed that in all the three categories of mills, thermal energy is mostly used, followed by electrical energy and manual energy. This shows that there is a measure of mechanization in the production of palm kernel oil in all the three plants. About 44.9% of the total energy in the small mill was due to thermal energy, but this increases to 50.1% in the medium mill and 82.4% in the large mill.

Table 1: Estimates of energy consumed/tonne of palm-nut in a typical small PKO mill

Unit Operation	Duration (h)	Energy (MJ)				Percent of Total
		Electrical	Thermal	Manual	Total	
Drying	3.00	-	-	11.25	11.25	3.24
Cracking	2.50	-	109.51	9.45	118.96	34.31
Roasting	1.00	-	46.09	2.70	48.79	14.07
Crushing	2.00	28.80	-	2.70	31.50	9.08
Oil Expression	5.00	129.74	-	5.4	135.14	38.97
Sifting	1.00	-	-	0.81	0.81	0.23
Bottling	0.40	-	-	0.32	0.32	0.10
Total	14.9	158.5	155.6	32.6	346.8	
Percent of Total		45.7	44.9	9.4		

Table 2: Energy consumed/tonne of palm-nut in a typical medium PKO mill

Unit Operation	Duration (h)	Energy (MJ) Electrical	Thermal	Manual	Total	Percent of Total
Drying	2.00	-	-	5.40	5.40	2.49
Cracking	1.20	-	72.76	3.24	76.00	34.98
Roasting	0.50	-	36.18	1.35	37.53	17.27
Crushing	1.00	11.80	-	2.70	14.55	6.70
Oil Expression	3.00	78.10	-	5.40	83.50	38.43
Sifting	0.15	-	-	0.243	0.243	0.11
Bottling	0.30	-	-	0.122	0.122	0.056
Total	8.15	89.9	108.9	18.5	217.3	
Percent of Total		41.4	50.1	4.2		

Table 3: Energy consumed/tonne of palm-nut in a typical large PKO mill

Unit Operation	Duration (h)	Energy (MJ) Electrical	Thermal	Manual	Total	Percent of Total
Cracking	0.70	-	67.81	1.32	69.13	39.15
Roasting	0.36	-	4.97	0.68	5.65	3.20
Crushing	0.55	13.51	-	0.60	14.11	7.99
Oil Expression	1.00	12.80	66.68	1.90	81.38	46.09
Sifting	0.10	-	5.65	0.08	5.73	3.25
Pumping	0.25	-	0.36	0.2	0.56	0.32
Total	2.96	26.3	145.5	4.8	176.6	
Percent of Total		14.90	82.39	2.71		

However, a decrease in the electrical energy consumed was observed from 45.7% in the small mill to 41.4% and 14.9% in medium and large mill respectively. This result is due to the epileptic supply of electricity from the national grid in Nigeria, leaving the industries to depend more on fuel energy; which represents the largest portion of the total energy used in all the plants (over 80% of the total energy). The differences in fuel energy intensities are due to the differences in quantity of palm-nut processed, sophistication of equipment used and age of factories (including equipment and other associated gadgets). In all the three categories of mills studied, manual input was least, from 9.4% in small mill to 4.1% and 2.7% in medium and large mill respectively.

Considering the unit operations during production (Figures 1 to 3), cracking and oil expression were found to require more energy input in all the three mills. In the small mill, cracking and oil _expression accounted for 73.3% of the total input energy, 73.4% in the medium mill and 85.2% in the large mill. This clearly shows that cracking and oil expression are the most energy intensive processes. There were noticeable variations in the fuel requirements by the energy intensive equipment during the study. This variation may be due to lack of adequate attention or lack of concern for energy conservation.

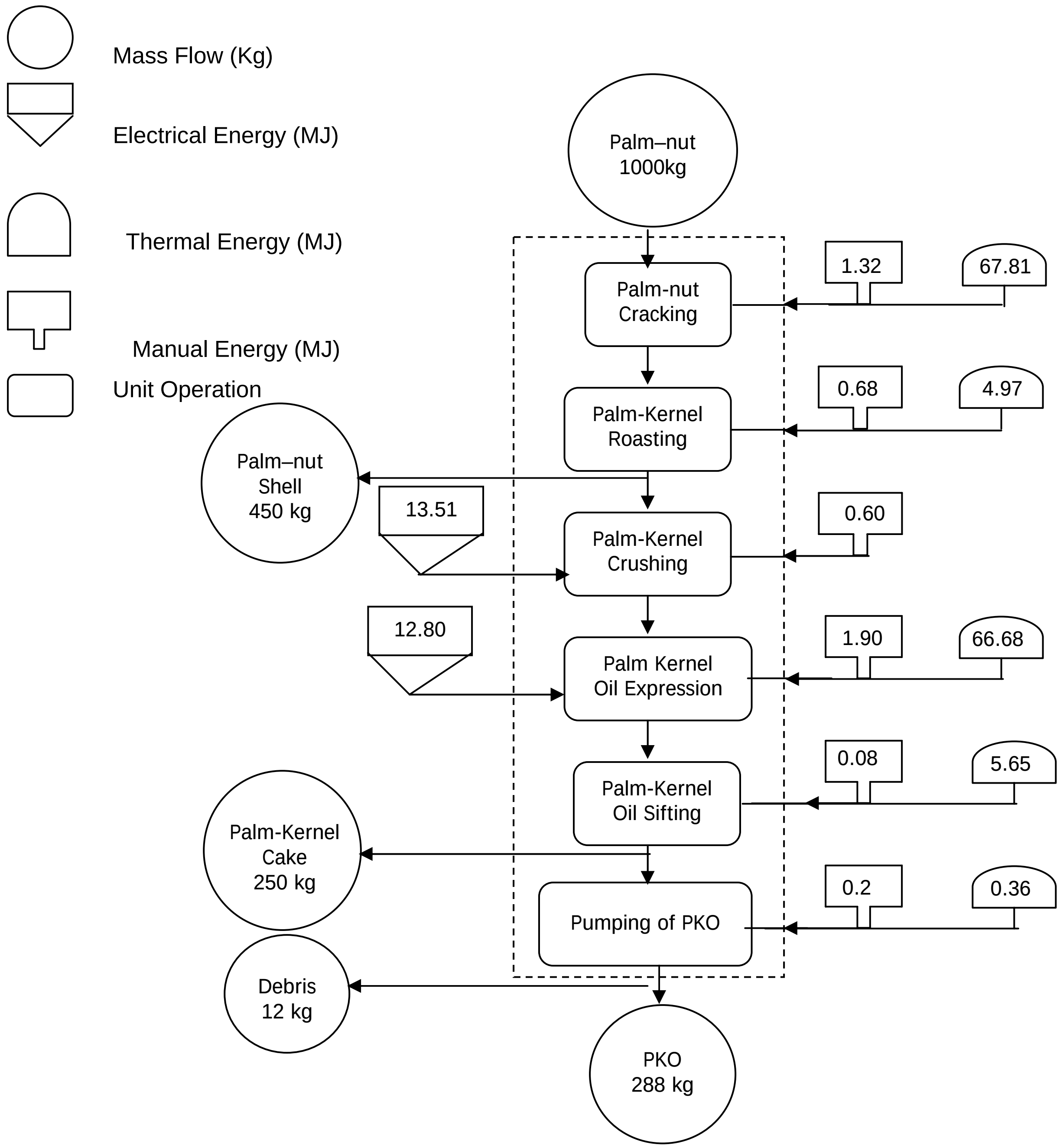

Fig. 1: Energy flow diagram in a Large PKO Mill

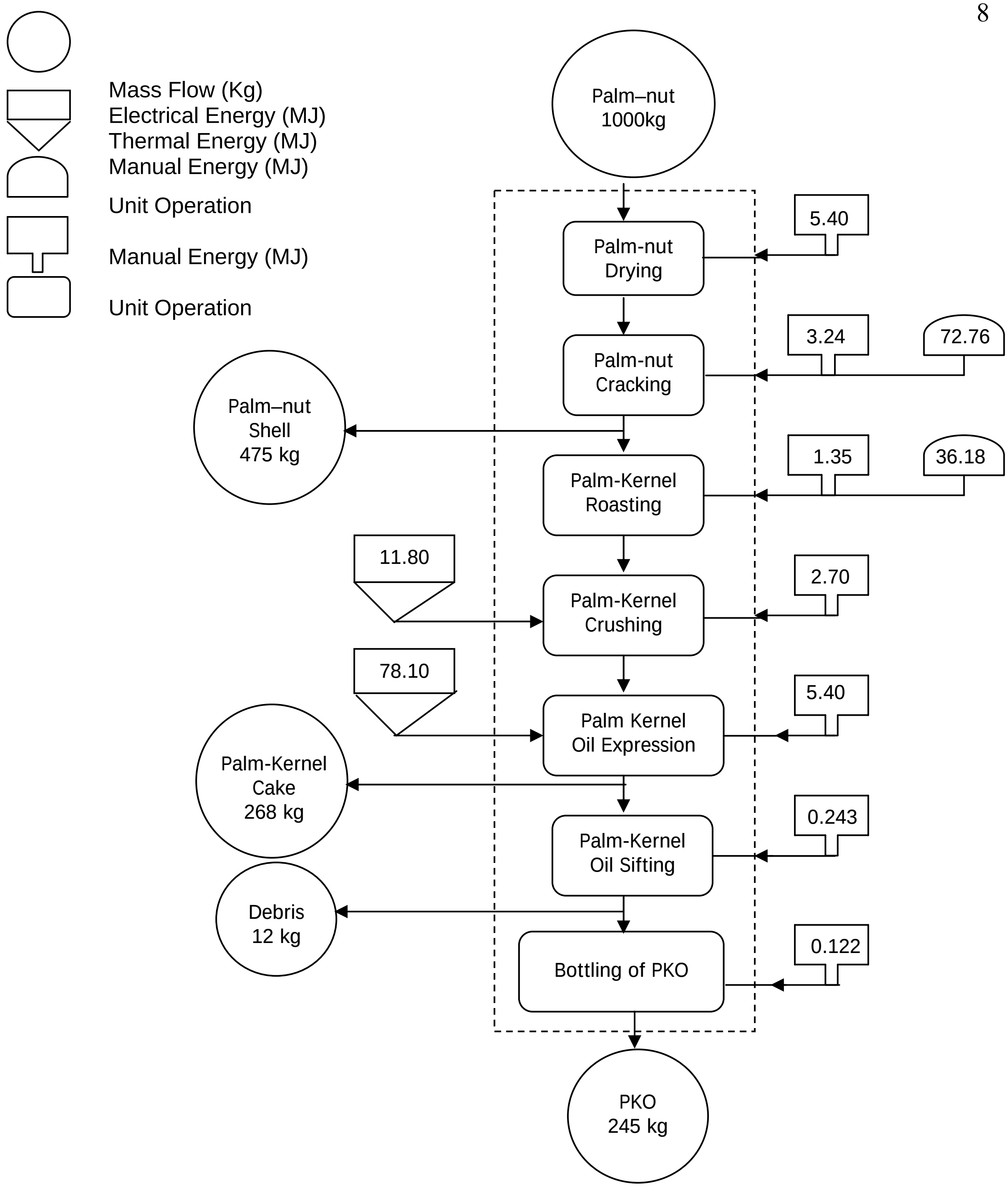

Fig. 2: Energy flow diagram in a Medium PKO Mill

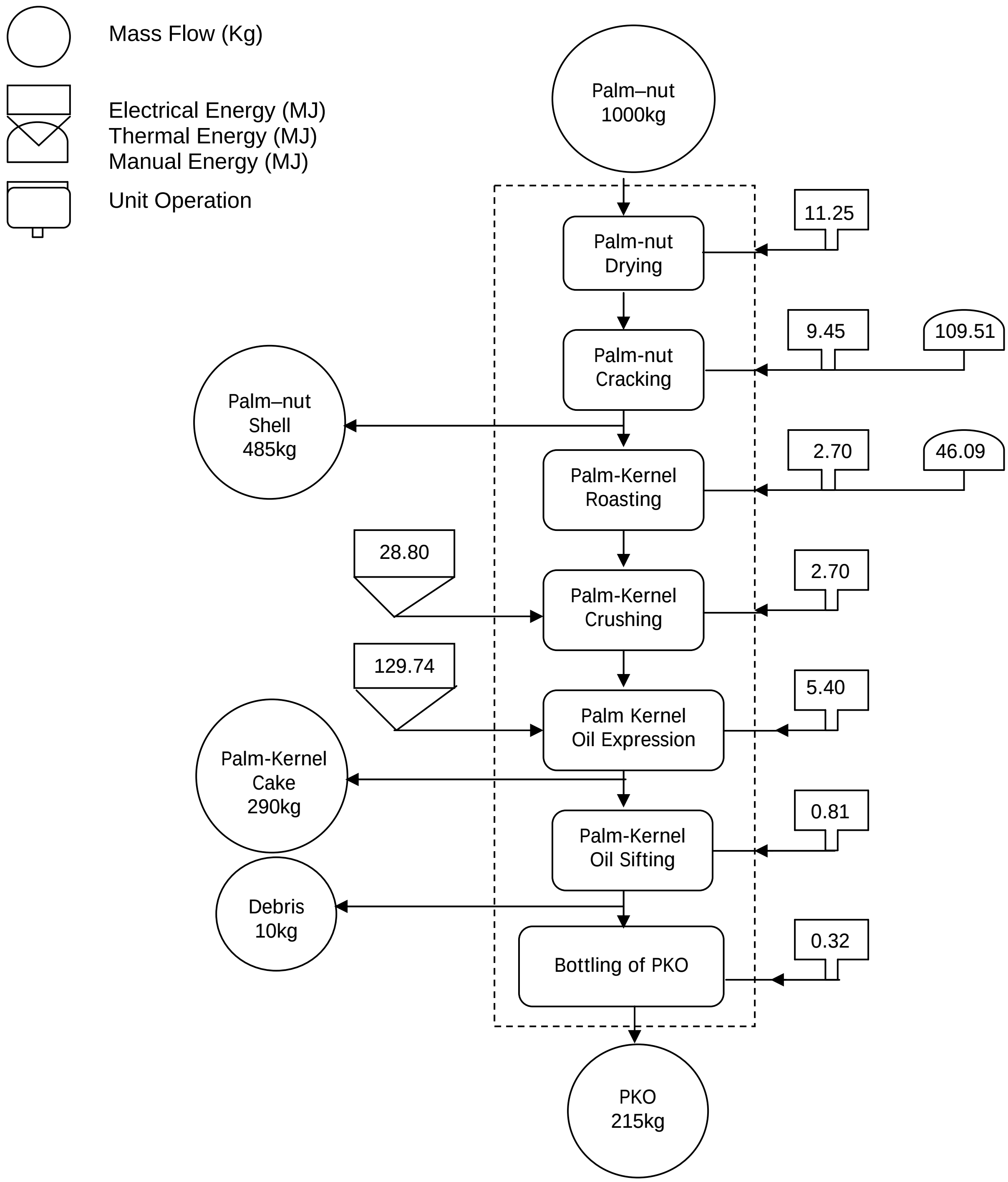

Fig. 3: Energy flow diagram in a Small PKO Mill

However, there are also some operational factors, which may explain variations between plants. The more important of these are: age of equipment installed, cost of energy; type of fuel available and extent to which available plant capacity is used. If careful attention is given to the maintenance and the type of equipment used together with the utilization capacity of the plants, considerable energy will be conserved. Adequate maintenance of the oil extractor and palm-nut cracking will reduce energy consumption pattern and will ultimately reduce the energy requirement of the PKO mill considered.

Energy consumption as a percentage of the total energy in typical small, medium and large plants are as shown in Tables 1, 2 and, 3. The values given in the tables include the total energy consumed by dryer, cracker, roaster, crusher, oil-expressing machine, sifter and bottles/pump during a 7-day operation. It is evident that the oil extractor and palm-nut cracker required more than 70% of the total energy consumed in PKO production in the three plant categories. To reduce the energy consumption of the mills, processing equipment that will reduce energy consumption in both the oil extractor and the palm-nut cracker should be designed and fabricated. The total energy required for processing 1000 kg of palm-nut in a small mill was found to be 346.77MJ, 217.30MJ in medium mills and 176.56MJ in the large mills. There is a decrease in the total energy consumption as we move from small mill to the large mills. This shows that more energy was needed in the small mills than in the medium and large mills respectively. This is an indication of better utilization of energy in the medium and large scale mills respectively. The time taken was less in the medium and large mills compared to the small mills. This likely may account for the energy usage in the mills. The more time is required, the more energy usage.

4. CONCLUSION

In summary, the study of the PKO production operations revealed that thermal, electrical, and manual energy are the main sources of energy input in palm-kernel mills. It was also observed that to produce one kg of PKO required 0.346MJ/kg, 0.217MJ/kg, and 0.176MJ/kg of energy in small, medium and large PKO mills respectively. Palm-nut cracker, Palm-kernel crusher and oil-expressing machine are the most energy- intensive equipment. Attempts should be made to modify or redesign this equipment to make them more energy-efficient.

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