Energy Use Patterns in Tomato Paste Production: A case study of Savannah Integrated Farms Limited, Dadin-kowa, Gombe State, Nigeria

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Abstract— A study was conducted on the evaluation of energy use patterns in tomato paste production in Integrated Farms Limited, Dadin-kowa, Gombe 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 diesel fuel consumed accounted for 98% of the total energy inputs over the years under review. The balance of 2% was in the form of manual energy. The minimum and maximum values of energy use ratios were 11.3:1 and 31.1:1 in 2003 and 2002, respectively. A correlation between energy inputs and outputs with R² value of 0.94 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.

Index Term— Energy use, Manual energy, Diesel fuel energy, Tomato paste production, Nigeria.

1. INTRODUCTION

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. According to Pimentel1 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],[2]. It has been realised that crop yields and food supplies are directly linked to energy availability or consumption [3],[4],[5]. Also, increases in yields and acreage in the developed countries were as a result of commercial energy inputs, in addition to improved varieties [6].

In Nigeria, energy and in particular oil, has continued to contribute over 70% of federated revenue. 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 and education) 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. 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 [7]. 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 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. However some of the studies that have been reported in literature on the determination of energy requirements/analysis in food processing and other agricultural operations includes [2],[8]-[15]. According to Jekayinfa and Olafimihan [16] energy analyses of food processing systems have also been reported by Chang et al [17], 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 [18] analysed the five-year energy consumption data for 25 tea factories in South India. Further more other reported works on energy analyses of beverage producing plants in Nigeria were [14]-[16]. Gombe 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 [19] 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 tomato paste 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 Integrated Farms Limited, Dadin-kowa, Gombe 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 tomato paste.
(e) To calculate the energy use ratios of the industry.
(f) To identify lapses in energy use.

2. MATERIALS AND METHOD

Data was collected from the industry through the following methods;

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

2.1 Energy Consumption

(a) Manual energy input

\[ EM_m = 0.75Ta \] (MJ) \[ (1) \] [20]

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) \[ (2) \] [20]

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

\[ ELFp = 47.8D \] (MJ) \[ (3) \] [1]

where, \( ELF_p \) = 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,

\[ ELF_p = 42.3 P \] (MJ) \[ (4) \] [1]

where, \( ELF_p \) = 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 Pimentel [1].

\[ E_E = 11.99 * kWh, (MJ) \] \[ (5) \]

(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\(^{-1}\) as reported by [21], [22].

\[ E_{MTR} = MTR * m, (MJ) \] \[ (6) \]

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;

\[ E_T = EM_m + EM_f + ELF_p + ELF_p + E_E + E_{MTR} \] \[ (7) \]

All symbols as defined earlier

(e) Total Energy Content (Energy Output) of Finished Product

This was evaluated from the equation below;

\[ E_{CP} = M_{FP} * E_{CP} \] \[ (8) \]

where, \( E_{CP} \) = 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;

\[ E_{UR} = E_{CP}/E_T \] \[ (9) \]

where, \( E_{UR} \) = Energy use ratio
\( E_{CP} \)=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 tomato paste industry are manual, and diesel fuel. 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.
The study reveals the various unit operations carried out at Savannah Integrated Farms Limited for production of tomato paste are depicted Fig. 1 below.

Fig. 1. Flow chart depicting for tomato paste production at the Savannah Integrated Farms Limited Dadin-kowa, Gombe State

Tables I and II show the energy use values from these sources, while Tables III and IV show total energy output of finished tomato paste and energy use ratios evaluated using Equations 1, 3, 8 and 9. Manual energy expended in operating machines was found to be the least consumer of energy (Table I) accounting for 2% of the total energy input. The diesel fuel energy was expended in operating diesel engines and was the highest energy consumer (Table II) and it accounted for 98% of the total energy input for the years studied. Table IV shows that in 2003 the highest energy use of 33.940 GJ was recorded while the lowest consumption was recorded in 2001 with a value of 21.990 GJ which could be attributed to diesel leakages and ages of some machines/equipment.

**Table I**

<table>
<thead>
<tr>
<th>Year</th>
<th>$EM_m=0.75<em>No M</em>Ta$</th>
<th>$(EM_m)$, MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1999</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2001</td>
<td>0.75 * 8 * 80</td>
<td>480</td>
</tr>
<tr>
<td>2002</td>
<td>0.75 * 8 * 90</td>
<td>540</td>
</tr>
<tr>
<td>2003</td>
<td>0.75 * 8 * 80</td>
<td>480</td>
</tr>
<tr>
<td>2004</td>
<td>0.75 * 8 * 80</td>
<td>480</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>495 ±30</td>
</tr>
</tbody>
</table>

**Table II**

<table>
<thead>
<tr>
<th>Year</th>
<th>$EF_{LD} = 47.8 D$</th>
<th>$(EF_{LD})$, MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>-</td>
<td>-</td>
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<tr>
<td>1999</td>
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</tr>
<tr>
<td>2000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2001</td>
<td>47.8 * 450</td>
<td>21510</td>
</tr>
<tr>
<td>2002</td>
<td>47.8 * 450</td>
<td>21510</td>
</tr>
<tr>
<td>2003</td>
<td>47.8 * 700</td>
<td>33460</td>
</tr>
<tr>
<td>2004</td>
<td>47.8 * 500</td>
<td>23900</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>25095 ±5689.3</td>
</tr>
</tbody>
</table>

**Table III**

<table>
<thead>
<tr>
<th>Year</th>
<th>Mass of finished tomato paste per production per year (M$_{FP}$), kg</th>
<th>Energy content of a unit mass of tomato paste (E$_{CP}$ MJ/kg)</th>
<th>Total energy content of finished tomato paste (E$_{FP}$), MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>-</td>
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<tr>
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<td>2000</td>
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<td>-</td>
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<tr>
<td>2001</td>
<td>80000</td>
<td>7.65</td>
<td>612000</td>
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<tr>
<td>2002</td>
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<td>7.65</td>
<td>688500</td>
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<tr>
<td>2003</td>
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<td>382500</td>
</tr>
<tr>
<td>2004</td>
<td>80000</td>
<td>7.65</td>
<td>612000</td>
</tr>
<tr>
<td>Mean</td>
<td>75000 ±17320.51</td>
<td></td>
<td>573750 ±132501.89</td>
</tr>
</tbody>
</table>

**Table IV**

<table>
<thead>
<tr>
<th>Year</th>
<th>$EF_P$ (Output), MJ</th>
<th>$E_T = EM_m$+$EF_{LD}$ (Input), MJ</th>
<th>$E_{UR}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>1999</td>
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<tr>
<td>2001</td>
<td>612000</td>
<td>21990</td>
<td>27.8:1</td>
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<td>2002</td>
<td>688500</td>
<td>22050</td>
<td>31.2:1</td>
</tr>
<tr>
<td>2003</td>
<td>382500</td>
<td>33940</td>
<td>11.3:1</td>
</tr>
<tr>
<td>2004</td>
<td>612000</td>
<td>24380</td>
<td>25.1:1</td>
</tr>
</tbody>
</table>

Energy use ratio signifies sufficient use of energy with a fluctuating pattern, which could be attributed to diesel leakages and ages of some machines/equipment. A correlation analysis of the result shows that a linear relationship given as Equation 10 best describes the relation between tomato paste production and energy input:


From the identified energy use sources in the tomato paste production industry studied, it was observed that manual energy was usually expended in operating machines. This energy was the least used, accounting for 2% 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. Diesel fuel energy expended in operating diesel engine/machinery in the industry has had the highest values of energy use accounting for 98% of the total energy used.

Fig. 2 shows the contribution of each energy source and extent of use over the years. It is clear from the fig. that much diesel fuel energy was used by the industry in the years under review, a scenario similar to the findings of Jekayinfa and Olafimihan [16]. 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 tomato paste production cost. 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. This signifies lack of good and effective energy conservation practices.

**Fig. 2.** Energy types and consumption levels for paste tomato production at Savannah Integrated Farms, Dadin-kowa, Gombe State

\[
Y = 2.9572X_{\text{ET}} + 150676
\]

\[
R^2 = 0.9394
\]

where, \(Y\) = Tomato paste production, kg

\(X_{\text{ET}}\) = Total energy inputs, MJ

\(R^2\) = Coefficient of determination

**REFERENCES**


