Energy Consumption Pattern of Selected Mechanized Farms in Southwestern Nigeria

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ABSTRACT

A study was conducted to determine and analyze the pattern of energy utilization in all sections of some selected mechanized farms in Southwestern part of Nigeria. In this study, three – year data (2002 – 2004) collected on energy performance of the farms was presented and analyzed indicating the yearly and total consumption of electricity and fuel. Energy performance indicators employed in the study include Normalized Performance Indicator (NPI), Energy Intensity (EI) and Energy Cost (EC). Average energy consumption per year of the 3 audit years was 1022.85GJ with fuel and electricity making up 58% and 42% respectively. The average value of the NPI (GJ/m^2) was 0.17, 0.28, 0.83, 0.0087, 0.015 and 0.082, for feed mill, hatchery, mechanical workshop, piggery, poultry and administrative section respectively. The corresponding average EI (GJ/m^2) and EC (₦'000) values are 0.128, 0.187, 0.105, 0.026, 0.011, 0.48 and 146.15, 91.99, 55.17, 34.38, 71.66, 374.7 respectively. The calculated NPI values indicate a good energy consumption and management for all the six sections of the farms studied.

Keywords: Energy Consumption, Mechanized Farm, Normalized Performance Indicator.

1. INTRODUCTION

Energy is the capacity to do work and the basic driving force in man's development. It is both the fuel and feedstock for agriculture. Agriculture is essentially an energy conversion process. It is the transformation of solar energy, fossil fuel products and electricity into food and fiber for human beings (Fluck and Baird, 1980).

Mechanization of agricultural production in the areas of handling and conveyance, thermal processing of farm products to assure safety and conversion processes that create new forms of agricultural products are examples of activities in which industrialized agriculture has relied on energy to carry out the desired operation and obtain high processing efficiencies. The intensity of mechanization of farming activities in Nigeria is still quite low and as such the agricultural energy consumption is not as high as in the developed countries. However, the key to economic development lies in raising the agricultural productivity which directly involves the utilization of more energy resources.

In recent years, there has been evolution of mechanized farms in Nigeria featuring large acreage of crop production and cottage agro-based industries such as feed mills, hatchery, modern poultry and piggery, and well-equipped mechanical workshops. These farms make use of energy in various forms for their daily operations. Igbeka (1986) stated that the economic performance of machinery system is measured in terms of money per unit output, so that maximum system performance occurs when the production cost per unit is low. This can only be achieved by continuously monitoring the management of the production inputs(energy inclusive) and making sure that wastage is minimized or eliminated entirely.

Energy is one of the largest controllable costs in most organizations and there is considerable scope for reducing energy consumption and hence cost. The benefits are reflected directly in an organizaiton's profitability while also making a contribution to global environmental improvement in terms of energy conservation. Energy audit is a review of the total energy used and costs, normally performed in conjunction with a site investigation. It involves the classification of the energy sources and their contribution in running the factory. It provides a structural review of how energy is being purchased, managed and used with the aim of identifying opportunities for energy cost saving through improved services. It also gives the estimate of potential annual energy savings with implementation costs and pay back periods. Energy survey is a methodical study to assess energy flows in a factory or building and establish a breakdown of the energy costs. Where performance is obviously poor, a full survey is needed.

Several researchers have reported on the energy consumption of different agricultural process operations both within and outside Nigeria (Singh, et. al, 1997; Edmundo, 1998; Palaniappan and Subramanian, Dauda, 2000; Jekayinfa, 2001; Jekayinfa and Olafimihan, 2000; and Aiyedun and Onakoya, 2000, Megbowon and Adewunmi, 2002; Ozkan et al., 2004; Mahapatra et al., 2003; Mrini et al., 2002). However, not much activity is evident in the area of energy utilization in mechanized farms in Nigeria, and even the availability of vital data regarding energy generation and use is doubtful.

This paper investigates the energy utilization pattern of selected typical mechanized farms in Oyo, Ogun and Osun States of Nigeria.

2. MATERIALS AND METHODS

2.1 Survey Areas

The twenty farms used for this survey are located in twenty Local Government Areas situated in Oyo, Ogun and Osun States in Nigeria with an average total farm area of about 250 hectares. Each farm has 6 distinct sections namely poultry, hatchery, feed mill, piggery, mechanical workshop and the administrative blocks. These States are located in the South-West of Nigeria with two dominant vegetation of tropical rain forest and tropical secondary forest. Temperatures range from 28 ^{o}C in the cold days to 38^{o}C in the hot months (Igbeka, 1986).

2.2 Data Collection

Information and data were collected from available records of the farms on such items as: amount of electricity consumed per month, amount of fuel consumed per month, the number of working days per years, the number of working hours per day and the floor area of each of the sections surveyed over a period of three years (2002 – 2004). Data on energy were reduced to common energy units using appropriate conversion factors.

2.3 Data Analysis

From the data collected, the following procedural steps were taken to get them analyzed and presented in the required forms:

- Energy types (electricity and fuel) were identified and collated
- Monthly consumption for each type was determined.
- The percentage breakdown of total consumption and cost by energy type was calculated.
- The average overall cost per GJ of each energy type per section was determined to establish relative significance.
- Tables were prepared for each section showing total annual consumption and cost for each energy type for the audit period.

2.4 Normalized Performance Indicator (NPI)

The normalized performance indicator (NPI) is a useful parameter to assess the energy performance of project buildings. It requires that energy consumption for the space heating is corrected for standard weather and exposures. But the weather condition in Nigeria is fairly favourable (Aiyedun and Onakoya, 2000) hence effect of weather correction is ignored in the present study ("Energy Audits and Surveys", 1976; Energy Audits for Industry" 1993; CIBSE, 1982).

To obtain the NPI for a particular building, the total energy consumed for the production purpose is divided by the total floor area of the building and multiplied by the hours of use factor. The value so obtained is then compared to the standard NPI values (Energy Audits for Industry, 1993) presented in Table 1. Building with a poor rating will obviously require immediate attention. If a building is rated as 'good', then a further investigation may be required unless there are no obvious areas of improvement. Buildings that are favourably rated may deteriorate, or the general standard may increase from time to time. Therefore, constant monitoring of such building is required to be carried out by energy engineer to maintain good standard for the building at all times. Table 2 gives the interpretation of the calculated NPI value based on comparison done with Table 1. Some of the considerations to be taken into account in calculating the NPI include the building type and factory. Jekayinfa (2004), Jekayinfa and Bamgboye (2004) and Jekayinfa and Bamgboye (2006 [a,b]) have used similar methods in previous studies.

Table 1: Performance indicator for some common building types

Building Type	Performance Classification GJ/m^2					
	Occupancy	Good	Satisfactory	Fair	Poor	Very Poor
Office	Single-shift, 5 day week	< 0.7	0.7 – 0.8	0.8 – 1.0	1.0 – 1.2	> 1.2
Factories	Single-shift, 5/6 day week	< 0.8	0.8 – 1.0	1.0 – 1.2	1.2 - - 1.5	> 1.5
Warehouses	Single-shift, 5/6 day week	< 0.7	0.7 – 0.8	0.8 – 0.9	0.9 – 1.2	> 1.2
School	Single-shift, 5 day week	< 0.7	0.7 – 0.8	0.8 – 1.0	1.0 – 1.2	> 1.2
Shops	Single-shift, 6 day week	< 0.7	0.7 – 0.8	0.8 – 1.0	1.0 – 1.2	> 1.2
Hotels	Continuous 7 day week	< 1.3	1.3 – 1.5	1.5 – 1.8	1.8 – 2.2	> 2.2

Note: Single shift occupancy implies normal daily use of about 8 – 10 hours including allowances for after hours clearing

Source: CIBSE Building Energy Code, Part 4 (1982).

Table 2: Energy performance classification

Performance Classification	Comments
Good	Low energy consumption indicative of careful control and good energy management procedures
Satisfactory	Energy usage consistent with sensible operating procedures
Fair	Barely average performance for typical situation, significant saving should be achievable
Poor	Energy usage is high for typical situation indicative of significant heat losses in winter and/or poor control of energy use
Very Poor	Energy usage is excessive, immediate action should be taken to investigate and remedy.

Source: CIBSE Building Energy Code, Part 4 (1982).

2.5 Intensity of the Energy

The ratio of the energy consumed per year in GJ to the floor area of the factory in square metres is the intensity of the energy consumed in any production factory.

$$\text{Intensity of Energy} = \frac{\text{Total Energy}}{\text{Floor Area}}$$

3. RESULTS AND DISCUSSION

3.1 Feed Mill

A sample procedure for calculating NPI value for the feed mill section is presented in Table 4. Feed mill operations required the two types of commercial energy considered in this study. Recorded total yearly energy consumption in this section of the farm between 2002 and 2004 is presented in Table 3. It can be observed from Table 3 that the ratio of electricity to fuel consumption in 2002, 2003 and 2004 are 55:45, 51:49 and 45:54 respectively. Except for 2004 when electricity supply in Nigeria was epileptic, higher energy consumption was from the national electricity grid. This was due to operations like conveyance of raw materials and prepared feed within the processing system, grain drying and commutation. All the machines (chain and belt conveyors, hammer mill, mechanical dryer etc) used in these operations were powered by electricity. Fig. 1 presents the graphical form of total energy consumption in each of the sections of the farms surveyed.

Higher percentage of fuel consumption in the feed mill was expended on the separate stand-by generator attached to the section. Other fuel use was for vehicular transportation of raw materials and prepared feed within the mill. An observation that was made concerning electricity use in the feedmill was the constant use of lighting points with and without normal operations going on. This has contributed in no small measure to higher energy consumed through electricity.

The Normalized Performance Indicator (NPI) calculated using the data collected from the feedmill indicated an average NPI value of 0.17 GJ/m^2. This NPI value, when compared to the standard values (EEO, 1993) presented in Tables 1 and 2 indicated that the energy consumption and management in the feedmill section of the farm is Good. This is because the calculated NPI value (0.716GJ/m^2) is below the fair range of (0.68 – 0.97). Values below this fair range is Good.

Table 3: Average yearly energy consumption and cost in the selected farms (2002 – 2004)

Section	**Electricity (GJ)**			**Fuel (GJ)**			**Total Energy (GJ)**			**Total Cost *(₦'000)**		
	2002	**2003**	**2004**	**2002**	**2003**	**2004**	**2002**	**2003**	**2004**	**2002**	**2003**	**2004**
Feed Mill	101.20	91.06	86.84	83.07	88.10	103.02	184.27	179.16	189.86	118.31	115.64	204.50
Hatchery	67.47	58.12	57.89	51.98	51.86	58.64	119.45	109.98	116.53	92.82	84.62	98.54
Administrative	33.76	30.36	8.95	50.85	53.58	61.85	84.61	83.94	70.80	51.39	48.41	65.70
Poultry	29.98	34.49	34.64	51.79	61.35	59.98	81.77	95.84	94.62	70.29	72.88	71.80
Piggery	31.14	23.53	26.78	23.75	24.99	21.60	54.89	48.52	40.38	42.47	30.01	30.66
Mechanical Workshop	361.98	354.48	353.85	126.36	164.71	152.55	488.34	519.19	506.40	369.0	371.1	384.0
Total	**625.53**	**592.04**	**568.95**	**387.80**	**444.59**	**459.64**	**1013.33**	**1036.63**	**1018.59**	**744.28**	**722.66**	**855.20**

*₦ (Naira) is a denomination for the Nigerian Currency. Current exchange rate is $1 = ₦125:00

3.2 Hatchery

Both electricity and fuel are used in the normal operations of the hatchery section. The energy consumption and cost for hatchery operations between 2002 and 2004 are shown in Table 3. It can be observed from the table that the ratio of electricity to fuel consumption in 2002, 2003 and 2004 are 56:44, 53:46 and 49:51 respectively. The same trend in energy consumption pattern could be noticed here when compared to that of feed mill. The year with the highest consumption of energy was 2002 with a value of 119.45GJ while the lowest consumption of energy was recorded in 2003 with a value of 109.98GJ.

Electricity is consumed in the hatchery unit of the farms through the use of incubators, hatchers, air conditioners and normal lighting services. Fuel use is mostly though the use of vehicles for transporting hatchable eggs from the parent stock-poultry to the hatchery and in the stand by generator provide for the unit for captive power generation. It was noticed that the hatchery managers lack necessary managerial ability in reducing electricity consumed though uncontrolled – constant use of lighting points whether an operation was going on or not. This negatively affected energy use through electricity.

The average NPI value calculated for the hatchery section was 0.28 GJ/m^2 which accordingly implies that the energy used per m^2 of the factory floor area for space heating is very low, an indication of good and profitable energy consumption and management. However, there are areas where improvement in energy management could be made. These include:

(1) uncontrolled use of lighting points especially during off – periods and holidays

(2) unnecessary use of air conditioners when the relative humidity in the cold store was adequate for eggs storage.

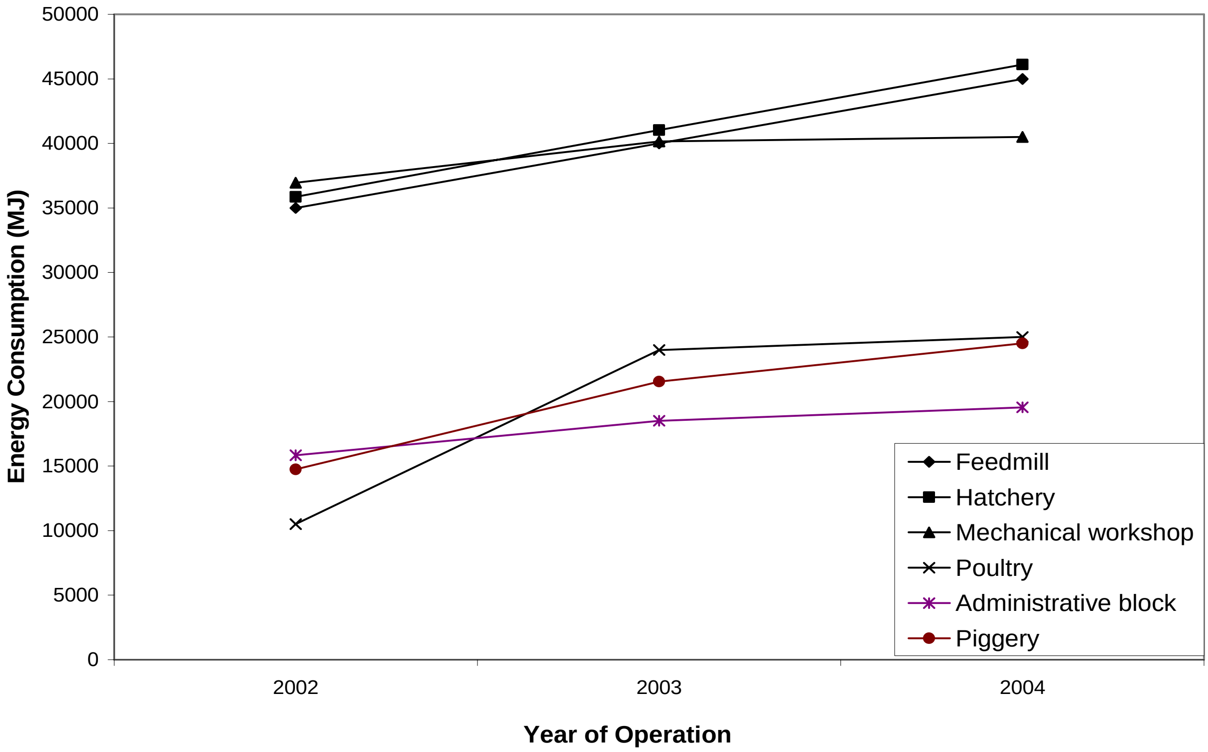

Fig. 1: Trends in energy use in each section of selected mechanised farms in southwestern Nigeria

Table 4: A sample calculation procedure of NPI for feed mill section over a period of three years

S/N	Data	Values		
		2002	2003	2004
1.	Hour of use (hr)	2112	2112	2112
2.	Energy Consumed (GJ):			
	Thermal	101.20	91.06	86.84
	Electrical	83.07	88.01	103.02
	Total	**184.27**	**179.86**	**189.86**
3.	Space Heating Energy (GJ)*	80.96	72.85	69.47
4.	Non Heating Energy (GJ)	103.31	106.22	120.39
5.	Standard Working hr/yr**	4800	4800	4800
6.	Hour of use Correction *** Factors (GJ)	234.80	241.41	273.61
7.	NPI (GJ/m^2)****	0.16	0.17	0.19
8	Building Assessment	Good	Good	Good

* 80% of Thermal Energy ** 300 days x 16 hours/days

*** $\text{Non Heating Energy} \times \dfrac{\text{Standard Working hour}}{\text{Hours of use}}$ **** Hour of use correction factor Floor Area.

3.3 Administrative Block

The administrative section of the farms makes use of both fuel and electricity, fuel for captive power generation and vehicles' use, while electricity from the national grid is used to power air conditioners, fans, refrigerators and secretarial equipment. The year with the highest energy consumption was 2004 with a value of 90.8 GJ, while the lowest consumption of energy was recorded in 2003 with a value of 83.94GJ. This variation could be attributed to increased load capacity, wastage and long period of power outages. The breakdown of energy consumption on the basis of energy type and cost for administrative section is presented in Table 3. From Table 3, it can be observed that the ratio of electricity to fuel consumption in 2002, 2003 and 2004 are 40:60, 36:64 and 32:68 respectively.

The NPI calculated for this section was 0.082 GJ/m^2. This value falls below the NPI fair range (Table 1) and therefore indicates that the assessment performance is good for the three years under review. This, however, does not mean that improvement could not be made in areas where energy losses were noticed. Such areas include (1) the uncontrolled use of lighting points whether or not the section was in normal operation even during holidays (2) use of twin florescent fittings in almost all the offices. It was also observed that some weak florescent tubes were left unchanged in the administrative section, whereas energy consumption could have been reduced either by replacing these tubes or removing them without replacement.

3.4 Poultry Section

Both electricity and fuel are used in the normal activities of the poultry section. Electricity is used for lighting purpose and in the brooding house. Fuel is used for plucking and in the transfer of materials and birds within and outside the poultry. The year with the highest energy consumption was 2003 with a value of 95.84GJ followed in 2004 and 2002 with values of 94.62GJ and 81.77GJ respectively. This variation could be attributed to increased load capacity occasioned by either more or less birds being reared, wastage and long period of power outages. The breakdown of energy consumption on the basis of energy type and cost for the poultry section is presented in Table 3. The ratio of electricity to fuel consumption is 37:63, 36:64 and 37:63 in 2002, 2003 and 2004 respectively.

The average NPI values calculated for the section for 2002 to 2004 as shown in Table 5 indicated that energy use management was good and could be improved upon by serious monitoring on the part of poultry manger(s) that must ensure that lighting points are put on only when normal operations are going on.

3.5 Piggery Section

The average energy consumption and the corresponding cost in the piggery section of the farms between 2002 and 2004 are shown in Table 3. From the table, it can be observed that the ratio of electricity to fuel is 57:43, 49:51 and 55:45 in 2002, 2003 and 2004 respectively. The total energy consumed over the years was fairly stable. The value ranged between 48.32GJ in 2004 and 54.89 GJ in 2003. The gradual increment over the three – year period could be attributed to increased load capacity and other auxiliary activities and general wastage.

3.6 Mechanical Workshop

In the normal activities of the mechanical workshop, both thermal and electrical energy are being consumed. Thermal energy is used in power generation (using electric generating plants) and testing of refurbished vehicles; electrical energy is used for welding, battery charging, fuel pumping, vulcanizing work and other auxiliary jobs. The mechanical workshop is the section of the farms where energy use is highest. As shown in Table 3 the total energy consumption ranged between 488.34 in 2002 and 519.19 in 2003. The difference in energy consumption noticed over the period could be attributed to increased load capacity occasioned by the number of jobs brought for repairs/refurbishment, electric motors and other auxiliary equipment not working properly and general wastage.

The NPIs calculated for the section as shown in Table 5 indicated favourable results implying that little energy is wasted in the normal operations of the workshop. A lot of avenues for improvement in the energy management of the workshop are noticed. These instances include (1) the lighting points that were always put on during the period this survey lasted (2) the use of equipment that are not working properly (3) uncontrolled use of fuel for the so called “testing” of vehicles.

Table 5: Average energy performance indicators of all sections of the selected farms

S/N	Farm Sections	Year	Parameter				
			Total Energy Consumed (GJ)	Energy Intensity (EI) (GJ/m^2)	Energy Cost (EC) (₦'000)	Normalized Performance Indicator NPI (GJ/m^2)	Performance Remark
1.	Feed mill	2002	184.27	0.128	118.31	0.16	Good
		2003	197.00	0.125	115.64	0.17	Good
		2004	189.86	0.132	204.50	0.19	Good
2.	Hatchery	2002	119.45	0.194	92.82	0.30	Good
		2003	109.98	0.179	84.62	0.27	Good
		2004	116.53	0.189	98.54	0.27	Good
3.	Administrative	2002	84.61	0.103	51.39	0.086	Good
		2003	83.94	0.102	48.41	0.080	Good
		2004	90.80	0.110	65.70	0.080	Good
4.	Piggery	2002	54.89	0.78	42.47	0.011	Good
		2003	48.52	0.0069	30.01	0.009	Good
		2004	48.38	0.0068	30.66	0.006	Good
5.	Poultry	2002	81.77	0.01	70.29	0.138	Good
		2003	95.84	0.012	72.88	0.0160	Good
		2004	94.62	0.012	71.80	0.0159	Good
6.	Workshop	2002	488.34	0.480	369.00	0.83	Good
		2003	519.19	0.490	371.10	0.84	Good
		2004	506.4	0.481	384.00	0.83	Good

4. CONCLUSIONS

Based on the energy efficiency study carried out on all sections (feedmill, hatchery, mechanical workshop, piggery, poultry and administrative section) of selected typical mechanized farms in Oyo, Ogun, Osun States of Nigeria, it can be concluded that energy use efficiency in all sections is good. This implies low energy consumption indicative of careful control and good energy management procedure.

The lowest energy consumption was recorded in the piggery section where a comparatively little energy was utilized. In all the sections, it was observed that energy wastage could be reduced through controlled use of all lighting points and careful monitoring of fuel use especially in the workshop section.

5. RECOMMENDATIONS

The following recommendations are hereby made for future improvement of energy consumption of the mechanized farms.

1. Light in all sections of the farms must be switched off on holidays and when work has been completed for the day especially in the feed mill, the administrative block and mechanical workshop.
2. The weak florescent tubes should be removed at the end of their effective performance period and replaced with new ones.
3. An energy management committee must be set up within the farms to always look into ways of reducing energy consumption.

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