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Energy and cost analysis of organic fertilizer production in Nigeria

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ABSTRACT

Energy study was conducted in an organic fertilizer production plant in Nigeria, to determine the energy consumption patterns and the associated costs for the production of both powdered and pelletised fertilizer. Analysis was conducted for a daily production of 9000 kg of the finished products. Eight and nine defined unit operations were required for production of powder and pellets, respectively. The electrical and manual energy required for the production of powder were 94.5 and 5.6% of the total energy, respectively, with corresponding 93.9 and 5.1% for the production of pellets. The respective average energy intensities were estimated as 0.28 and 0.35 MJ/kg for powder and pellets. The most energy intensive operation was identified as the pulverizing unit with energy intensity of 0.09 MJ/kg, accounting for respective proportions of 33.4 and 27.0% of the total energy for production of powder and pellets. The energy cost per unit production for powdered and pelletised fertilizer using generator were evaluated as ₦2.92 ($0.021) and ₦3.87 ($0.028), respectively, with corresponding values of ₦1.65 ($0.012) and ₦2.00 ($0.014) when electrical energy from the national grid was used. The energy intensities for the production of organic fertilizers were significantly lower than that of inorganic fertilizers.

1. Introduction

In manufacturing industries, energy cost constitutes a major component of the overall production cost. Therefore, energy utilization efficiency is a major determinant of the profitability of manufacturing system [1]. The type of energy usage and the source are significant factors that affect the energy cost in the manufacturing industries. In Nigeria, the conventional energy resources available are crude oil (21.0%), natural gas (24.8%), tar sand (28.4%), coal and lignite (12.7%) and hydro power (13.1%) [2]. At present, Nigeria generates a total of about 2000–3000 MW electrical energy from the combination of hydro and thermal power plants, which is distributed through the national power grid system. Electrical energy supply from the national grid is the cheapest and the most commonly used source of energy for the manufacturing industry. However, the supply of electrical energy is in acute shortage, due in part to the dearth of underlying power generation technology and old facilities of the power stations. Other reasons include problems in transmission and distribution of the energy. Consequently, most manufacturing industries now rely mainly on the use of heavy-duty generating sets for alternative supply of electrical energy [3]. The rising cost of diesel fuel coupled with the environmental impacts connected with the noise and exhaust generated from these power generating sets make their use more expensive. Hence, energy cost of manufactured products is generally higher in developing nations as compared to the developed nations.

Therefore, energy audit has become an important management tool required for economic utilization of energy resources in any manufacturing outfit [3]. This accounts for the extensive work that has been done on energy auditing system of many manufacturing operations with the aim of improving the design and performance of energy transfer systems. Although, extensive literature exists concerning energy audit of many manufacturing processes such as rice processing [4], sunflower oil expression [5], palm-kernel oil processing [6], [7], cashew nut processing [8], poultry processing [9], cassava-based foods [10], milk processing [11], and sugar production [12], limited work has been reported on energy audit of fertilizer processing operations.

The energy requirements for the production of inorganic fertilizers have been reported by Helsel [13]. The study revealed inorganic fertilizer production as an energy intensity operation with energy intensities for production of Nitrogen, Phosphate and Potash fertilizers as 69.5, 7.7 and 6.4 MJ/kg, respectively. The adoption of modern manufacturing techniques has led to significant improvement in the energy efficiency for Nitrogen fertilizer production from a threshold value of about 400 MJ/kg (1910) to theoretical minimum of 40 MJ/kg (2000) [14]. Gellings and

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Nomenclature

Kc	cost of electrical energy per unit operation (₦)
Mc	cost of manual energy per unit operation (₦)
Etc	sum of cost of electrical and manual energy per unit operation (₦)
ξ	thermal efficiency of the generator
ρ	density of diesel
Ep	electrical energy (MJ)
Em	manual energy (MJ)
η	power factor
Et	sum of electrical and manual energy per unit operation (MJ)
Vol	volume diesel (l)
C	calorific value of diesel (MJ/kg)
EI	energy intensity
N	number of persons involved per unit operation
P	rated power of motor (kW)
t	time required for production (h)
Subscript	
i	number per unit operation
tt	total of all unit operations

Parmenter [15] reported energy requirements for transportation and application of inorganic and organic fertilizers. The study revealed that higher energy values were required for transportation and application of organic fertilizer compared to inorganic fertilizers. However, the study did not quantify the energy requirement for production of organic fertilizer. To the best of the authors' knowledge, no work has been conducted on energy consumption pattern and energy cost analysis of organic-based fertilizer manufacturing operations.

In Nigeria, organic fertilizer is produced in forms of powder or pellets. The bulkiness of powdered form makes it more difficult and uneconomical in handling operations. In an attempt to solve the problem of bulkiness, the powdered fertilizer is often compressed into pellets which reduces it volume and ease the handling operations [16].

Organic fertilizer production involves the conversion of organic wastes by aerobic degradation. The basic operations involved in the production process include operations such as collection of the organic waste stocks, transportation, sorting, shredding, composting and curing, drying, screening, pulverising, mixing, pelletising and bagging. These operations require high and steady supply of energy. Therefore, there is need for efficient energy management strategy for the production system. The aim of this study is to analyse the energy consumption pattern and to determine the associated energy cost of the various unit operations required for the production of both powdered and pelletised organic fertilizer in Nigeria. The essence of the study is to access the energy effectiveness of the system in order to assist policy makers to adopt new innovation that could be implemented for optimization of the system and for increased production of organic fertilizer for sustainable crop production and land use development.

2. Materials and method

2.1. Process description

An organic fertilizer processing plant located in Ibadan, Oyo State, southwestern Nigeria, was selected for this study. The plant, located in a typical municipal market, is owned and managed by the Oyo State Government under the auspices of the Ministry of Environment. It was designed, fabricated locally and commissioned in 1996 with a daily production capacity of 9000 kg [1]. The main energy inputs for the production system were electrical and manual energy. Due to inconsistency in power supply from the national grid, a backup power generating set with a capacity of 135 kVA was used as alternative source of electrical power.

There were nine defined unit operations for the production of pelletised fertilizer, while 8 unit operations were involved for the production of powdered fertilizer. The process flow chart of the production system is shown in Fig. 1. Market refuse and animal intestinal (abattoir) waste generated in the market were collected daily. The processing operations began by manual sorting of the non bio-degradable components of the market refuse from the bio-degradable components. The sorted bio-degradable component was shredded and co-composted aerobically with the abattoir waste at ratio of 3:1 by wet weight inside open windrows for about 60 days. The compost was then cured for another 60 days and dried in a rotary dryer. The dried compost was the screened with a sorting machine, milled to fine powder with a pulverizing machine. Mineral fertilizers such as Urea and Rock Phosphate were added as additives and mixed with the milled compost. For production of pellets, Kaolin was added as artificial binding agent and compacted mechanically with an extrusion pelletiser. The finished products (powder or pellets) were then bagged in 50 kg nylon laminated bags. The units operations were carried out in batch process and the energy input into each of these unit operations was accounted for by noting and quantifying the type of energy that was used.

2.2. Data collection

The primary energy resources that were utilized in the plant were electrical and/or manual energy. An inventory of the electrical motors, power rating of the machines, heaters, number of personnel involved, time required for production and material flow in each of the unit operation was made. The power rating of the electrical devices and capacity of each unit were collected from the plant's manager. The production processes were monitored and data were collected over a period of 2 months. The measuring devices used in the course of collecting the data include: (i) a stopwatch for measuring the time that was spent in each unit, (ii) a measuring cylinder for measuring the amount of water and (iii) a weighing balance for measuring the quantity of materials that were used. The respective sensitivities of the stopwatch, measuring cylinder, and weighing balance were 0.01 s, 0.02 ml, and 0.03 g, with corresponding accuracies of 0.02, 0.03, and 0.05%. The data for the time and energy input into each of the unit operations are presented in Table 1.

2.3. Estimation of energy input

The energy components (electrical and manual) for each of the unit operations were calculated for a daily production of 9000 kg of finished fertilizer for both powdered and pelletised fertilizer. The following procedures were used:

2.3.1. Electrical energy

The electrical energy usage by the equipment was obtained as the product of the rated power of each motor and the number of hours of operation. A motor efficiency of 80% was assumed to compute the electrical inputs [5]. This was calculated mathematically as:

$$Ep = \eta Pt \tag{1}$$

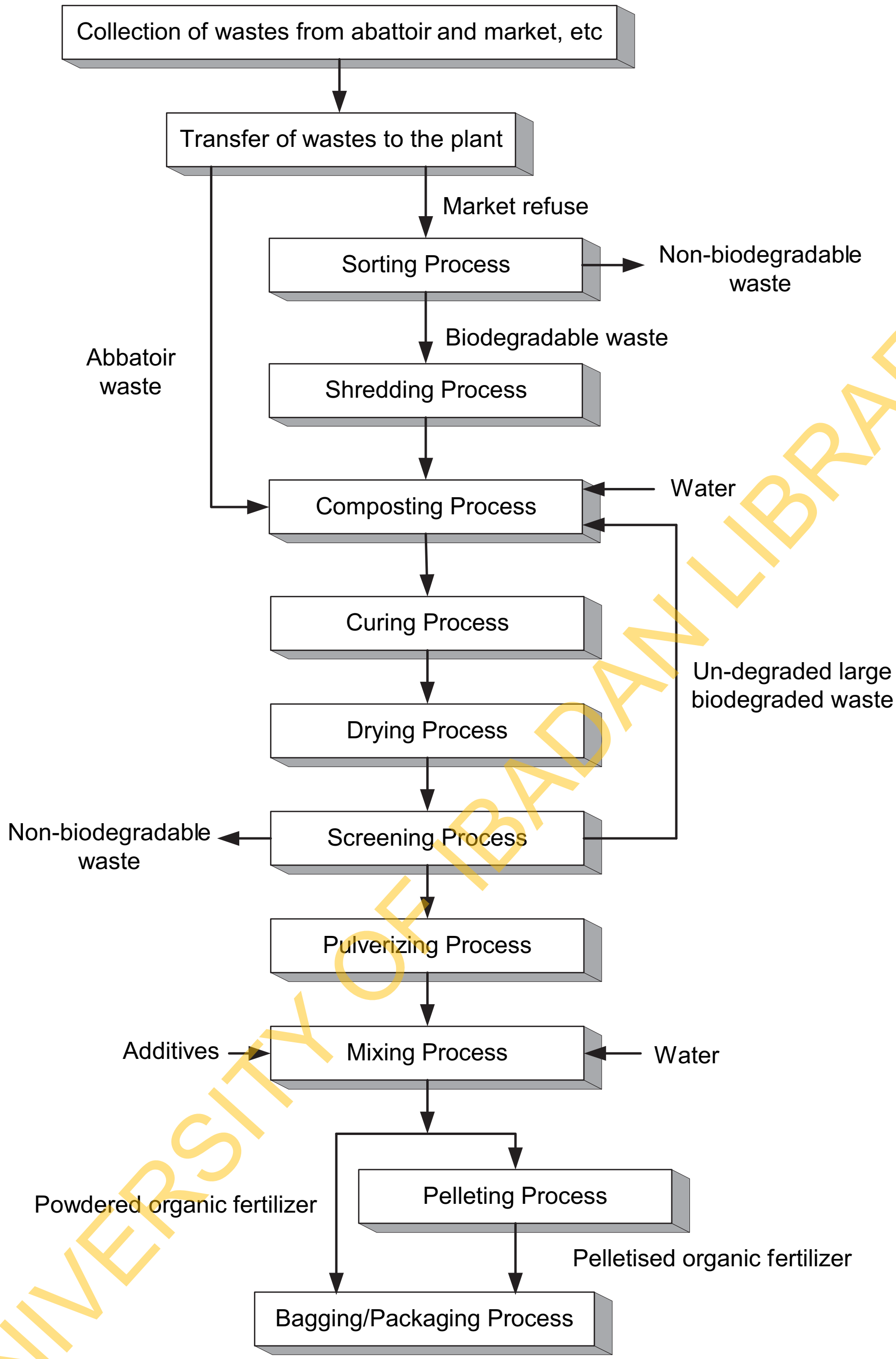

Fig. 1. Process flow chart of the organic fertilizer processing operation.

where *Ep* is the electrical energy consumed in kW h, *P* is the rated power of motor in kW, *t* the hours of operation in hours and η, the power factor (assumed to be 0.8).

2.3.2. Manual energy

This was estimated based on the values recommended by Odigboh [17]. According to him, at the maximum continuous energy consumption rate of 0.30 kW and conversion efficiency of 25%, the physical power output of a normal human labourer in tropical climates is approximately 0.075 kW sustained for an 8–10 h workday. This was calculated mathematically as [3,7,8]:

$$Em = 27Nt \tag{2}$$

where *Em* is the manual energy in MJ, 27 is the average power of a normal human labour in MJ, *N* is the number of persons involved in an operation and *t*, the useful time spent to accomplish a given task in hours.

2.4. Estimation of energy intensity (EI)

The energy intensity (energy consumed per unit product) for each of the unit operation (EI_i) required for the production of powdered pelletised fertilizer were estimated as the ratio of the

Table 1
Required parameters for evaluating energy per unit operation in organic fertilizer plant.

Operation description	Required parameters	Value
Sorting	Time taken for sorting (h)	8.0
	Number of persons involved in sorting	5
Shredding	Electrical power (kW)	11.25
	Time taken for shredding (h)	9.0
	Number of persons involved in shredding	2
Composting	Time taken for sorting (h)	7.0
	Number of persons involved in sorting	5
Drying	Electrical power (kW)	5.25
	Time taken for drying (h)	9.0
	Number of persons involved in drying	2
Screening	Electrical power (kW)	15.00
	Time taken for screening (h)	9.0
Pulverizing	Electrical power (kW)	26.25
	Time taken for pulverising (h)	9.0
Mixing	Electrical power (kW)	7.13
	Time taken for mixing (h)	9.0
Pelleting	Electrical power (kW)	18.75
	Time taken for pelleting (h)	9.0
	Number of persons involved in pelleting	2
Bagging	Electrical power (kW)	5.63
	Time taken for bagging (h)	9.0
	Number of persons involved in bagging	4

sum of energy inputs per unit operation (Et_i) and the total weight of the product output. It is expressed as:

$$EI_i = \frac{\text{sum of energy inputs per unit operation, } Et_i \text{ (MJ)}}{\text{total weight of product output (kg)}} \quad (3)$$

The average energy intensity (EI_{tt}) for the production of powdered pelletised fertilizer were estimated as the ratio of the sum of energy inputs for all unit operations (Et_{tt}) and the total weight of the product output. It is expressed as:

$$EI_{tt} = \frac{\text{sum of energy inputs for all unit operations, } Et_{tt} \text{ (MJ)}}{\text{total weight of product output (kg)}} \quad (4)$$

2.5. Estimation of energy costs

2.5.1. Cost of electrical energy

The cost of electrical energy required for the production of both powdered and pelletised fertilizer was computed, based on the two available sources of electrical energy. In Nigeria, available sources of

Table 2
Time and energy requirement per unit operation for the production of powdered organic fertilizer.

S/N (i)	Process	Production time (h)	Electrical energy, Ep_i (MJ)	Manual energy, Em_i (MJ)	Total energy, Et_i (MJ)	Percentage energy (Et_i Et_i/Et_{tt}) *100 (%)
1	Sorting	8	–	38.88	38.80	1.53
2	Shredding	9	365.50	17.50	383.00	15.06
3	Composting/ Curing	7	–	34.02	29.16	1.15
4	Drying	9	325.62	17.50	343.12	13.5
5	Screening	9	486.00	–	486.00	19.11
6	Pulverizing	9	850.50	–	850.50	33.4
7	Mixing	9	230.85	–	230.85	9.08
8	Bagging	9	162.00	34.40	182.25	7.17
Total			Ep_{tt} = 2420.47	Em_{tt} = 142.30	Et_{tt} = 2523.68	100.00
Percentage of total (%)			94.45	5.55	100.00	

$Ep_{tt} = \sum_{i=1}^{8} Ep_i$; $Em_{tt} = \sum_{i=1}^{8} Em_i$; $Et_{tt} = \sum_{i=1}^{8} Et_i$.

Table 3
Time and energy requirement per unit operation for the production of pelletised organic fertilizer.

S/N (i)	Process	Production time (h)	Electrical energy, Ep_i (MJ)	Manual energy, Em_i (MJ)	Total energy, Et_i (MJ)	Percentage energy (Et_i/Et_{tt}) *100 (%)
1	Sorting	8	–	38.88	38.80	1.23
2	Shredding	9	365.50	17.50	383.00	12.15
3	Composting/ Curing	7	–	34.02	29.16	0.93
4	Drying	9	325.62	17.50	343.12	10.89
5	Screening	9	486.00	–	486.00	15.42
6	Pulverizing	9	850.50	–	850.50	26.99
7	Mixing	9	230.85	–	230.85	7.33
8	Pelleting	9	540.00	17.50	607.50	19.28
9	Bagging	9	162.00	34.40	182.25	5.78
Total			Ep_{tt} = 2960.47	Em_{tt} = 159.80	Et_{tt} = 3151.18	100.00
Percentage of total (%)			93.95	5.07	100.00	

$Ep_{tt} = \sum_{i=1}^{9} Ep_i$; $Em_{tt} = \sum_{i=1}^{9} Em_i$; $Et_{tt} = \sum_{i=1}^{9} Et_i$.

electrical energy are mainly from national grid power supply or by use of a self power generating set. To determine the cost of electrical energy, based on the national grid, the current energy tariff of ₦20 ($0.14)/kW h was used, while the unit cost of ₦115 ($0.82) per litre was used to determined the cost of diesel fuel required to run the generator. The volume of diesel fuel required to run the generator, based on the energy requirement of the unit operations was calculated from the expression:

$$Vol = \frac{10^3 \times Ep}{\rho \times \xi \times C} \quad (5)$$

Where, Vol is volume of diesel fuel required in litre, Ep is electric energy in MJ, ξ is thermal efficiency of the generator (assumed to be 40%), ρ is density of diesel fuel (894 kg/m^3) and C is calorific value of the fuel (assumed to be 42 MJ/kg).

The cost of electrical energy, based on the national grid was calculated as the product of the energy consumption per unit operation and the unit cost of energy of ₦20 ($0.14)/kW h (national energy tariff), while the electrical energy cost, based on the use of self power generating set was calculated as the product of the diesel consumption of the generator in litres and the unit cost of ₦115 ($0.82) per litre for diesel fuel.

2.5.2. Cost of manual energy

The current minimum wage of ₦7,500 ($53.57) per month paid by the Oyo State Government was used to compute the unit cost of manual energy in accordance with Odigboh [17] as ₦34.72 ($0.25)/kW h. The cost of manual energy per unit operation was calculated as the product of the manual energy consumption and the unit cost of manual energy.

3. Results and discussion

The time and energy requirement for a daily production of 9000 kg of both powdered and pelletised products are given in Tables 2 and 3. The energy consumption data that was obtained provides useful information on the sources of energy requirement of each processing unit. The data revealed that the total energy requirement for production of powder and pellets were found to be 2523.68 and 3151.18 MJ, respectively. The total energy intensities were estimated to be 0.28 and 0.35 MJ/kg for production of powdered and pelletised fertilizers, respectively. The estimated energy intensities for production of both powdered (0.28 MJ/kg)

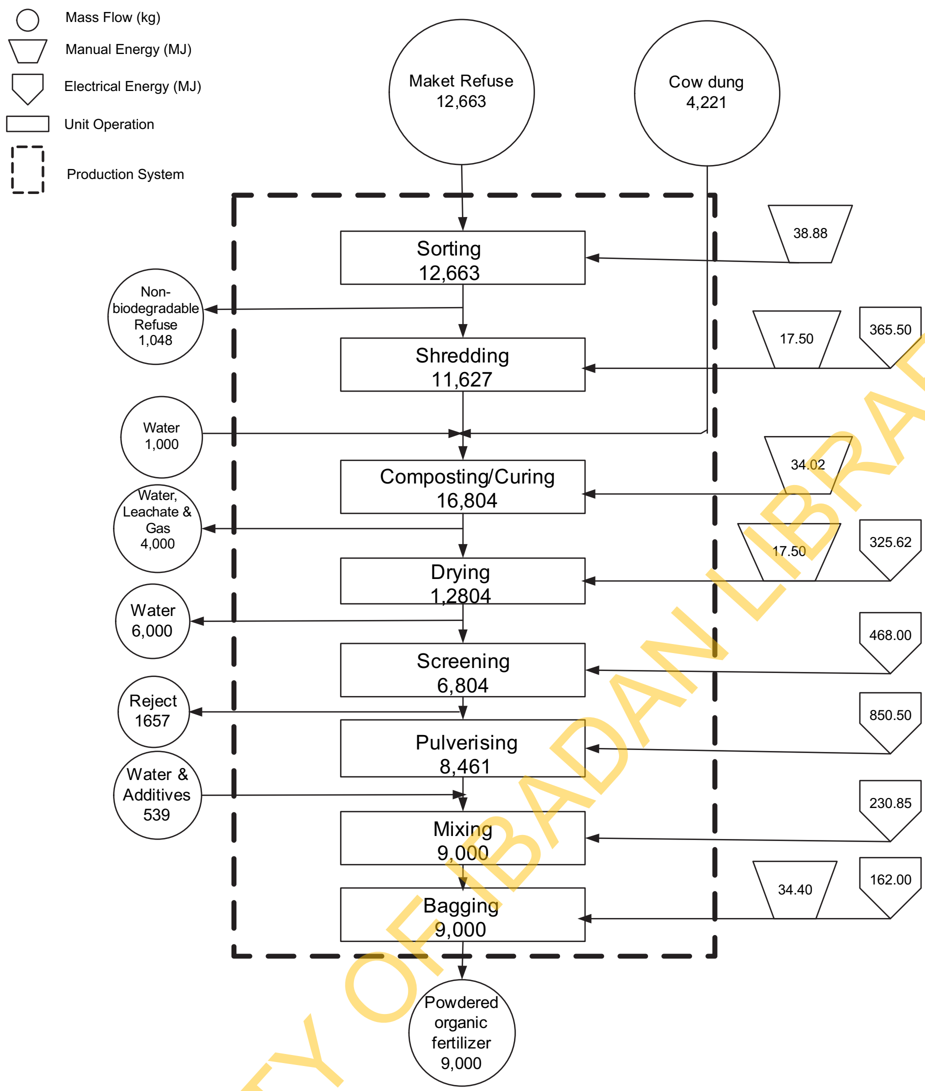

Fig. 2. Energy and mass flow diagram for the production of powdered organic fertilizer.

and pelletised (0.35 MJ/kg) organic fertilizers were considerably lower, compared to the energy intensities that was required for the production of Nitrogen (69.5 MJ/kg), Phosphate (7.7 MJ/kg), and Potash (6.4 MJ/kg) fertilizers [13]. The electrical energy intensities were 0.27 and 0.33 MJ/kg for the production of powdered and pelletised products, respectively. The corresponding manual energy intensities were 0.016 and 0.018 MJ/kg. These clearly indicated that the pelletised product consumed more energy than the powdered product. The manual energy consumption for both powdered and pelletised fertilizer represented proportions which are lower than 6% of the total energy consumption.

It was observed that all the unit operations required electrical energy except for composting and sorting that were done manually. However, screening, pulverizing and mixing utilised only electrical energy without manual energy. The most energy intensive operating unit in the production system was identified as the pulverising unit with 850.50 MJ of energy, accounting for 33.4 and 26.99% of total energy required for the production of powder and pellets, respectively. To optimize the energy consumption of the pulverising unit, two options can be considered: (1) process modification and (2) design modification. The process modification option will involve a change in the unit operation. In this case, a wet grinding method is suggested rather than the dry grinding method currently in use because of the low energy input requirement for wet grinding. The wet grinding method requires a wetting process and subsequently a drying process after the grinding process in order to remove added moisture. But the drying of organic matter such as compost is known to be energy intensive [1]. On the other hand, the second option (design modification) will involves the modification of the design of the pulverising machine in order to increase its capacity. For the first option, a huge sum of additional investment will be required for the modification of the unit operation, while a minimal additional cost is required for the design modification option. In terms of cost effectiveness, the second option (design modification) is considered to be more feasible.

The energy and mass flow diagrams for the production of powdered and pelletised products are shown in Figs. 2 and 3, respectively, using the modified form of energy accounting symbol, presented by Singh [18]. The electrical and manual energy consumption, together with the material mass flow are assigned to each unit operations. The pelletised product involves nine defined unit operations while the powdered production unit involves 8 units.

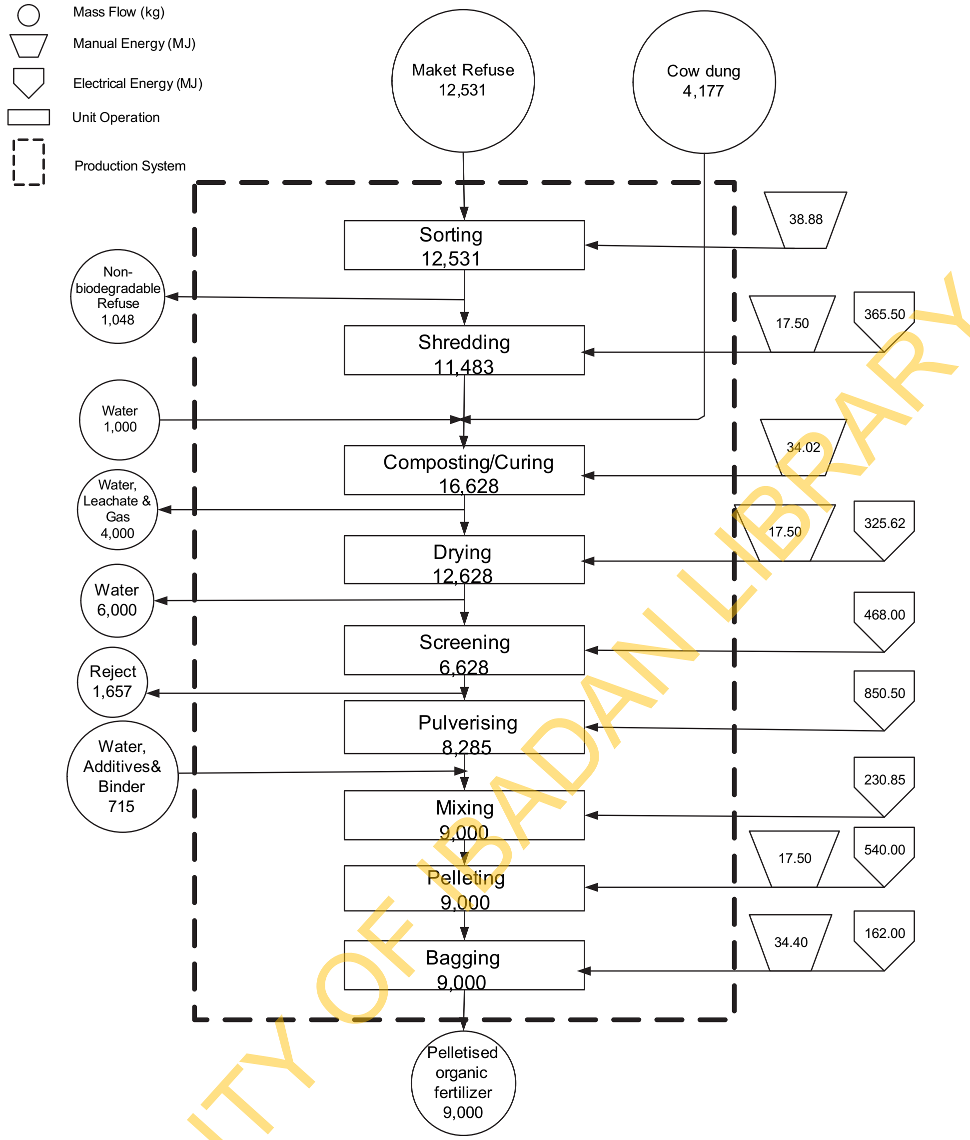

Fig. 3. Energy and mass flow diagram for the production of pelletised organic fertilizer.

The unit cost of energy is largely dependent on the source of electrical energy that was used in the plant. The instability of power supply on the national grid often necessitated the use of a standby self power generating set as an alternative source for electrical power supply. The daily power outage for the national grid was calculated to range between 10 and 100% with the average of 54.4% of the total production time. The daily diesel consumption that was required to run the power generator for the same period is shown in Fig. 4. A total of 260 L of diesel was consumed on day eight, which represents the highest volume of diesel consumed, while on day four, a total of 25 L was used, this being the least volume of diesel consumed during the period. The variation in volume of diesel that was consumed indicates the change in the source of power supply from generator to national grid and vice-versa. This is due to inconsistent power supply from the national grid in Nigeria.

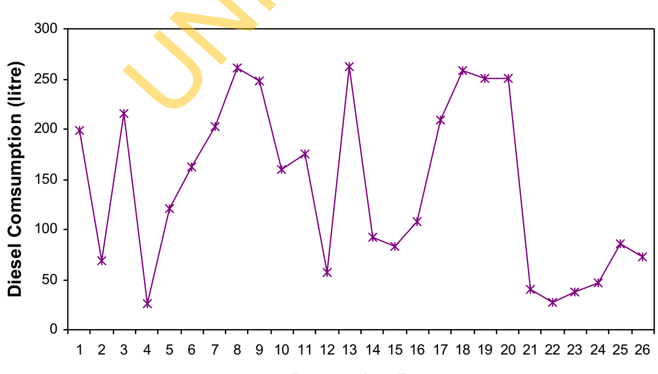

Fig. 4. Volume of diesel consumed daily for the production of the organic fertilizer.

The two primary sources of electrical energy utility in the plant were the national grid and generating set. The acute energy crisis in the country often necessitated the use of generator for most of the production time. In order to calculate the cost of energy inputs of the plant, two scenarios were considered. The first condition was a case 0% power outage involving the use of national grid for the total production time, while the second condition was a case 100% power outage involving the use of only the power generator as source of electrical energy. The energy costs for the production of 9000 kg of powdered and pelletised fertilizer using the two different sources of electrical energy are given in Tables 4–7.

Table 4
Energy cost per unit operation for production of powdered fertilizer using power supply from the national grid and manual energy.

S/N (i)	Process	Energy from national grid		Manual energy		Total cost of energy $Etc_i = Kc_i + Mc_i$ (₦)	Percentage cost of energy (%)
		Electrical energy, Ep_i (kW h)	Cost of energy[a] Kc_i (₦)	Energy consumption, Em_i (kW h)	Manual energy cost[b] Mc_i (₦)		
1	Sorting	–	–	10.80	374.98	374.98	2.53
2	Shredding	101.53	2030.60	4.86	168.74	2199.34	14.84
3	Composting/Curing	–	–	9.45	328.10	328.10	2.21
4	Drying	90.45	1809.00	4.86	168.74	1977.74	13.34
5	Screening	135.00	2700.00	–	–	2700.00	18.21
6	Pulverizing	236.25	4725.00	–	–	4725.00	31.87
7	Mixing	64.13	1282.60	–	–	1282.60	8.65
8	Bagging	45.00	900.00	9.72	337.48	1237.48	8.35
Total		$Ep_{tt} = 672.33$	$Kc_{tt} = 13{,}447.20$	$Em_{tt} = 39.69$	$Mc_{tt} = 1378.04$	$Etc_{tt} = 14{,}825.24$	100
Percentage of total (%)			90.70		9.30	100	

$Ep_{tt} = \sum_{i=1}^{8} Ep_i$; $Kc_{tt} = \sum_{i=1}^{8} Kc_i$; $Em_{tt} = \sum_{i=1}^{8} Em_i$; $Mc_{tt} = \sum_{i=1}^{8} Mc_i$; $Etc_{tt} = \sum_{i=1}^{8} Etc_i$.
[a] Unit cost of electric from national grid = ₦20/kW h.
[b] Unit cost of manual energy = ₦34.72/kW h.

Table 5
Energy cost per unit operation for production of pelletised fertilizer using power supply from the national grid and manual energy.

S/N (i)	Process	Energy from national grid		Manual energy		Total cost of energy $Etc_i = Kc_i + Mc_i$(₦)	Percentage cost of energy (%)
		Electrical energy, Ep_i (kW h)	Cost of energy[a] Kc_i (₦)	Energy consumption, Em_i (kW h)	Manual energy cost[b] (Mc_i) (₦)		
1	Sorting	–	–	10.80	374.98	374.98	2.08
2	Shredding	101.53	2030.60	4.86	168.74	2199.34	12.22
3	Composting/Curing	–	–	9.45	328.10	328.10	1.82
4	Drying	90.45	1809.00	4.86	168.74	1977.74	10.99
5	Screening	135.00	2700.00	–	–	2700.00	15.01
6	Pulverizing	236.25	4725.00	–	–	4725.00	26.26
7	Mixing	64.13	1282.60	–	–	1282.60	7.13
8	Pelleting	150.00	3000.00	4.86	168.74	3168.74	17.61
9	Bagging	45.00	900.00	9.72	337.48	1237.48	6.88
Total		$Ep_{tt} = 822.36$	$Kc_{tt} = 16{,}447.20$	$Em_{tt} = 44.55$	$Mc_{tt} = 1546.78$	$Etc_{tt} = 17{,}993.98$	100
Percentage of total (%)			91.40		9.60	100	

$Ep_{tt} = \sum_{i=1}^{8} Ep_i$; $Kc_{tt} = \sum_{i=1}^{8} Kc_i$; $Em_{tt} = \sum_{i=1}^{8} Em_i$; $Mc_{tt} = \sum_{i=1}^{8} Mc_i$; $Etc_{tt} = \sum_{i=1}^{8} Etc_i$.
[a] Unit cost of electric from national grid = ₦20/kW h.
[b] Unit cost of manual energy = ₦34.72/kW h.

The energy costs of the different unit operations for the production of powder and pellets, using only the national grid as source of electrical energy are given in Tables 4 and 5, respectively. The energy cost analysis for using power from the national grid as source of electrical energy for the production of powdered fertilizer is given in Table 4. The total cost of energy was estimated as ₦14,825.24 ($105.895) with energy cost per unit production of N1.65 ($0.012). The data showed that the cost of electrical energy was ₦13,447.20 ($96.051), which accounts for 90.70% of the total energy cost, while the cost of manual energy was estimated to be ₦1,378.04 ($9.843). The highest and the lowest energy cost were 31.87 and 1.21% of total cost for pulverizing unit and composting/curing process, respectively.

For the production of pelletised fertilizer, using the national grid as source of electrical energy (Table 5), the total energy cost was estimated to be ₦17,993.98 ($128.53), with the cost of electrical and manual energy having respective proportions of 91.40 and 9.60% of the total cost. The energy cost per unit production was

Table 6
Energy cost per unit operation for production of powdered fertilizer using power from generator and manual energy.

S/N (i)	Process	Energy required to run Generator		Manual energy		Total cost of energy, $Etc_i = Kc_i + Mc_i$ (₦)	Percentage cost of energy (%)
		Volume of diesel required, Vol_i (liters)	Cost of diesel required[a] Vc_i (₦)	Energy consumption, Em_i (kW*h)	Manual energy cost[b] Mc_i(₦)		
1	Sorting	–	–	10.80	374.98	374.98	1.43
2	Shredding	32.36	3721.40	4.86	168.74	3890.14	14.80
3	Composting/Curing	–	–	9.45	328.10	328.10	1.25
4	Drying	28.91	3324.65	4.86	168.74	3493.39	13.29
5	Screening	43.14	4961.10	–	–	4961.10	18.87
6	Pulverizing	75.50	8682.50	–	–	8682.50	33.03
7	Mixing	20.49	2356.35	–	–	2356.35	8.96
8	Bagging	16.18	1860.70	9.72	337.48	2198.18	8.36
Total		$Vol_{tt} = 216.18$	$Vc_{tt} = 24{,}906.70$	$Em_{tt} = 39.69$	$Mc_{tt} = 1378.04$	$Etc_{tt} = 26{,}284.74$	100
Percentage of total (%)			94.76		5.24	100	

$Vol_{tt} = \sum_{i=1}^{8} Vol_i$; $Vc_{tt} = \sum_{i=1}^{8} Vc_i$; $Em_{tt} = \sum_{i=1}^{8} Em_i$; $Mc_{tt} = \sum_{i=1}^{8} Mc_i$; $Etc_{tt} = \sum_{i=1}^{8} Etc_i$.
[a] Unit cost of diesel = ₦115/L.
[b] Unit cost of manual energy = ₦34.72/kW h.

Table 7
Energy cost per unit operation for production of pelletised fertilizer using power from generator and manual energy.

S/N (i)	Process	Energy required to run Generator		Manual energy		Total cost of energy $Etc_i = Kc_i + Mc_i$ (₦)	Percentage cost of energy (%)
		Volume of diesel required, $Vol_{,I}$ (liters)	Cost of diesel required[a] Vc_i (₦)	Energy consumption, Em_i (kW h)	Manual energy cost[b] (Mc_i) (₦)		
1	Sorting	–	–	10.80	374.98	374.98	1.08
2	Shredding	32.36	3721.40	4.86	168.74	3890.14	11.17
3	Composting/Curing	–	–	9.45	328.10	328.10	0.94
4	Drying	28.91	3324.65	4.86	168.74	3493.39	10.03
5	Screening	43.14	4961.10	–	–	4961.10	14.25
6	Pulverizing	75.50	8682.50	–	–	8682.50	24.94
7	Mixing	20.49	2356.35	–	–	2356.35	6.77
8	Pelleting	53.93	8359.15	4.86	168.74	8527.89	24.50
9	Bagging	16.18	1860.70	9.72	337.48	2198.18	6.31
Total		$Vol_{tt} = 270.51$	$Vc_{tt} = 33{,}256.85$	$Em_{tt} = 44.55$	$Mc_{tt} = 1546.78$	$Etc_{tt} = 34{,}812.63$	100
Percentage of total (%)			95.56		4.44	100	

$Vol_{tt} = \sum_{i=1}^{9} Vol_i$; $Vc_{tt} = \sum_{i=1}^{9} Vc_i$; $Em_{tt} = \sum_{i=1}^{9} Em_i$; $Mc_{tt} = \sum_{i=1}^{9} Mc_i$; $Etc_{tt} = \sum_{i=1}^{9} Etc_i$.
[a] Unit cost of diesel = ₦115/L.
[b] Unit cost of manual energy = ₦34.72/kW h.

estimated as ₦2.00 ($0.014). The pelletising process increased the unit cost of energy by 30.30% compared to the unit cost for the production of powdered fertilizer.

For the production of powdered fertilizer with the use of power generator and manual energy (Table 6), the total cost of energy was estimated as ₦26,284.74 ($187.75) with energy cost per unit production of ₦2.92 ($0.02). The data showed that a total of 216.18 L of diesel was required to supply the needed electrical energy at the cost of ₦24,906.70 ($177.91) which accounts for 94.76% of the total cost of energy. The cost of manual energy was estimated to be ₦1,378.04 ($9.84). The highest and the lowest energy cost were 33.03 and 1.25% of total cost for pulverizing unit and composting/curing process, respectively.

The production of pelletised fertilizer with the use of power generator and manual energy (Table 7), required a total energy cost of ₦34,812.63 ($248.66), with the cost of electrical and manual energy having respective proportions of 95.56 and 4.44% of the total cost. The energy cost per unit production was estimated as ₦3.87 ($0.03).

The comparative cost analysis for using the national grid (Tables 4 and 5) and generator (Tables 6 and 7) for the production of both powdered and pelletised fertilizer showed an increase of ₦11.459.50 (77.30%) in the total cost of energy for the production of powdered fertilizer when power generator was used compared to the use of the national grid, while a corresponding increase of ₦16.818.65 (93.45%) was obtained for the production of pelletised fertilizer. From the foregoing, it can be concluded that the production of both powdered and pelletised fertilizer are more economical with the use of the national grid as source of electrical energy. However, the energy crisis in the country has led to acute shortage in supply of electricity. Hence most companies in the country are compelled to rely mainly on the use of heavy-duty power generating set for supply of their electrical energy. However, the rising cost of diesel fuel and the associated environmental pollution are major set-backs which limits the use of generators as alternative source of electrical energy.

4. Conclusions

In this study, the energy cost analyses for the production of powdered and pelletised organic fertilizer in Nigeria was investigated. The results indicated that electrical and human energy constituted the major portion of the energy input used for the production of organic fertilizer. The estimated energy intensities for production of powdered and pelletised organic fertilizer were 0.28 and 0.35 MJ/kg, respectively. The most energy intensive operation was the pulveriser, which accounts for 27.0% of the total energy for production of pellets and 33.4% for powdered fertilizer. The energy cost per unit production with the use of electricity from the national grid for the production of powdered and pelletised organic fertilizer were estimated to be ₦1.65 ($0.012) and ₦2.00 ($0.014), respectively. The pelletising process increased the unit cost of energy by 30.30% compared to the unit cost for the production of powdered fertilizer. The use of power generator led to an increase of ₦11.459.50 (77.30%) and ₦16.818.65 (93.45%), respectively in the total cost of energy for the production of powdered and pelletised fertilizer compared to use of electrical energy from the national grid.

Authors observed that energy input varies from 1 unit operation to another. It can be stated that the variation is due to energy consumption pattern of each units. The data found in the study can be used as a basis to evaluate energy input and cost benefit of producing an organic fertilizer in any part of the country.

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