Comparison and Evolution of Energy Consumption in Moroccan Agro-food Industries

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Abstract. The aim of this article is to establish a comparison between the Moroccan energy consumption and the BREF the reference document on best available techniques in the food industries, then an evolution of this consumption by 2030 in order to better understand it and to define strategies to reduce energy bill. According to a survey conducted among 5000 Moroccan companies, we were able to compare the energy consumption of the agro-food industries including sugar industry, dairy industry, cereal industry; fatty substances industry and fishing industry with that of the BREF. Also an evolution of Moroccan consumption was established by 2030 using the linear regression method, and then calculated a non-negligible average annual growth rate (AAGR). The results show that the Moroccan energy consumption is adequate to that of the BREF, and an energy consumption constantly increasing by registering a non-negligible AAGR.

1. Introduction

The sector of agro-alimentary industries (IAA) occupies the second place in the Moroccan industry after the chemical and Para chemical industries, it accounts for nearly 30% of total industrial production [1].

In 2013, this large sector has 2062 companies, and employs 140,975 people. Thus an energy consumption recording a value of 378.182 toe of which 130.499 toe electrical energy and 247.683 toe thermal energy [2]. The sugar industry, the dairy industry, the cereal industry, the fats and oils industry and the fishing industry count among the most energy-consuming food processing industries by counting approximately 55% of total energy consumption in the agro-food sector [3]. In order to reduce the consumption of the sector, Morocco aims by 2030 to minimize it by implementing various strategies to cite Green Morocco Plan.

2. Methodology

Our article is based on the results of a survey conducted among 5000 Moroccan companies including the agro-food industries focusing on their energy consumption and comparing it with that of the BREF so as to better know the energy consumption of the sector.

In order to predict the energy consumption, the following linear regression method was used for the agro-food industries: the sugar industry, dairy industry, cereal industry, fatty industry and fishing industry.
Dairy Industry
- Electric energy consumption: \( y = 0.27x - 536.38 \)
- Thermal energy consumption: \( y = 0.452x - 897.45 \)

Where “x” is the year of energy consumption and “y” is the energy consumption including electric and thermal.

Cereal Industry
- Electric energy consumption: \( y = -0.83x + 1706.8 \)

Fat industry
- Olive oil industry
  - Electric energy consumption – Olive oil: \( y = 0.3813x - 764.21 \)
  - Electric energy consumption – Table olive: \( y = 0.6963x - 1398.7 \)
- Oilseed industry
  - Electric energy consumption: \( y = 0.079x - 158.45 \)
  - Thermal energy consumption: \( y = 0.203x - 407.18 \)

Fishing industry
- Electric energy consumption: \( y = 0.007x - 11.59 \)
- Thermal energy consumption: \( y = 0.029x - 48.38 \)

3. Results and Discussion

This section is interested in presenting the results, as well as their discussions. First, we present below the comparison of the energy consumption, including the electrical and thermal consumption with that of the BREF, and then the consumption evolution is predicted using the linear regression method cited above.

Also, the AAGR is calculated using the following formula; \( \text{AAGR} = \left( \frac{\sqrt[n]{\text{EV}}}{\sqrt[n]{	ext{FV}}} - 1 \right) \times 100 \)

With “EV”: End value, refers to the value of the later year.

“FV”: First value refers to the value of the earlier year.

“n”: Number of periods between the earlier and the later periods.

This indicator measure the average evolution in energy consumption from 2013 to 2030

3.1. Sugar industry

The sugar industry is one of the major consumers of energy to quote 44% of the total energy consumption. Table 1 and Table 2 show the total energy consumed in the sugar industry according to the BREF and the Moroccan one, while Figure 1 represents the evolution of the Moroccan industry's energy consumption by 2030.

**Table 1.** Total energy consumed in the sugar industry according to the BREF

| Specific value per ton of beet | Total energy consumed (KWh) |
|--------------------------------|-----------------------------|
| Average                        | 307                         |
| Range                          | 232-367                     |
| Specific value per ton of sugar produced | 1987                         |
| Average                        | 1554-2379                   |
Table 2. Energy consumed per ton of sugar produced in Moroccan industries

| Products          | Electricity (KWh/t) | Fuel (KWh/t) |
|-------------------|---------------------|--------------|
| Sugar industry    | 39                  | 2242         |

According to the results of Tables 1 and 2, the total energy consumed per ton of sugar produced in Moroccan industries amounts to 2281 kWh, which is in line with the range delivered by the BREF with respect to figure 1 whose consumption of electricity, as well as fuel by 2030, has an average annual growth rate of around 6.97% for the first consumption. While the second one mark a humble AAGR of 0.83%. The latter Rate is the result of the integration of other energy alternatives, namely the valued bagasse thus re-use it in order to minimize the use of fossil energy as well as a reduction of the energy bill of this sector.

3.2. Dairy industry

In order to extract dairy products, energy consumption is essential, recording a consumption of around 6% of the total energy consumption of the agro-food sector. 80% of this energy consumption is in the form of thermal energy. The rest is in the form of electrical energy. Table 3 shows the Moroccan energy consumption and that of the BREF of dairy products. Regarding figure 2, it shows us an evolution of the energy consumption by 2030.

Table 3. Energy Consumption of Dairy Products

| Products                        | Electricity (KWh/t) | Fuel (KWh/t) | Moroccan consumption | Range (BREF) |
|---------------------------------|---------------------|--------------|----------------------|--------------|
| Milk and yogurt marketed        | 46                  | 42-694       | 178                  | 50-417       |
| Cheese                          | 417                 | 22-805       | 410                  | 42-1278      |
| Milk and milk powder            | 66                  | 17-917       | 233                  | 333-5555     |
Table 3 above shows that the Moroccan energy consumption respects the data of the BREF except the consumption of thermal energy of milk and milk powder, which is a little less than the range. Concerning Figure 2 Electricity and fuel consumption are constantly increasing, with an average annual growth rate of around 2.96% for the first consumption, while the second marks an AAGR of 2.87%. This is due to the recent policy adopted by the sector to minimize their energy consumption [4].

### 3.3. Cereal industry

The cereal sector is one of the main sectors of agricultural production in Morocco, recording a consumption of 27% of the total electricity consumption of the agro-food sector. Table 4 shows energy consumption of the pasta according to the BREF, while Figure 3 shows the evolution of the electrical consumption of the sector.

**Figure 2.** Evolution of Moroccan energy consumption in 1000 Toe

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**Table 4. Energy consumption of pasta according to BREF**

| Energy consumption | Range (KWh/t) |
|--------------------|---------------|
| Electric           | 140-220       |
| Thermal            | 0.417-0.527   |

**Figure 3.** Electricity consumption for Moroccan cereal industry in 1000 Toe
Concerning figure 3, electricity consumption for the Moroccan cereal industry is down by -2.85%. This can be explained by the decrease in production of the three main cereals [5, 6] and the major dependence of this sector on rainfall.

3.4. Fat industry

Considering the importance of oils (in terms of food, energy or industry), the fatty substances industry accounts for a significant percentage in the agro-food transformation by 10.40%, but its energy consumption remains minimal, namely 3% of the total energy consumption of the agro-food sector. Table 5 shows the energy consumption of Moroccan fatty substances. As for figure 4, 5 and 6, they show the increasing evolution of energy consumption in the sector.

Table 5. Energy consumption of the fatty substances industry in Morocco

|                | Electricity (KWh/t) | Fuel (KWh/t) |
|----------------|---------------------|--------------|
| Olive oil      | 209                 |              |
| Soybean oil, sunflower | 116               | 295          |

Figure 4. Evolution electricity consumption of Moroccan olive oil in 1000 Toe

Figure 5. Evolution of electricity consumption of Moroccan table olive in 1000 Toe
Table 5 the Moroccan consumption highlights the energy consumed by fatty industry and shows that the Moroccan consumption of thermal energy respects the range delivered by the BREF: 155-390 KWh / t while that of Morocco is 294.59 KWh / t. According to figure 4, it shows the evolution of electricity consumption from 2012 to 2030 in olive oil. This consumption continues to increase, registering an average annual growth rate in the order of 7,018%, figure 5 is about the electricity consumption of table olives, it shows an average annual growth rate of about 9.87% and finally figure 6 shows us the increase in electricity and fuel consumption for the oilseed industry, with an average annual growth rate of around 7.35% for first-time consumption, while the second marks an AAGR of 7.64%. These rates obtained from the Moroccan strategy “Green Morocco Plan” concerning the olive oil industry, aim to reach an olive oil production of 330,000 tons by 2020 and a table olive of 320,000 tons, the government as well signed a contract with the inter-professional of oilseed crops FLOEA so as to be able to increase the production of edible oils to reach 95,000 tons in 2020 [7].

3.5. Fishing industry
According to the National Fisheries Office, Morocco ranks first as a fish producer in Africa, as well as the production and export of sardines at the international level. This sector consumes 10% of the total agribusiness. According to the BREF, the energy consumption during the canning is between 150 and 190 KWh/t while the Moroccan consumption is of 189.84 KWh/t the order of electric energy. Figure 7 shows the evolution of Moroccan energy consumption.

Figure 7. Evolution of energy consumption of Moroccan fishing sector in 1000 toe

Figure 7 shows a slight increase in electricity and fuel consumption in the fishing sector, with an modest average annual growth rate of around 0.27% for the first consumption while the second marks an AAGR of 0.283%. These rates are due to the low Moroccan consumption of sea products, to bearing in mind 11 kg / person / year, compared with 18.9 kg / person / year worldwide [8].
4. Conclusion
The aim of this article is comparing and studying the evolution of Moroccan energy consumption, using the linear regression method. The results obtained from the comparison enabled us to deduce the following conclusions:

- The Moroccan sugar industry has a total energy consumption of around 2281 Kwh / t which is respectable by the margin delivered by the BREF[9] : [1554-2379]
- Moroccan dairy products also recorded adequate energy consumption to that of the BREF to quote milk and yogurt marketed which their electrical consumption is around of 46 KWh/t and the thermal consumption is 178 KWh/t which are adequate to the margin of the BREF to know [42-694] for electrical consumption then [50-417] for thermal consumption.

On the other hand, they show us that the agro-food industry, represented by its sub-sectors will constantly increase its energy consumption from 378,182 toe in 2013 to 690,000 toe in 2030. The energy bill will also significantly record a high AAGR of around 7.59% for electrical energy from 28078.53MDH / year in 2013 to 97468.74MDH/year in 2030 while thermal energy marks a low decrease of about -0.3% ranging from 10836,13 MDH/year in 2013 to 10368,75MDH/year in 2030, which is presented below in figure 8. For this reasons some recommendations have been dictated for the agro-food sector and are presented below:

- Installation of economic lamps
- Optimization of compressed air
- Installation of thermal solar panels for process water heating
- Installation of energy management system
- Installation of photovoltaic panels
- Improvement of natural lighting
- Optimization of refrigeration units

![Figure 8. Moroccan energy bill in MDH of 2013 as well as for the 2030](image)

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