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Energy Use Patterns in Sugar Production: A case study of Savannah Sugar Company, Numan, Adamawa State, Nigeria

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Abstract: A study was conducted on the evaluation of energy use patterns in sugar production in Savannah Sugar Company, Numan, Adamawa State. Energy use and production data in this agro-allied company for seven years (1998-2004) were collected through the administration of a structured questionnaire. Results show of the two energy sources examined electrical energy consumed accounted for 93% of the total energy inputs over the years under review. The balance of 7% was in the form of manual energy. The minimum and maximum values of energy use ratios were 16.2:1 and 23.9:1 were obtained for 2000 and 2002 respectively. A correlation between energy inputs and outputs with R^2 value of 0.57 was obtained. Some energy use lapses were identified in the course of the study, which includes 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 industry would be able to relate energy use with commodity production so as to enhance production with minimum energy input.

Key words: Energy use, Manual energy, electrical energy, sugar production, Nigeria.

INTRODUCTION

According to Pimentel[1], 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 (fertilizer, pesticides, herbicides), electrical, heat, etc. The amount of energy used in agricultural production, processing and distribution is significantly high in order to feed the expanding population and to meet other social and economic goals of society. Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production[1]. It has been realised that crop yields and food supplies are directly linked to energy availability or consumption[2]. Also, increases in yields and acrage in the developed countries were as a result of commercial energy inputs, in addition to improved varieties[3]. 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[4]. 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's Gross Domestic Product (GDP), representing the highest contributor after crop production[4]. 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[5]. 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

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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 of textiles, pulp, paper, etc. by modern, capital-intensive methods. 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 manufacturing.

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 to some extent fruits require 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 °C. Heat sterilization can use atmospheric steam at 100 °C for high-acids-foods, and pressurized steam at around 120 °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. Meanwhile, a limited number of studies have been reported in literature on the determination of energy requirements of processing operations[1,6,7,8]. According to Jekayinfa and Olafimihan[9] energy analyses of food processing systems have also been reported by[10] 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[11] 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[9,12,13,14].

Adamawa State is located in the north eastern region of Nigeria, which contributes a sizeable proportion of total Nigerian agricultural output. Despite its large food resources, industrial development, food-processing industries activities are still very low[15]. In addition, there is no information on the patterns of energy use of the few agro-processing industries sited in the region. In this study, an attempt is made to examine the patterns of energy use in the sugar production industry.

1.2 Objectives of the Research: The aim of the research was to study the patterns of energy use in the tomato paste production. The specific objectives of the study were:

(a) To identify the major energy source in use in the Savannah Sugar Company Numan, Adamawa State.
(b) To determine the level of consumption of the energy sources.
(c) To determine energy consumption for tomato paste production.
(d) To sort the energy content to produce a unit mass of sugar.
(e) To calculate the energy use ratios of the industry.
(f) To identify lapses in energy use.

MATERIALS AND METHOD

Data was collected from the industry through the following methods;

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

2.1 Energy Consumption:

a. Manual Energy Input:

$$EM_m = 0.75\ Ta,\ MJ \quad (1)$$

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, hour

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

$$EM_F = 0.68\ Ta,\ MJ \quad (2)$$

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.

b Liquid Fuel Energy:

$$EF_{LD} = 47.8D, \text{ MJ} \quad (3)$$

where EF_{LD} = liquid fuel energy input for diesel, MJ
47.8 = Unit energy value of diesel, MJL^{-1}
D = Amount of diesel fuel consumed per unit operation, litre
For petrol,

$$EF_{LP} = 42.3 \text{ P, MJ} \quad (4)$$

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, litre

c. Electrical Energy: Data on electricity consumption (kWh) was estimated from the past PHCN 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 [1]

$$E_E = 11.99 * \text{kWh, MJ} \quad (5)$$

d. 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 $MJkg^{-1}$ [17]. E_{MTR} was determined as follows;

$$E_{MTR} = MTR \text{ x m, MJ} \quad (6)$$

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;

$$E_T = E_{Mm} + EM_F + EF_{LD} + E_{FLp} + E_E + E_{MTR} \quad (7)$$

All symbols as defined earlier

e. Total Energy Content (Energy Output) of Finished Product: This was evaluated from the equation below;

$$E_{FP} = M_{FP} \text{ x } E_{CP} \quad (8)$$

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, $MJkg^{-1}$

f. Energy Use Ratio: Energy use ratio was evaluated from the equation below;

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

where
E_{ur} = Energy use ratio
E_{FP}=Total energy content of finished product, MJ
E_T = Total energy input for operation, MJ

RESULTS AND DISCUSSION

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

3.1 Savannah Sugar Company, Numan, Adamawa State: The study reveals the various unit operations carried out at Savannah Sugar Company for sugar production are depicted Figure 1 below.

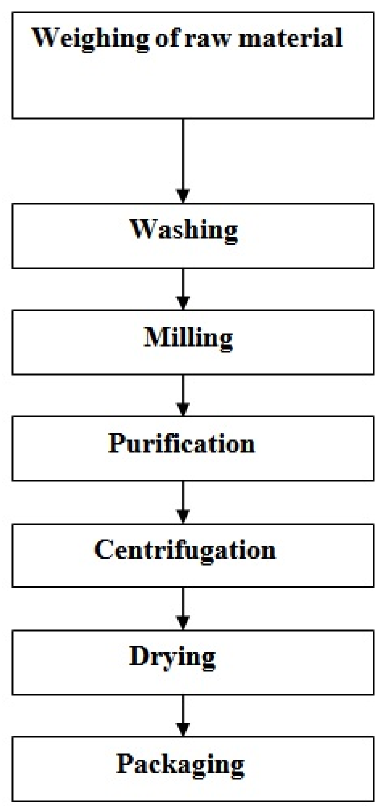

Fig. 1: Flow chart for Sugar production at Savannah Sugar Company, Numan, Adamawa State

The major energy sources used are manual and electrical. Tables 1 and 2 show the energy use values from these sources while Table 3 and 4 show the total energy output of finished sugar and energy use ratio obtained using Equations 1, 5, 8 and 9. Table 1 reveals that manual energy, mostly expended in operating machines, was the less consumed energy with a value of 2.745 GJ over the period under review, accounting for 7% of the total energy input. Electrical energy was expended in operating machines/equipment and its consumption was 29.975 GJ in 2001, 35.970 GJ in 2000 and 35.970 GJ in 2002, accounting for 93% of the total energy input.

Table 1: Manual energy consumption at the Savannah Sugar Company

Year	EM_M =0.75*No of M *Ta	EM_M, MJ
1998	-	-
1999	-	-
2000	0.75 * 12 * 305	2745
2001	0.75 * 12 * 305	2745
2002	0.75 * 12 * 305	2745
2003	-	-
2004	-	-
Mean		2745 ±

0 ± Standard deviation

Table 2: Electrical energy consumption at the Savannah Sugar Company

Year	E_E= 11.99 * kWh	E_E, MJ
1998	-	-
1999	-	-
2000	11.99 * 3000	35970
2001	11.99 * 2500	29975
2002	11.99 * 3000	35970
2003	-	-
2004	-	-
Mean		33972 ±3461.2

The fluctuating values of electrical energy consumed could be due to power outages from National grid, which might consequently affect production. Table 4 shows that in both 2000 and 2002 the energy input was 38.715 GJ which was higher while the lower energy consumption was recorded in 2001 with a value of 32.720 GJ. The higher value of energy used in 2002 could be justified by the quantity of sugar produced (56 tons) while 2000 indicates energy wastage to produce 3.79 tons of sugar (Table 3). This inconsistency in energy use could be attributed to lack of effective energy conservation practices and ageing of some electric motors/equipment. Energy use ratios of 16.2:1, 22.0:1, and 23.9:1 were obtained for 2000, 2001and 2002 respectively.

A correlation analysis of the results shows that a linear and exponential relationship given as polynomial Equation 10 best describes the relation between sugar production and energy input. Linear and exponential equations were also tested for comparison and they yielded weaker correlation ($R < 0.5$).

$$Y = -1E\text{-}06\ X_{ET}^{\ 3} + 0.1469\ X_{ET}^{\ 2} - 5483.9\ X_{ET} + 7E{+}07 \qquad (10)$$

$R^2 = 0.5744$

Where, Y = Sugar production, kg

X_{ET} = Total energy input, MJ

R^2 = Coefficient of determination

4. General Observations: From the identified energy use sources in the sugar production industry studied, it was observed that manual energy was usually expended in operating machines. This energy was the least used, accounting for 7% 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 low number of hours of work in a day. Electrical energy expended in operating engine/machinery in the industry has had the highest values of energy use accounting for 93% of the total energy used.

Figure 2 shows the contribution of each energy source and extent of use over the years. It is clear from the figure that much electrical energy was used by the industry in the years under review, a scenario similar to the findings of Jekayinfa and Olafimihan[9]. In the agro-allied industry, some energy use lapses were observed that lead to fluctuating patterns of the energy use values. This implies that a lot of energy might have been wasted which could cause increase in the cost of sugar production. The waste energy could be due to several reasons such as higher power demand from the national grid than required, excess security and office lightings, etc. This signifies lack of good and effective energy conservation practices.

Conclusion: The study on patterns of energy use in sugar production at Savannah Company, Numan, Adamawa State in north eastern Nigeria revealed the following:

1. The major energy sources were manual and electrical. Electrical energy was the highest energy consumed. It accounted for 93%. Manual energy consumption was much lower accounting for 7%.
2. Energy use lapses identified were due to lack of good energy conservation practices (such as replacing worn engine parts) and ageing of machines/equipment.

In order to optimize energy use in achieving maximum production, the following recommendations were suggested: (1) Operators of machines/equipments should have adequate skills on effective energy conservation practices; (2) Old machines/equipment should be replaced with new ones to avoid energy

Table 3: Total energy content of finished sugar (energy output) at the Savannah Sugar Company

Year	Mass of a finished sugar per production year (M_{FP}), kg	Energy content of a unit mass of sugar (E_{CP}),MJ/kg	Total energy content of finished sugar (E_{FP}), MJ
1998	-	-	-
1999	-	-	-
2000	37900	16.54	626866
2001	43600	16.54	721144
2002	56000	16.54	926240
2003	-	-	-
2004	-	-	-
Mean	45833 ±9254.4		758083 ±153067

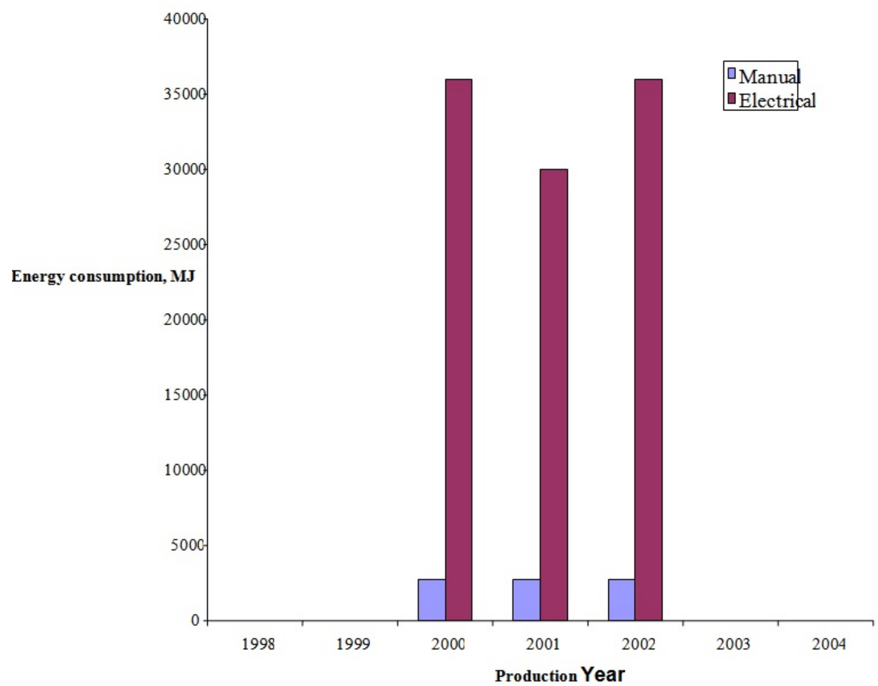

Fig. 2: Energy types and consumption for sugar production at Savannah Company, Numan, Adamawa State

Table 4: Energy use ratio at the Savannah Sugar Company

Year	E_{FP} (Output), MJ	$E_T = EM_M + E_E$ (Input), MJ	E_{UR}
1998	-	-	-
1999	-	-	-
2000	626866	38715	16.2:1
2001	721144	32720	22.0:1
2002	926240	38715	23.9:1
2003	-	-	-
2004	-	-	-

wastage from leakages and stabilize energy supply; (3) 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.

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