Comparison of Energy Use Patterns in Maiduguri and Yobe Flour Mills, Nigeria

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ABSTRACT

A study was conducted on the evaluation of energy use patterns in two flour mills (Maiduguri and Yobe). Energy use and production data in the two agro-allied industries for seven years (1998-2004) were collected through the administration of a structured questionnaire.

Results show that three energy sources manpower, electricity and diesel fuel were used. For Yobe Flour Mills, manual energy consumed accounted for 0.1%, electrical energy accounted for 7% while diesel fuel consumed accounted for 92.9% of the total energy inputs over the years under review. Maiduguri Flour Mills, manual energy accounted for 0.1% while diesel fuel energy consumed accounted for 99.9%. The minimum and maximum values of energy use ratios for Yobe Flour Mills were 0.12:1 and 0.16:1 in 2003 and 2002 respectively. The mean energy use ratio was 0.15:1. The mean energy use ratio for Maiduguri Flour Mills was 0.36:1 while the minimum and maximum values were 0.33:1 and 0.40:1 in 2003 and 2004 respectively.

For Yobe State Flour Mills Company there was linear relationship between energy inputs and outputs with R^2 values of 0.87. For Maiduguri Flour Mills, energy input and output relationships was best described by polynomial equation with R^2 values of 0.99. Comparing the data of the two flour mills using t-test at 0.05 level of significance, it was found that there is a significant difference between their mean total energy inputs as well as their mean total energy outputs. The energy use ratios obtained show that neither of the flour mills efficiently used energy. Some energy use lapses were identified in the course of the study, which include malfunctioning of some electric motors and other auxiliary equipment and general wastage.

Manufacture, Transport and Repair (MTR) energy was not evaluated due to insufficient data on the masses of machines available in the industries and on their usage. Thus, the results of energy use obtained from the industries are incomplete because the MTR energy plays a significant role in energy use analysis.

The significance of the results obtained in this work is that since the level of use of each energy source was determined, the agro-allied industries would be able to relate energy use with commodity production so as to enhance production with minimum energy input.

Keywords: Energy use**,** flour production, Nigeria.

1. INTRODUCTION

According to Pimentel (1992), energy is one of the most valuable inputs in agricultural production. It is invested in various forms such as mechanical (from machines, human labour, animal draft), chemical (fertiliser, pesticides, herbicides), electrical, heat, etc. The amount of energy used in agricultural production, processing and distribution should be significantly high in order to feed the expanding population and to meet other social and economic goals. Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production (Pimentel, 1992). It was realised that crop yields and food supplies are directly linked to energy (Stout, 1990). Also, increases in yields and acreage in the developed countries were as a result of commercial energy inputs, in addition to improved varieties (Faidley, 1992).

Energy is said to be the engine for growth and development in all economies of the world. In all parts of the world today the demand for energy is increasing almost on daily basis. In Nigeria, energy and in particular oil, has continued to contribute over 70% of federated revenue (CBN, 1999). National developmental programmes and security depend on energy. It is also true that all activities for the production of goods and services in the nation's major sectors of the economy (industries, transport, agriculture, health, politics, education, etc) have energy as an indispensable input. Energy, proxies by crude oil, has over the past five years contributed an average of 13.5% of Nigeria Gross Domestic Product (GDP), representing the highest contributor after crop production (CBN, 1999). The contribution of energy to GDP is expected to be higher when renewable energy, which constitutes about 90% of the energy utilised by the rural population is taken into account (The Presidency, 1992). Consequently, energy in Nigeria serves not only as a tradable commodity for the earning of national income, but also as an input to the production of all goods and services as well as an instrument for politics, security and diplomacy.

1.1 Energy and Agro-processing

The agro-processing industry transforms products originating from agriculture into both food and non-food commodities. Processes range from simple preservation (such as sun-drying) and operations closely related to harvesting, to the production, by modern, capital-intensive methods of textiles, pulp, paper, etc. Upstream industries are engaged in the initial processing of products such as rice and flour milling, leather tanning, cotton ginning, oil pressing, saw milling and fish canning. Downstream industries undertake further manufacturing operations on intermediate products made from agricultural materials. Examples are noodle and bread making, textile spinning and weaving, paper production, clothing, footwear and rubber manufacture.

An energy input is required in food processing, as well as in packaging, distribution and storage. Many food crops when harvested cannot be consumed directly, but must pass through several stages of processing as well as cooking in order to be palatable and digestible. Raw meats, uncooked grains, vegetables and even fruits required preparation and heating to enhance their flavour, rendering their components edible and digestible. The processing and cooking stages reduce harmful organisms and parasites, which might pose health hazards. Poorly handled and stored food can become spoiled and contaminated. Food preservation usually requires the application of heat to destroy microbiological agents such as bacteria, yeast and mould. Pasteurization causes the inactivation of spoilage enzymes and reduction of bacteria at temperatures around 80 - 90^{0}C. Heat sterilization can use atmospheric steam at 100^{0}C for high-acids-foods, and pressurized steam at around 120^{0}C for low acid foods. Other techniques include dehydration to reduce moisture content, smoking to reduce microbial activity, fermentation, salting and freezing. Food transformation activities are generally less energy intensive and release less carbon dioxide than most other industrial activities per unit of the product. Agro-processing industries, such as sugar mills, can become not only energy self-sufficient through the conversion of biomass residues, but also electricity producers for export and other uses.

1.2 Objectives of the Research

The aim of the research was to study the patterns of energy use of two agro-allied industries in northeastern Nigeria. The objectives of the study were:

(a) To identify the major energy sources in use.
(b) To determine the level of consumption of the energy sources.
(c) To determine energy consumption for commodity production in two agro-allied industry.
(d) To sort the energy content to produce a unit mass of flour.
(e) To calculate the energy use ratios of the industries.
(f) To identify lapses in energy use.

Meanwhile, a limited number of studies have been reported in literature on the determination of energy requirements of processing operations (Akinbami *et al.*, 2001; Pimentel, 1992; Sarker and Farouk, 1982; and Chinnan *et al,* 1980). According to Jekayinfa and Olafimihan (2000) energy analyses of food processing systems have also been reported by Chang *et al.* (1996) who developed an energy model to assess the requirements of electricity, fuel and labour for rice handling storage and milling in a rice-processing complex in Korea. Palaniappan and Subramanian (1998) analysed the five-year energy consumption data for 25 tea factories in South India. Other reported works include energy analyses of beverage producing plants in Nigeria

(Olafimihan, 1998; Jekayinfa and Olafimihan, 2000; Aiyedun and Onakoya, 2000; and Aiyedun *et al.*, 2002).

Maiduguri and Yobe Flour Mills are located at northeastern region of Nigeria, which contributes a sizeable proportion of total Nigerian agricultural output. The region produces cereals and legumes (sorghum, maize, millet, cowpea and groundnuts) as well as fruits and vegetable (oranges, mangoes, tomatoes, onions, spinach and water-melon). Despite its large food resources, industrial development, including food-processing industries is still very low (Igene *et al.,* 1990). In addition, there is no information on the patterns of energy use of the few agro-processing industries sited in the region. In this work, patterns of energy use in selected agro-allied industries in the region were studied so that the position of energy use in such industries could be determined.

2. MATERIALS AND METHOD

Data was collected from each industry through the following methods:

i. On-site study of all unit operations in each industry.
ii. Structured questionnaire was administered on patterns of energy use by the above-mentioned agro-allied industries for the period 1998 to 2004.
iii. Oral interviews.

2.1 Energy Consumption

2.1.1 Evaluation of Manual Energy Input

$EM_m = 0.75\ Ta$, MJ ……………………………… 1 Norman (1978)

Where, EM_m = Male manual energy input, MJ.

0.75 = Energy input of an average adult male, MJh^{-1}.

Ta = useful time spent by a male worker per unit operation, h.

For a female worker the manual energy input was evaluated as;

$EM_F = 0.68\ Ta$, MJ ……………………… 2 Norman (1978)

Where, EM_F = Female manual energy input, MJ.

0.68 = Energy input of an average adult female, MJh^{-1}

Ta = useful time spent by a female worker per unit operation, h.

2.1.2 Liquid Fuel Energy

$EF_{LD} = 47.8D$, MJ ………………………….. 3 Pimentel (1992)

Where, EF_{LD} = liquid fuel energy input for diesel, MJ.

47.8 = Unit energy value of diesel, MJL^{-1}

D = Amount of diesel consumed per unit operation, L.

For petrol,

EF_{LP} = 42.3 P, MJ ………………….………. …..4 Pimentel (1992)

Where, EF_{LP} = Liquid fuel energy input for petrol, MJ.

42.3 = Unit energy value of petrol, MJL^{-1}

P = Amount of petrol consumed per unit operation, L.

2.1.3 Electrical Energy

Data on electricity consumption (kWh) was estimated from the past NEPA bills collected over the years under review. These values were converted into common energy unit (MJ) by using appropriate coefficient [one-kilowatt-hour of electricity = 11.99 MJ] as reported by Pimentel (1992)

E_E = 11.99 * kWh, MJ………………………… 5 Pimentel (1992)

2.1.4 Manufacture, Transport and Repair (MTR) energy

Indirect mechanical energy was to be estimated by considering the energy expended to MTR from a unit mass of the machine obtained. The MTR energy was 100.7 $MJkg^{-1}$ (Bridges and Smith, 1979). E_{MTR} was determined as follows:

E_{MTR} = MTR x m, MJ…………………………. 6 Bridges and Smith (1979)

Where, E_{MTR} = Indirect mechanical energy.

MTR = energy used to manufacture, transport and repair a unit mass of machinery, 100.7 $MJkg^{-1}$.

m = Mass of machinery, kg.

Hence for each of unit operation, the total energy input was:

$E_T = E_M + E_{FL} + E_E + E_{MTR}$ ……..………………..7

All symbols as defined earlier

2.1.5 Total Energy Content (Energy Output) of Finished Product

This was evaluated from the equation below:

$E_{FP} = M_{FP} \times E_{CP}$ ……………………………………8

Where

E_{FP} = Total energy content of finished product, MJ.

M_{FP} = Mass of finished product, kg.

E_{CP} = Energy content of a unit mass of product, $MJkg^{-1}$

2.1.6 Energy Use Ratio

Energy use ratio was evaluated from the equation below:

$$E_{ur} = E_{FP} / E_T \quad \ldots\ldots 9$$

Where

E_{ur} = Energy use ratio.

E_{FP}=Total energy content of finished product, MJ.

E_T = Total energy input for operation, MJ.

3. RESULTS AND DISCUSSION

The results obtained from the study show that the major energy sources that are used in the two agro-allied industries are manual, fuel and electrical. MTR energy could not be accounted for because of insufficient data on the masses of machines available in the industries and on their usage. Hence, the results presented in the following sections do not include MTR energy.

3.1 Maiduguri Flour Mills Limited, Borno State

The various unit operations involved in wheat flour production at the Maiduguri Flour Mills are weighing, cleaning/separation, milling and package.

Only flour production was considered in the above industry. The major energy sources used were manual and liquid fuel. Tables 1 and 2 show the energy values from these sources while Tables 3 and 4 show the total energy output of finished flour and energy use ratio using Equations 1, 3, 8 and 9. Manual energy expended in operating machines was found to be the least consumed energy with values ranging between 120 to 144 MJ (Table 1) accounting for only 0.1% of the total energy inputs for the periods under review. This could be due to the low number of industry workers deployed to perform individual operations.

Fuel energy consumptions, mostly expended in operating diesel engines were between 191.200 GJ and 215.100 GJ (Table 2), which account for 99.9% of the total energy inputs. This could be as a result of the industry not connected to the National grid as its source of energy.

Table 1: Manual Energy Consumption at the Maiduguri Flour Mills

Year	EM_M =0.75*No of Male *Ta	EM_M , MJ
1998	0.75 * 8 * 20	120
1999	0.75 * 8 * 22	132
2000	0.75 * 8 * 20	120
2001	0.75 * 8 * 22	132
2002	0.75 * 8 * 21	126
2003	0.75 * 8 * 20	120
2004	0.75 * 8 * 24	144
Mean		128 ±8.9

Table 2: Liquid Fuel Energy Consumption at the Maiduguri Flour Mills

Year	EF_{LD} = 47.8D	EF_{LD} , MJ
1998	47.8 * 4000	191200
1999	47.8 * 4000	191200
2000	47.8 * 4200	200760
2001	47.8 * 4350	207930
2002	47.8 * 4350	207930
2003	47.8 * 4500	215100
2004	47.8 * 4500	215100
Mean		204174 ±10126.5

Table 3: Total Energy Content of Finished Flour (energy output) at the Maiduguri Flour Mills

Year	Mass of a finished flour per production per year (M_{FP}), kg	Energy content of a unit mass of flour (E_{CP}), MJ/kg	Total energy content of finished flour (E_{FP}), MJ
1998	75000	0.96	72000
1999	75000	0.96	72000
2000	75000	0.96	72000
2001	75000	0.96	72000
2002	75000	0.96	72000
2003	75000	0.96	72000
2004	90000	0.96	86400
Mean	77143 ±5669.5		74057 ±5442.7

Table 4 shows that in 2004 energy input were highest, with value of 215.244 GJ. This justifies the higher quantity of flour produced (90 tons) in the same year. The lowest energy consumption was recorded in 1998 with value of 191.320 GJ. It was observed that in the years under review, energy use increased while flour production remained unchanged until 2004 where production of flour increased to 90 tons. This trend could be observed as energy wastage in flour production. The energy use ratios indicate that energy use was insufficient within the years under review since in all cases, energy outputs were less than inputs. These ratios would be even lesser if MTR energy were accounted for. Correlation analysis of the results showed that polynomial Equation 10 best describes the relationships between energy input and output values.

$$Y = 1E\text{-}14X_{ET}^5 - 1E\text{-}08\, X_{ET}^4 + 0.0043\, X_{ET}^3 - 862.13\, X_{ET}^2 + 9E{+}07\, X_{ET} - 3E{+}1 \quad \ldots 10$$

$R^2 = 0.9978$

Where, Y = Flour production, kg

X_{ET} = Total energy input, MJ

R^2 = Coefficient of determination

Table 4: Energy Use Ratio at the Maiduguri Flour Mills

Year	E_{FP} (Output), MJ	$E_T = EM_M + EF_{LD}$ (Input), MJ	E_{UR}
1998	72000	191320	0.38:1
1999	72000	191332	0.38:1
2000	72000	200880	0.36:1
2001	72000	208062	0.35:1
2002	72000	208056	0.35:1
2003	72000	215220	0.33:1
2004	86400	215244	0.40:1

3.2 Yobe State Flour and Feed Mills Company Limited, Potiskum

The various unit operations involved in maize flour production at the Yobe State Flour and Feed Mills Company are weighing, cleaning/separation, milling and packaging.

Only flour production was considered in the above industry. The major energy sources used were manual, electrical and fuel. Tables 5, 6 and 7 show the energy use values from these sources, while Tables 8 and 9 show total energy output of finished flour and energy use ratios evaluated using Equations 1, 3, 5, 8 and 9. Manual energy expended in operating machines was the least consumed energy (Table 5), accounting for only 0.1% of the total energy input. Electrical energy expended in operating most of the machines/equipment accounted for 7% of the total energy input. Fuel energy expended in operating diesel engines accounted for 92.9% of the total energy inputs (Tables 6 and 7). The least values of manual energy may be attributed to low number of industry workers deployed to perform individual operations. A Table 9 shows that the highest and lowest energies of 181.868 GJ and 143.672 GJ were consumed in 2001 and 2004, respectively. Energy use ratios show insufficient within the years under review since in all cases, energy outputs were less than inputs. These ratios would even be lesser if MTR energy were accounted for.

Table 5: Manual Energy Consumption at the Yobe Flour Mills

Year	EM_M =0.75*No of Male Workers *Ta	$EM_{M,}$ MJ
1998	-	-
1999	-	-
2000	-	-
2001	0.75 * 8 * 30	180
2002	0.75 * 8 * 32	192
2003	0.75 * 8 * 32	192
2004	0.75 * 8 * 32	192
Mean		189 ±6

Table 6: Electrical Energy Consumption at the Yobe Flour Mills

Year	E_E = 11.99 * kWh	$E_{E,}$ MJ
1998	-	-
1999	-	-
2000	-	-
2001	11.99 * 1200	14388
2002	11.99 * 1700	20383
2003	11.99 * 2000	23980
2004	11.99 * 2000	23980
Mean		20683 ±2698.4

Table 7: Liquid Fuel Energy Consumption at the Yobe Flour Mills

Year	$EF_{LD} = 47.8D$	EF_{LD}, MJ
1998	-	-
1999	-	-
2000	-	-
2001	47.8 * 3500	167300
2002	47.8 * 3000	143400
2003	47.8 * 3000	143400
2004	47.8 * 2500	119500
Mean		143400 ±19514.3

Table 8: Total Energy Content of Finished Flour (energy output) at the Yobe Flour Mills

Y ear	Mass of a finished flour per production per year (M_{FP}), kg	Energy content of a unit mass of flour (E_{CP}), MJ/kg	Total energy content of finished flour (E_{FP}), MJ
1998	-	-	-
1999	-	-	-
2000	-	-	-
2001	30000	0.96	28800
2002	28000	0.96	26880
2003	25000	0.96	24000
2004	18000	0.96	17280
Mean	25250 ±5252		24240 ±5041.9

Table 9: Energy Use Ratio at the Yobe Flour Mills

Year	E_{FP} (Output), MJ	$E_T = EM_M + E_E + E_{FLD}$ (Input), MJ	E_{UR}
1998	-	-	-
1999	-	-	-
2000	-	-	-
2001	28800	181868	0.16:1
2002	26880	163975	0.16:1
2003	24000	167572	0.14:1
2004	17280	143672	0.12:1

This may be attributed to diesel leakages, power outages from the National grid, and ageing of machines/equipment. Correlation analysis of the results showed that linear Equation 11 best describes the relationship between energy input and output values.

$$Y = 0.3105X_{ET} - 25752 \qquad (11)$$

$R^2 = 0.8678$

Where, Y = Flour production, kg
X_{ET} = Total energy input, MJ
R^2 = Coefficient of determination

4. GENERAL OBSERVATIONS

From the identified energy use sources in the two agro-allied industries, it was observed that manual energy was usually expended in operating machines. This energy was the least used, accounting for less than 1% of the total energy consumed. This could be because of two reasons; firstly, due to low number of workers deployed to perform individual operations, and secondly due to inconsistent number of hours of work in a day. Fuel energy expended in operating diesel engine/machinery in the various industries has had the highest values of energy use accounting for more than 90% of the total energy used. Electrical energy, which was expended for operating machines/electric motors varied from 5-10% of the total energy use depending on the sources as well as the industry. Figures 1 and 2 show the contribution of each energy source from the different sources for the two agro-allied industries. It is clear from the figures that much diesel fuel energy was used by the industries in the years under review, a scenario similar to the findings of Jekayinfa and Olafimihan (2000).

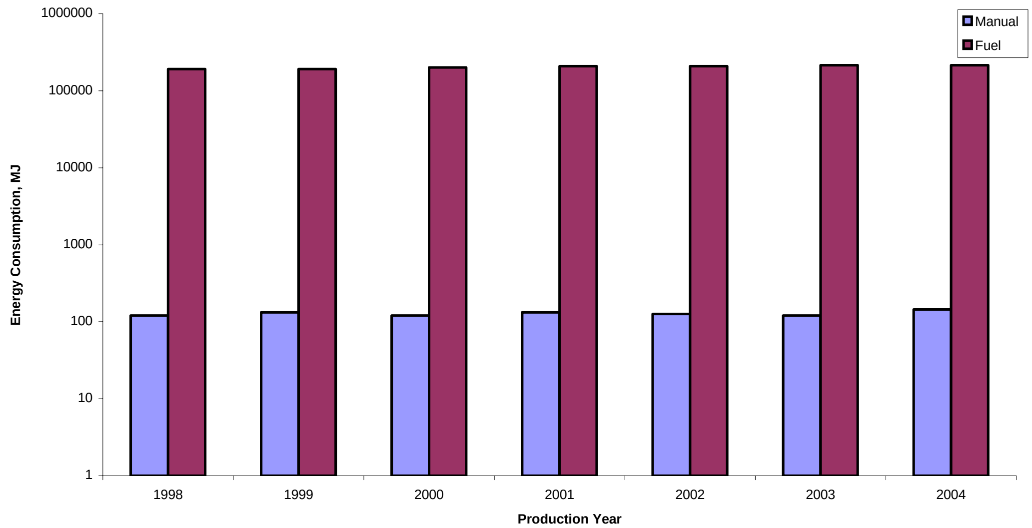

Figure 1: Energy types and consumption levels for flour production at Maiduguri Flour Mills, Borno State

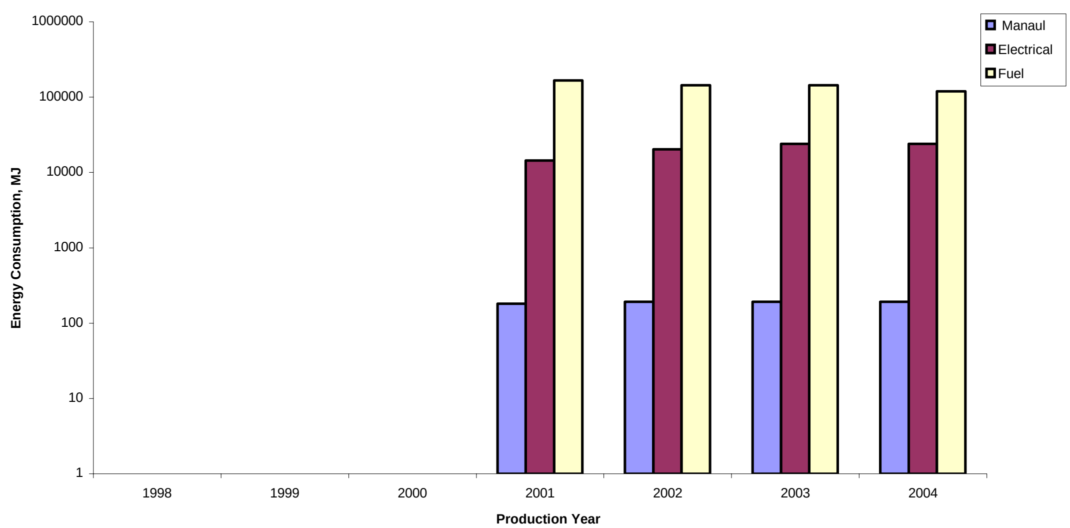

Figure 2: Energy types and consumption levels for flour production at Yobe Flour Mills, Potiskum, Yobe State

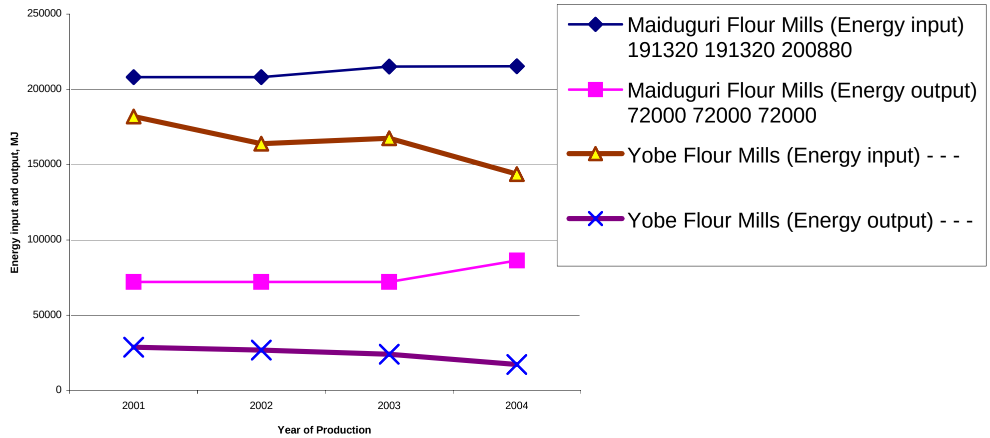

Figure 3: Comparison between energy input and energy output in Maiduguri and Yobe Flour Mills

It was also observed that fuel energy has relatively higher unit price than the other sources of energy (electrical and manual). This implies that lower cost of production would have been expected if electricity supply had been steady. It is worth noting that the cost of fuel had an upward increase for 5-6 times during the period under review. This high fuel energy consumption could be attributed to the long periods of power outages from the National grid and uses for transportation. Some energy use lapses were observed that lead to fluctuating patterns of the energy use values. This signifies lack of good and effective energy conservation practices. After comparing the data of the two flour mills using t-test, it was found that there is a significant difference (at 0.05 level) between their mean total energy inputs as well as total energy outputs; therefore neither of the flour mills is making an efficient use of energy. Figure 3 shows the effect of total energy input and that of output against years of production for the two agro allied industries, having total energy inputs greater than the total energy outputs. In view of the energy use lapses identified in production of flour by the two industries, ideal energy use relationships (Equations 12 and 13) were developed to estimate optimum energy use and maximum flour production. The following equations were achieved using assumed values of energy inputs:

(a) For Maiduguri Flour Mills;

$$Y = 8E\text{-}05X_{ET}^2 - 30.428\, X_{ET} + 3E{+}06 \qquad \ldots 12$$

$$R^2 = 0.9988$$

(b) For Yobe Flour Mills;

$$Y = 0.0008\, X_{ET}^2 - 278.89\, X_{ET} + 3E{+}07 \quad \ldots\ldots 13$$
$$R^2 = 0.9994$$

Where, Y = Flour production, kg
X_{ET} = Assumed total energy input, MJ
R^2 = Coefficient of determination

Manufacture, Transport and Repair (MTR) energy was not evaluated due to insufficient data on the masses of machines available in the industries and on their usage.
The waste energy could be due to several reasons such as higher power demand from the national grid than required, excess power generation from standby generators, excess security and office lightings, etc

5. CONCLUSIONS

The study on patterns of energy use in two agro-allied industries in northeastern Nigeria revealed the following:

1. The major energy sources were manual, fuel (diesel) and electrical energies. Diesel energy was the highest energy consumed. It accounted for over 90%. Electrical energy and manual energy consumption were much lower.
2. Energy use ratio values in the two flour mills (Maiduguri and Yobe Flour Mills) revealed that there was insufficient use of energy in flour production in the two flour mills.
3. Energy use lapses identified were due to lack of good energy conservation practices (such as replacing worn engine parts), diesel leakage, ageing of machines/equipment, and power outages from the National grid.

In order to optimize energy use in achieving maximum production, the following recommendations were suggested, operators of machines/equipments should have adequate skills on effective energy conservation practices, old machines/equipment should be replaced with new ones to avoid energy wastage from leakages and stabilize energy supply. In order to evaluate Manufacture, Transport and Repair (MTR) energy, equipment manuals and other related documents should be kept intact for the purpose of indirect energy consumption analysis.

6. ACKNOWLEDGEMENT

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