# ENERGY ANALYSIS OF A WHEAT PROCESSING PLANT IN NIGERIA

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**ABSTRACT**

Energy study was conducted in a wheat processing plant in Nigeria, to determine the energy consumption pattern for the production of flour. Process analysis method of energy was adopted to evaluate the energy requirement for each of the operations involved in the processing of wheat. The analysis revealed that eight defined unit operations were required for the production of wheat flour. The types of energy used in the processing of wheat flour were electrical and manual with the respective proportions of 99.87 and 0.13% of the total energy. Average energy intensity was estimated to be 0.101 MJ/Kg for the production of wheat flour. The most energy intensive operation was identified as the milling unit with energy intensity of 0.073 MJ/kg (72.20%) followed by the packaging unit using 0.015 MJ/kg (14.39%). Optimization of the milling process is suggested to make the system energy efficient.

**Keyword:** wheat processing, energy requirement, unit operation, Nigeria.

## 1. INTRODUCTION

The most important resource to both human being and industrial activities is energy. The significant of energy cost in a particular processing industry is dependent on the type of products manufactured, the processing methods adopted and relative price of energy [1]. In most cases, energy cost outweighs the costs of other resources such as raw materials, personnel, depreciation and maintenance [2, 3]. This made effective utilization of energy a major determinant in the overall cost of production as well as necessitate energy audit which is an important tool needed for economic utilization of energy resources in industries. Inefficient and excessive usage of energy could lead to economic loss and increase in costs of goods especially in the energy intensive industries.

In view of this, effort should be made to ensure a better efficient utilization of fuel, electricity, thermal energy and labour, these being the major components of manufacturing cost. In Nigeria, the major sources of industrial energy are fossil fuel, natural gas, coal and electricity generated by thermal and hydro-power stations. The supply of electricity in the country is in acute shortage and epileptic due in part to the dearth of underlying power generation technology and old facilities of the power stations, and the problems in the transmission and the distribution of the energy. Consequently, most companies in the country now rely mainly on the use of heavy-duty generating plant for the supply of their electrical energy which is used for operations such as air conditioning, lighting and some machining processes [4].

The increasing energy demands coupled with the finite energy resources, the rising cost of fossil fuels and the considerable environmental impacts connected with their exploitation necessitate the needs to understand the mechanisms, which degrade the quality of energy and energy systems. The processes that degrade the quality of energy resources can only be identified through a detailed analysis of the whole system [5]. This account 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 the energy audit of many manufacturing processes such as fertilizer production [2], rice processing [4], sunflower oil expression [5], palm-kernel oil processing [6, 7], cashew nut processing [8], poultry processing [1], cassava-based foods [9], milk processing [10], sugar production [11], and facility design of flour mill [12] limited work has been reported on energy audit of wheat processing operations.

The need for adequate storage and processing, as well as for all year availability of flour has made the industry very important. Wheat processing involves operations such as cleaning, tempering/conditioning, holding bin, and milling. These operations require high and regular energy supply to function, thus an efficient energy system is needed. Inefficient industrial energy use could lead to huge economic losses as excessive energy consumption adds to the costs of goods produced especially in energy intensive industries.

The aim of this study was therefore to analyze the energy consumption pattern of various unit operations required for the wheat processing plant in Nigeria. The essence of the study is to identify the energy inefficiencies in the unit operations as a step towards the optimization of the system.

## 2. MATERIALS AND METHODS

### 2.1. Process description

A wheat processing plant located in Nigeria was selected for this study. The types of energy sources utilized in the production system were electrical and manual. Electrical energy was the major source of energy used during product. Due to inconsistency in power from the National grid, a standby generating set with a capacity of 1000 kVA was used as an alternative source for electrical power supply.

The processing comprises eight unit operations. The process flow chart of the production system is shown in Figure-1. Wheat is received and weighed using weighing machine capable of weighing loaded trucks. The weight is obtained by subtracting the weight of the truck when emptied from the weight when it was loaded. It is then transferred to the storage facility where it was to be stored using elevators and conveyors. The wheat is tested for protein and other characteristics and graded into various categories. This is followed by cleaning which is done by first passing the wheat over series of coarse fine sleeves that remove unwanted materials such as chaffs and straws. Stones may be removed by passing wheat over short openings that allows stones to fall out of mass and be trapped. The wheat is then passed over a magnetic separator to remove any metallic particle present. The wheat is tempered/conditioned for milling by adding a little quantity of water (usually between 4 - 6%) depending on the initial moisture content of the wheat being milled in order to soften the outer layer of the wheat grain to ease milling. The wheat is then allowed to lie in the conditioning bins for between 10 and 24 hours.

Milling is the process by which the endosperm is extracted from the grain by passing it through series of rollers rotating at different speeds. The break system primarily comprised of roller mills that run in opposite directions at different speeds. Its purpose is to separate the endosperm from the rest of the kernel. To achieve this, the wheat is allowed to run through the roller mills up to five times. After this, sifters are also used to separate the endosperm from the bran and germ which is typically a co-product known as wheat feed.

The purification system consists of purifiers, roller mills and sifters. Purifiers sort particles based on size, air resistance and specific gravity. The roller mills further reduce the size of the particles. The reduction system consists of roller mills and sifters in sequence. The roller mills in this sequence are smooth, resulting in a finer grind. This phase reduces the endosperm to flour. This process is repeated up to 11 times to obtain the finess required for the flour. The mill products are flour (75%), semolina (3%) and bran (22%). The finished product (flour) was then bagged in 50 kg bags. The bagging process includes the following operations such as loading, weighing and sewing. The energy input into each unit operation was accounted for by noting and quantifying the type of energy used which was either one or a combination of electrical and manual energy. All electric motors in the plant were identified, and the amperage and horsepower rating, number of phases and voltage were noted to enable the estimation of electrical energy.

### 2.2. Data acquisition

The primary energy resources utilized in the plant for production were electrical and/or manual energy. An inventory of the electric motors, power rating of the machines, number of personnel involved, time required for production in each unit operation and material flow was made.

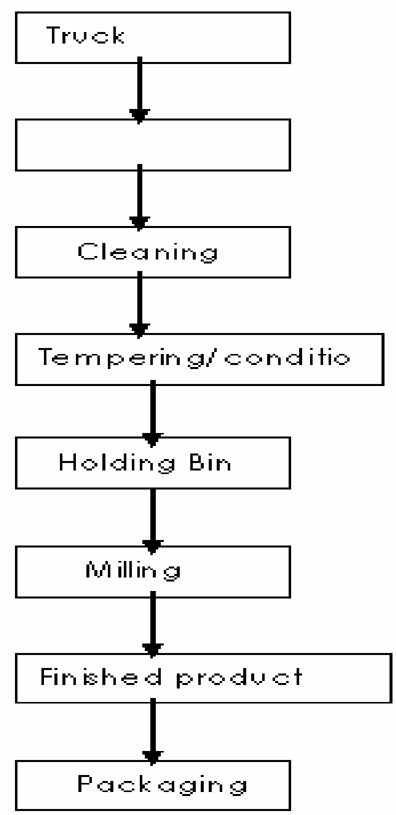


**Figure-1.** Flow chart of the wheat processing operations.

In each of the unit operation, the power rating of the electrical devices and capacity of each unit were collected from plant's manager. The production processes were monitored and data collected over a period of 1year. The measuring quantities used in the course of the data acquisition include: (i) a stopwatch for measuring the time 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 used. 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 into each unit operation (quantity)

The energy components (electrical and manual) from each source were calculated for the wheat processing using the following procedure.

#### 2.3.1. Electrical energy

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

$$Ep = \eta Pt \quad (1)$$

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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 [13]. According to him, at the maximum continuous energy consumption rate of 0.30kW and conversion efficiency of 25%, the physical power output of a normal human labourer in tropical climates is approximately 0.075kW sustained for an 8-10 h workday. This was calculated mathematically as:

$$Em = 0.075Nt \quad (2)$$

where $E_m$ is the manual energy in kW h, 0.075 is the average power of a normal human labour in kW, N is the number of persons involved in an operation and t useful time spent to accomplish a given task in hours.

**Table-1.** Required parameters for evaluating energy in organic fertilizer plant.

| Unit operation | Required parameters | Value |
|---|---|---|
| Truck unloading | Time taken (h) | 2 |
| | Number of persons involved | 6 |
| Intake | Electrical power (kW) | 49 |
| | Number of persons involved | 1 |
| | Time taken (h) | 6 |
| Cleaning | Electrical power (kW) | 30.23 |
| | Number of persons involved | 1 |
| | Time taken (h) | 10 |
| Tempering | Electrical power (kW) | 26.80 |
| | Number of persons involved | 1 |
| | Time taken (h) | 8 |
| Holding Bin | Electrical power (kW) | 31.13 |
| | Number of persons involved | 1 |
| | Time taken (h) | 3 |
| Milling | Electrical power (kW) | 529.39 |
| | Number of persons involved | 2 |
| | Time taken (h) | 12 |
| Finished product storage | Electrical power (kW) | 109.55 |
| | Number of persons involved | 1 |
| | Time taken (h) | 2 |
| Packaging | Electrical power (kW) | 62.79 |
| | Number of persons involved | 6 |
| | Time taken (h) | 18 |

## 3. RESULTS AND DISCUSSIONS

The energy accounting data was analyzed based on an input of 250 tonnes of wheat flour during a double shift of 11 hours per shift in a day for a year. Electrical energy utilized during production was obtained either from the national grid or the company's power generating set. The electrical energy consumption data as well as the operating time for all equipments requiring electrical energy were obtained. The manual energy was obtained based on the total number of workers per shift. The manual energy used was small due to the comparative high level of automation of the factory.

### 3.1. Energy expenditure

The time and energy for the production of 250tonnes of wheat flour is given in Table-2. Information on the energy requirement of each processing unit was known using the energy consumption data obtained. It was revealed that the total energy requirement for the production of wheat flour was 25339.469 MJ. The total energy intensities were estimated to be 0.101 MJ/kg at a cost of ₦0.6936491/kg. It was noted that only two processes (truck unloading and packaging) required manual energy putting the percentage of manual energy in the total generated energy at 0.13%. This also shows the level of automation of the company. The most energy intensive operating unit in the production system was identified as the milling unit with 18295.718MJ of energy followed by packaging with 3645.864MJ accounting for 72.20% (0.073 MJ/kg) and 14.39% (0.015 MJ/kg) of the energy required for production, respectively.

To optimize the energy consumption of the milling unit, process and/or machine design modifications will be required. The process modifications option will be in the conditioning. If the wheat is properly conditioned, the repetitions in the milling process will be reduced. This will reduce energy consumptions and therefore reduce cost of production. The design modification option will involve increasing the efficiency of the milling process; this will decrease the use of purifier. Also if the efficiency of the milling process can be improved, it will reduce the number of repeated processes and energy consumption will be reduced. However, additional cost of investment will be required for the process modification option, while minimal additional cost may be required for the machine design modification option. Therefore, in terms of cost effectiveness the machine design modification is considered to be the most feasible option.

**Table-2.** Time and energy requirement for the production wheat flour.

| **#** | **Process** | **Operation time** (h) | **Electrical energy Epi** (MJ) | **Manual energy $Em_i$** (MJ) | **Total energy $Et_i$** (MJ) | **Percentage energy** ($Et_i/Et_{tt}$)***100**(%) |
|---|---|---|---|---|---|---|
| 1 | Truck unloading | 2 | - | 3.240 | 3.240 | 0.01 |
| 2 | Intake/storage | 6 | 1006.560 | - | 1006.560 | 3.97 |
| 3 | Cleaning | 10 | 870.624 | - | 870.624 | 3.44 |
| 4 | Tempering | 8 | 617.472 | - | 617.624 | 2.44 |
| 5 | Holding bin | 3 | 268.963 | - | 268.983 | 1.06 |
| 6 | Milling | 12 | 18295.718 | - | 18295.718 | 72.20 |
| 7 | Finished product storage | 2 | 613.008 | - | 631.008 | 2.49 |
| 8 | Packaging | 18 | 3616.704 | 29.160 | 3645.864 | 14.39 |
| **Total** | | | 25307.069 | 32.400 | 25339.469 | 100.00 |
| **Percentage of total (%)** | | | 99.87 | 0.13 | 100.000 | |

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

The energy and mass flow diagrams for the wheat processing plant are shown in Figure-2, using the modified form of energy accounting symbol presented by [14]. The electrical and manual energy consumption together with the material mass flow was assigned to each unit operations. The wheat processing plant involves eight defined unit operations.

The two main 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 power generator for most of the production time.

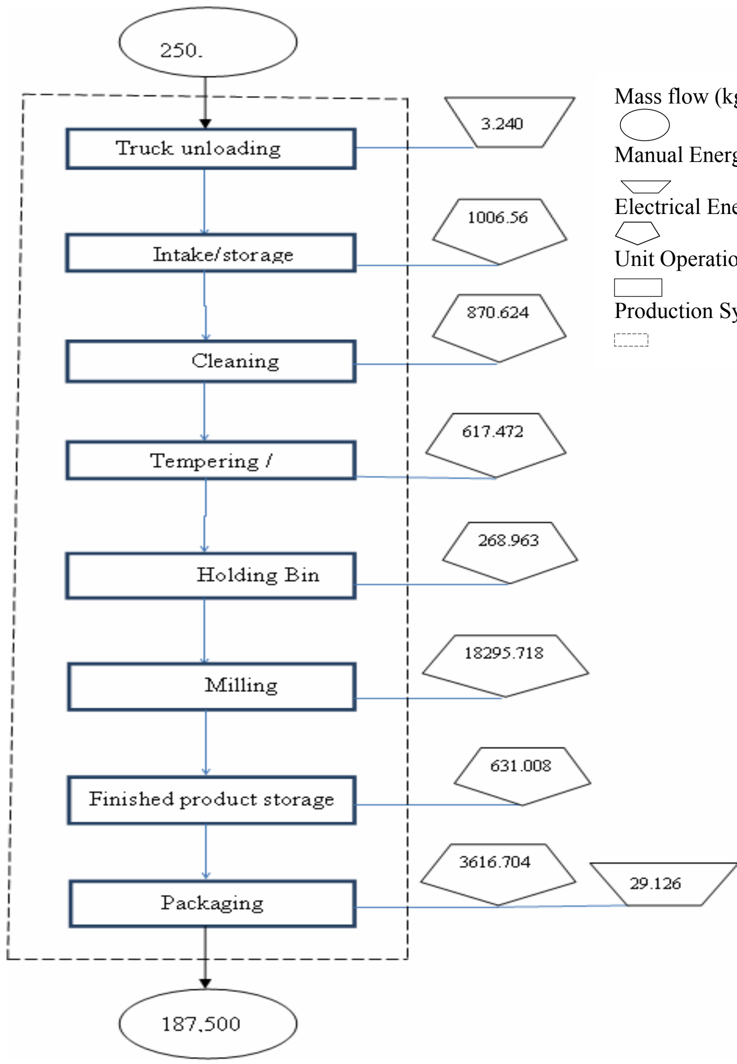


**Figure-2.** Energy and mass flow diagram of wheat processing plant.

## 4. CONCLUSIONS

The energy analysis that was conducted on a wheat processing industry in Nigeria suggested that.

- The company depended on electricity from the national grid and the company's generating set;
- Eight defined unit operations were required for the production of wheat flour;
- Electrical and manual energy were the two major sources of energy input in the production of wheat flour;
- The estimated energy intensity for production was 0.101 MJ/kg;
- The most energy intensive operation was the milling, which accounts for 72.20% of the total energy for production

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