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Energy Efficiency Measures in Bakeries toward Competitiveness and Sustainability—Case Studies in Quito, Ecuador

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Abstract: This paper evaluates the energy efficiency in the bakery industry toward competitiveness and sustainability through energy audits that were carried out on six bakeries located in Quito, Ecuador. Firstly, an initial meeting was held. After this, an energy survey was carried out in all areas of the bakeries. The information of the energy consumption of the facilities was collected. This was based on electricity bills, power data, equipment usage time, habits, and monthly consumption. With the energy balances, the critical points were identified, resulting in the baking process and the production activity, as those with the highest energy consumption within each establishment. Subsequently, with the indicator of electrical energy consumed per unit produced, the energy consumption by production processes and the bakery's total energy consumption were determined. Several improvement proposals were generated for the bakery industry based on the results. Finally, it is concluded that the consumption of electrical energy in the bakery industry in Quito is efficient when compared to other bakeries, since they use less energy per unit of mass processed to produce products.

Keywords: eco-efficiency; emission reduction; energy efficiency; energy management; energy saving strategies; power analysis

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1. Introduction

The depletion of fossil fuels and environmental concerns have to be addressed in the short future. Many energy policies have been imposed in various energy-consuming activities, such as the energy efficiency, which is defined as the ratio of service output of a process to the energy input into that process. Energy efficiency can be used for analysis of industrial operation and its performance, especially at the macrolevel. Thermodynamic, thermophysical, thermoeconomic, and economic metrics can be categorized through energy performance indicators [1,2].

Global total final energy consumption of the manufacture industry was 1978 Mtoe in 2016 and 74.7% of energy belongs to the mechanical manufacturing industry [3]. The industrial sector in Europe had a final energy consumption of 274.7 Mtoe in 2015, which accounted for 25.35% of the whole energy used in this region [4]. The food sector is an essential industry in this region, which has an energy intensity of 23 toe/10^6 € in 2015 [5]. The values are different in other regions; for example, China's food industry consumed 76.61 (Mtoe), which represented 3.2% of the entire manufacturing industry [6]. The industry in Brazil had an estimated energy intensity of 586 toe/10^6\$, where the most important industries were iron and steel, pulp and paper, food, and beverage [7].

Many studies have performed energy audits in various industries. For example, in [8], an energy audit in a paper mill in China was executed in order to reduce the energy use and CO_2 emissions. The authors of [9] carried out an energy audit in a Scandinavian chemical wood-pulp mill, resulting in some proposals for energy-saving. In [10], thermal energy audit analysis was employed for a pyroprocessing unit of a typical dry process cement plant in the North-east of Nigeria. The authors of [11] investigated the outcomes of energy efficiency improvements and analyzed the benefits that were achieved under various energy efficiency measures from energy audits based on case studies. In [12], a novel methodology for energy audit was presented and applied in a large manufacturing company in the home appliances industry.

Based on the energy audits, many improvements in technologies or devices have been also proposed and studied in industries. For example, in [13], the potential of different control strategies in heating, ventilation, and air-conditioning (HVAC) systems was assessed to minimize the energy use. The authors of [14] improved the use of water pumps of petrochemical plant operations to obtain electricity savings. In [15], the existence of non-energy benefits that can be taken into account in an energy efficiency investment in an oil and gas processing center in México was presented. The authors of [16] described three identical groundwater heat pumps for heating two pig houses on a farm in West Germany.

The bakery industry is one of the most important activities in the food industry. The world bakery market was approximately valued in $216 billion in 2020 [17]. Europe had 190,000 small and medium enterprises in the bakery sector, where the craft bakeries represent 55% and the industrial sector 45%. The industrial bakery is different in each country, for instance, in UK, industrial bakery represents 80% of the market, while, in Germany, it is 40%, in France, 30%, and in Spain it is 19% [18]. In Latin America, the bakery sector is mainly developed by micro-business or artisan bakeries, like in Mexico, where 97% of bakeries are micro-business, and Peru, where 80% of bakeries are artisan [19]. Ecuador has 166 formal bakery companies and 76 formal companies that elaborate cakes in 2021 [20]. Nevertheless, Ecuador had 8200 bakeries in 2010, and most of them were artisan bakeries [21].

Only a few works have studied the energy efficiency in bakeries. For example, in [22], some energy management practices in a bakery in Germany were proposed. The authors of [23] compared the thermodynamic performance of three industrial bakeries, demonstrating that a par-baked brown bun production chain had the best thermodynamic performance. In [24], the impact of electrical and hybrid heating on bread quality during baking was analyzed; the hybrid heating mode resulted in the best performance in terms of moisture, volume, and firmness. The authors of [25] proposed a point energy technology for improving the the insight of the energy usage in a bakery in Northern Ireland. In [26], an energy consumption analysis was performed in a bakery by optimizing the total energy that is absorbed by the food product. The authors of [27] integrated a solar thermal energy storage reactor to improve the performance of a solar bakery.

The aim of this paper is to provide specific data from a sector where there are not much data published and that can be used as benchmarks, since they are small stores. Still, they are very numerous in towns and cities all over the world. The work performed energy audits in six bakeries in Quito, Ecuador, by evaluating electricity bills, power data, equipment usage time, habits, and monthly energy consumption. The relative indices of consumption per kg of material produced have been calculated. Using energy consumption data that were provided in the invoices ensures that the consumption considered are those that occur and are data that may be available in other studies at no additional cost. It is essential to highlight that the main processes in which the energy is consumed have been analyzed. Different efficiency measures have been proposed to improve efficiency that can serve as a basis for other studies. After that, the energy-saving potential will be assessed in the bakeries.

The rest of this paper is organized, as follows: Section 2 describes a background of the bakery industry. Section 3 presents the energy efficiency methodology. The results are discussed in Section 4. Finally, Section 5 is devoted to the main conclusions.

2. Background

2.1. Bakeries

The process of making bread, cake, and small pastry (cookies, chocolates, nougat, truffles, alfajores, brownies, etc.) consists of some stages, such as mixing and kneading ingredients based on a previous recipe to give a form of homogeneous and uniform dough, which will later be subjected to forming processes to finish with baking. The various processes are described in Figure 1 and they are detailed below:

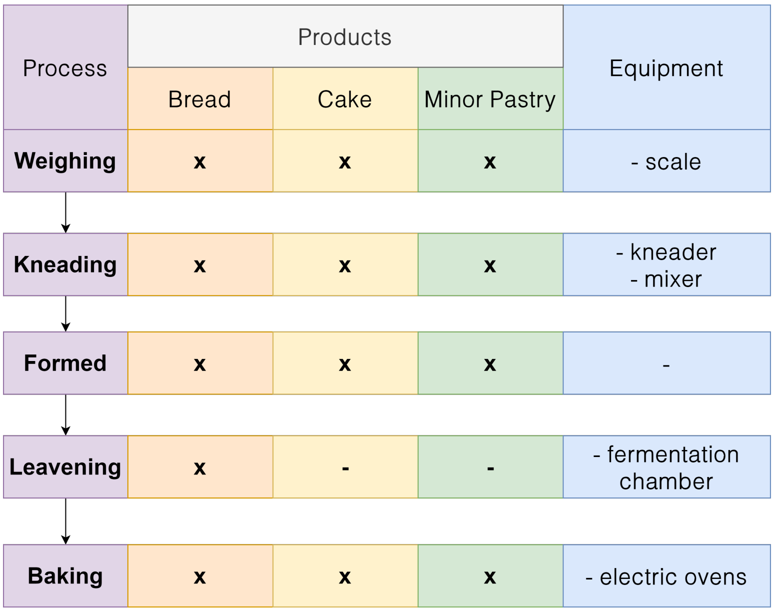

Figure 1. Processes in Bakery.

- Weighing: The first stage of production uses a scale to weigh all solid ingredients such as flour and yeast. After that, the eggs, salt, sugar, and butter are added to a container. Afterward, liquids, such as water, are measured. Finally, all of the ingredients are placed in a container.
- Kneading: With the ingredients already weighed, it is deposited inside the kneading equipment. They are combined for around 5 to 10 min., depending on the quantity. In the end, the mixture is collected from the kneader. Subsequently, the final mixture is deposited in a container to rest for a time of 10 min.
- Forming: Once the dough rests, we proceed to make cuts with previously indicated dimensions and then shape the dough. Besides, to add some other necessary detail for the bread, cake or little bakery. They are then placed in cans or molds, so that, in this way, they can enter the oven.
- Leavening: This stage is specifically for bread preparation. Here the cake or minor bakery is not included. With the help of cars, the loaves are entered into the fermentation chamber. They will remain for about 45 min., so that the bread takes the necessary size before baking. After the loaves come out of the chamber, let it rest for about 5 min.
- Baking: In this stage, electric ovens with a maximum temperature of 250 °C are used, regular cooking is from 190 °C to 250 °C; this depends on the size and quantity of the smaller bread, cake, or bakery, and this will be for a time of 20 to 45 min.

2.2. Energy Efficiency Policies: ISO Standard 50001

This standard is based on energy management systems analysis to improve organizations' energy performance based on energy efficiency use, and energy consumption to minimize environmental problems, such as gas emissions and save energy payment. This can be applied with the commitment of the organization's stakeholders, especially of the top management in any industry, company, or business.

Having the ISO 50001 is an advantage, since it reduces maintenance prices, includes a culture of progressive improvement and assistance to have workers committed to their work. Likewise, it manages to save 5% to 15% by measures implemented in the operating area.

To implement this standard, the following steps are required:

- Pre-Audit: It is the beginning of the contact between the two parties whose purpose is to inspect the establishment, in addition to previously verifying the requirements of the standard. During this period, a team is usually established with part of the consulting firm and company personnel.
- First Phase of the Audit: All of the data concerning energy consumption in the establishment are collected, such as natural gas, fuel, and electricity consumption bills. The staff in charge of this work will reveal the establishment's location and the area with the highest energy consumption.

2.3. Energy Baseline

The UNE-EN ISO 50001: 2011 Standard defines a quantitative reference that provides the basis for the comparison of energy performance. For this reason, it reflects the conditions of a specific period. It is also used to calculate energy savings as a reference before and after taking actions to improve energy performance.

2.4. State of the Facilities

In this activity of an energy audit, the facilities' current conditions are analyzed. Some of the actions are surveying of equipment characteristics, like power, time of use of equipment, and behavior of employees.

2.5. Energy Audit

It is a process of systematic evaluation and monitoring to obtain a complete judgment on energy consumption and its cost. Likewise, it allows for seeing which factors influence higher energy consumption and to assess the different opportunities for improvement. It plays the role of finding the possible sources of reduction of electricity consumption in the industry, by examining the areas in search of viable energy savings or considering individual energy saving measures.

2.6. Energy Indicator

They are used for comparison between energy use with productive values. These indicators reveal where energy savings can be implemented in the processes. They also provide information on trends in relation to historical energy use or for benchmarking.

3. Methodology

Figure 2 describes the methodology followed, and it will be explained below.

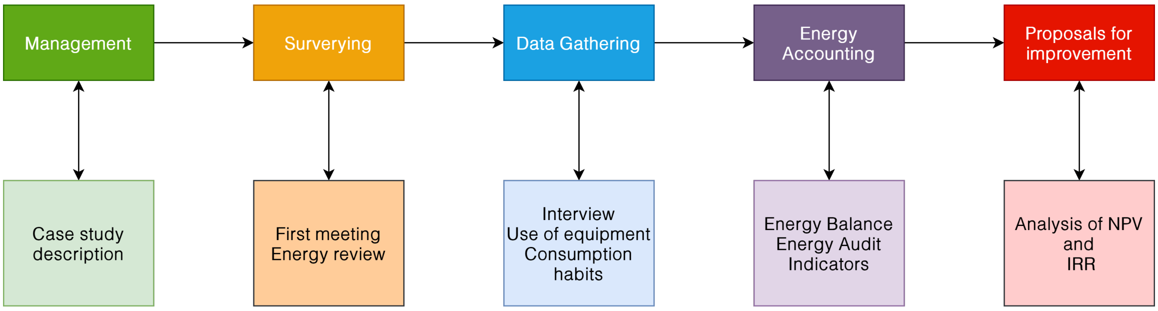

Figure 2. Methodology.

3.1. Management

Case Study Description

The selected case studies were carried out in the San Carlos Sector on Machala and transversal avenues, located in the north of Quito, Ecuador. The bakeries have an average area of 60 square meters. Their daily production is around 4000 loaves, nine cakes, and 130 pieces of a small pastry. For elaborating these products, equipment, such as the kneader or mixer, leavening chamber, and oven are required, related to energy consumption. Additionally, other additional activities are carried out in the establishment, such as the sale of dairy products, sausages, and other essential products. Figure 3 illustrates the map of the six selected bakeries.

Figure 3. Location of the six selected bakeries.

3.2. Surveying

The surveying was divided in the following steps:

- First Meeting: At this stage, a confidentiality agreement was established for the project data with the bakeries and communication with those responsible for the industry, and how the information from the establishment will be collected. Finally, an appointment was scheduled for a technical and visual examination of the equipment.
- Energy Review: A visit was made to all areas of the bakeries, for both sale and production, to record the status of the equipment and electrical appliances present in the facilities to obtain all of the characteristics of the equipment and the tasks that are carried out in the place. This was done with the help of a weekly schedule.

3.3. Data Gathering

Detailed information regardinf the energy consumption of the facilities is acquired through the administration with surveys. It was based primarily on the establishment's electricity bill.

- Interviews: Information was collected through interviews with those in charge of energy consumption data for April 2020 and measures related to production equipment consumption. Furthermore, the review of essential documents and records to determine energy consumption and management was performed. Likewise, whether the devices or equipment are in good condition was analyzed. The questions considered in the interviews carried out were divided based on the different activities and processes (see Appendices A–E).
- Use of equipment: Information was collected regarding the use of the equipment and working hours; the lighting system and lower consumption electrical equipment were verified during the week and weekends to determine the consumption during the month.
- Consumption habits: Information was collected about the employees' consumption habits within the establishment through personnel surveys to obtain data on hours of consumption and the use of electrical equipment during their recess or end of their hours of workdays. Awareness and proper energy management by management and employees were also taken into account.

3.4. Energy Accounting

3.4.1. Energy Balance

With the data from the surveys, an energy balance was generated for April. This month was taken as a reference, since it was the date on which the information from the bakeries was collected. Additionally, points of highest consumption were identified according to the area, the type of production equipment, and energy consumption of other electrical equipment types present in the establishment.

To carry out the energy balance, the following equation was used:

$$H_m = H \cdot F + H_o \cdot F_o \tag{1}$$

where H_m is the hours of use per month, H the hours of daily use on weekdays per device, H_o the hours of daily use weekend per device, F the working weekdays factor, which is 20 weekdays for the month of April, and F_o the working weekends factor, which is 10 weekend days for the month analyzed.

Moreover, the device consumption is defined:

$$E_d = P \cdot H_m \tag{2}$$

where E_d is the device energy consumption per month (kWh/month) and P is the power consumption (kW)

The production energy consumption (kWh/month) is defined:

$$E_p = E_k + E_{br} + E_{ba} \tag{3}$$

where E_k is the energy consumed by the kneading (kWh/month), E_{br} the energy consumed by the leavening (kWh/month), and E_{ba} the energy consumed by the baking (kWh/month).

The total energy consumption is defined:

$$E_T = E_P + E_R + E_L + E_O \tag{4}$$

where E_P is the production energy consumption (kWh/month), E_R the refrigeration energy consumption (kWh/month), E_L the lighting energy consumption (kWh/month), and E_O the rest of the energy consumption (kWh/month).

3.4.2. Energy Audit

In this section was compared the energy balance with the electrical bills. With the energy audit results, the processes and activities with the highest consumption were analyzed in order to develop proposals that reduce energy consumption.

3.4.3. Indicators

According to the energy balance data, the points with the highest energy consumption were found based on the processes and activities that were present in the establishment.

To identify those critical points, the indicator of electrical energy by quantity of flour per process is defined:

$$I_p = \frac{E_p}{W_f} \quad (5)$$

where W_f is the weight of flour used per process (kg/month).

4. Results and Discussion

4.1. Energy Audit

With each bakery's bill and electricity consumption values, a balance was made of the processes present in the production stage. Likewise, any activity carried out in the bakery requires the use of electrical energy. Thus, the first instance was to determine the hours of use per month using Equation (1). Subsequently, to find the value of equipment consumption with Equation (2) and to immediately find the total consumption of each process with Equation (3). Next, with the help of Equation (4), each bakery's total energy consumption values were determined. Finally, the percentage of error for each bakery was compared to the electricity bill's value of April, which considers 30 days, as summarized in Table 1.

Table 1. Energy Consumption in each studied bakery.

	Electricity Bill Total Electricity Consumption (kWh/month)	**Electricity Bill ($)**	**Estimated Electricity Consumption (kWh/month)**	**Error (%)**
Bakery 1	1043	137.18	1049.82	0.653
Bakery 2	1492	171.43	1472.31	1.320
Bakery 3	1303	165.69	1295.00	0.614
Bakery 4	1101	138.52	1063.22	3.431
Bakery 5	1324	168.57	1316.69	0.552
Bakery 6	1176	148.26	1154.85	1.798

4.2. Indicators

With each bakery's electricity consumption value and the respective total amount of flour used during the month, the value of the energy consumption indicator of each bakery was determined. For this, Equation (5) was used first, which corresponds to the electrical energy per quantity of flour per process. Equation (5) was also used to analyze the whole energy used in the bakery per amount of flour of all products. The best energy indicator corresponds to bakery 2, which has a value of 0.124 kWh/kg. This means that it is the most efficient bakery, since it requires less energy and produces greaters quantities. On the other hand, bakery 4, with a value of 0.315 kWh/kg, has the worst indicator since it consumes more energy for production, as shown in Table 2. The mean value of the energy indicators of the six Bakeries analyzed is 0.204 kWh/kg.

According to the data that were obtained in each baker's interview about the time of use of each equipment for production, it was divided bread production processes into kneading or mixing, leavening, baking, and, additionally, the entire process was analyzed. Subsequently, with Equation (5), the amount of energy used per month was calculated by the amount of flour in each of the processes. The Energy Indicator for bread production by bakery is depicted in Figure 4 and in Appendix F in the Appendix section. Besides, it is observed that bakery 2 presents better results than the other bakeries. This is because its equipment works properly without presenting poor handling problems or is sub-used like bakeries 1, 3, and 5. It is important to note that bakeries 1, 2, 3, and 5 have ovens with similar space and power capacities, as shown in Appendix B. However, bakery two processes more mass of flour, as shown in Table 2. Likewise, it can be observed that bakery 1 presents results that are not so adequate for its production, some equipment are household equipment, like the kneader, and others are subutilized, like the fermentation chamber and oven.

Table 2. Energy Indicator by bakery.

	Energy Use (kWh/month)	Mass of Flour Processed (kg/month)	Energy Indicator (kWh/kg)
Bakery 1	1043.00	3628	0.287
Bakery 2	1491.22	12,000	0.124
Bakery 3	1303.00	9000	0.145
Bakery 4	1101.00	3500	0.315
Bakery 5	1325.00	10,000	0.133
Bakery 6	1173.00	5000	0.235

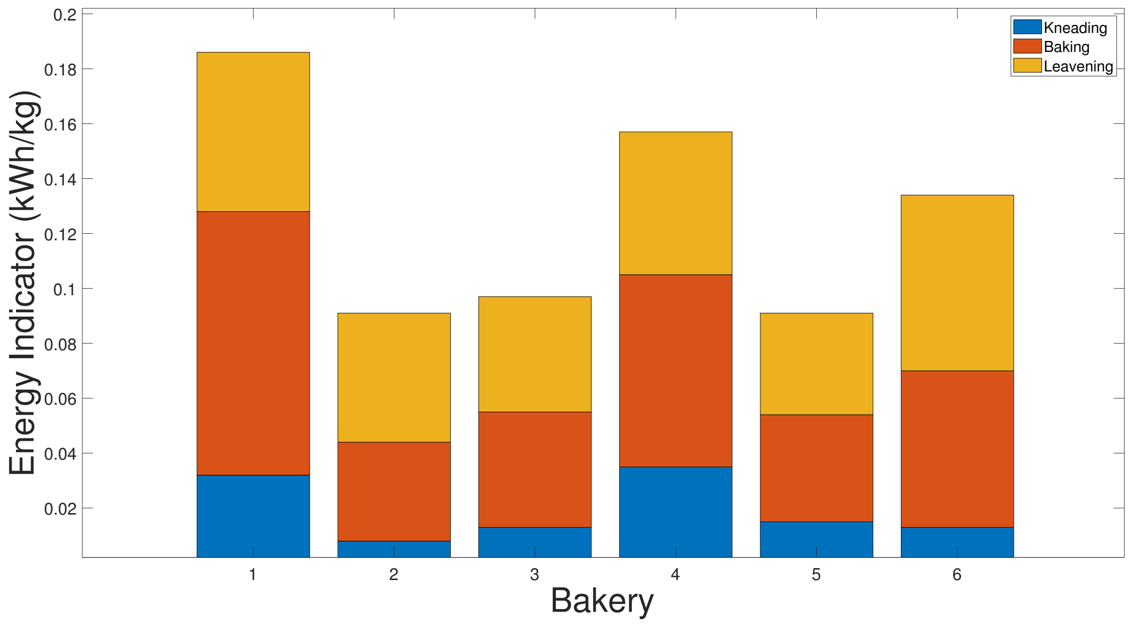

Figure 4. Energy Indicator for bread production by bakery.

According to the data that were obtained in the interview of each baker about the time of use of each equipment for production, it was divided by cake production processes, such as kneading or mixing and baking; without counting on the leavening process because this process only corresponds to the production of bread. Next, with Equation (5), the amount of energy used per month was calculated by the amount of flour in each of the processes. The Energy Indicator for cake production by bakery is illustrated in Figure 5 and detailed in Appendix G. In addition, it can be seen how bakery 3 presents better results than other bakeries. Moreover, bakery 4 has the poorest results, since it consumes a more significant amount of electrical energy in all cake production processes.

According to the data that were obtained in the interview of each baker about the time of use of each piece of equipment for production, it was divided by the production processes of little bakery, such as kneading or mixing and baking. In Figure 6 and Appendix H , the

Energy Indicator for minor pastry by bakery is depicted. Note that bakery 2 presents better results than other bakeries. This is because the production works properly and it generates less electrical energy losses in the little bakery's production process. It can also be seen how bakery 4 is less favorable than the rest. This is because it consumes a more significant amount of electrical energy in all smaller bakery production processes.

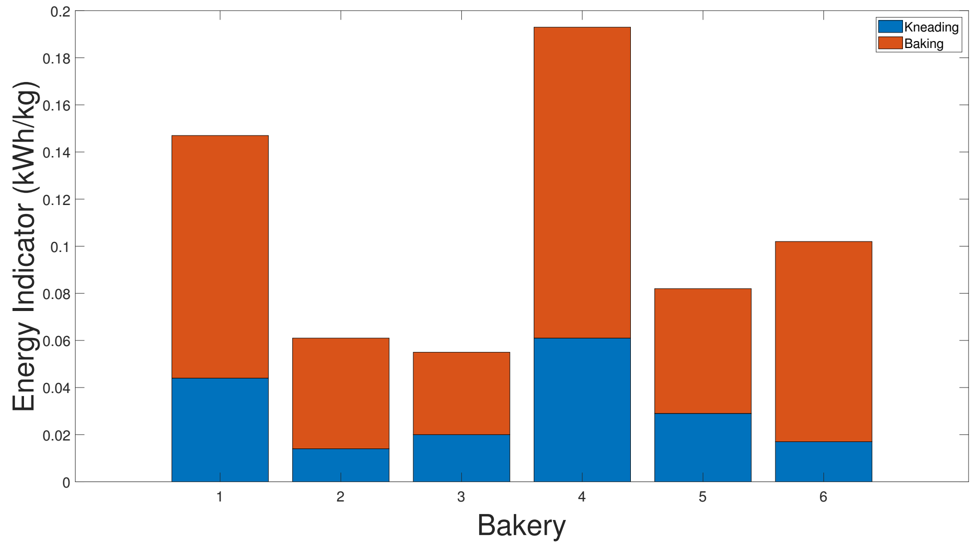

Figure 5. Energy Indicator for cake production by bakery.

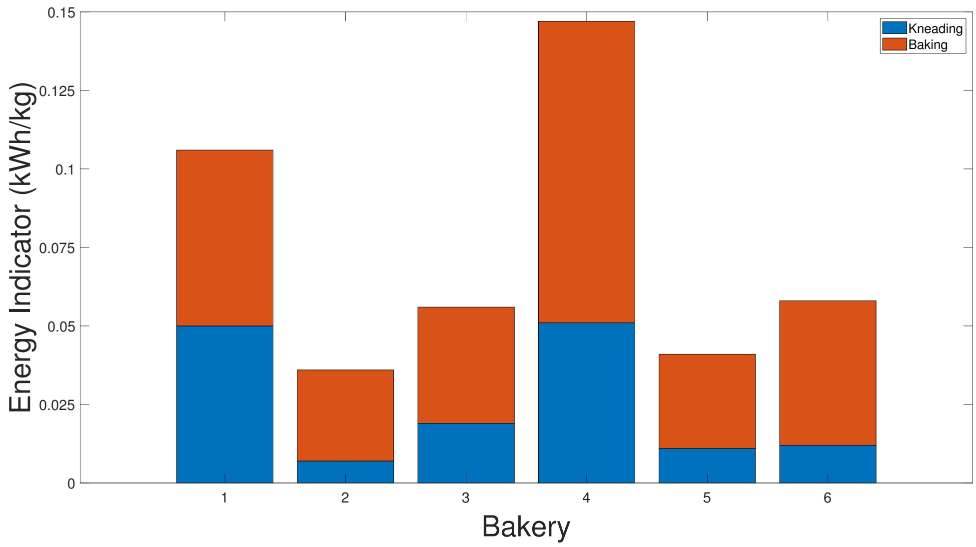

Figure 6. Energy Indicator for minor pastry by bakery.

4.3. Higher Consumption Processes

Figure 7 illustrates the monthly energy consumption by bread, cake, and small pastry processes in Bakery 2, which is the bakery with the best results in terms of energy efficiency. The baking process within the bread production stage represents the activity with the highest consumption due to the product's cooking, whose energy demand is high. Leavening is the next most consuming process because the bread is given the ability to take volume, which requires more electrical energy and time. Finally, the mixing or kneading process consumes less electricity. This is because it takes little time to mix the ingredients.

The production of cakes has two processes that use energy, such as mixing or kneading and baking. The last consumes more energy, because it requires more time and greater electricity consumption.

The production of minor bakery products has only two processes that take up energy, such as mixing or kneading and baking. Baking has the highest electricity consumption, which is based on the product's cooking.

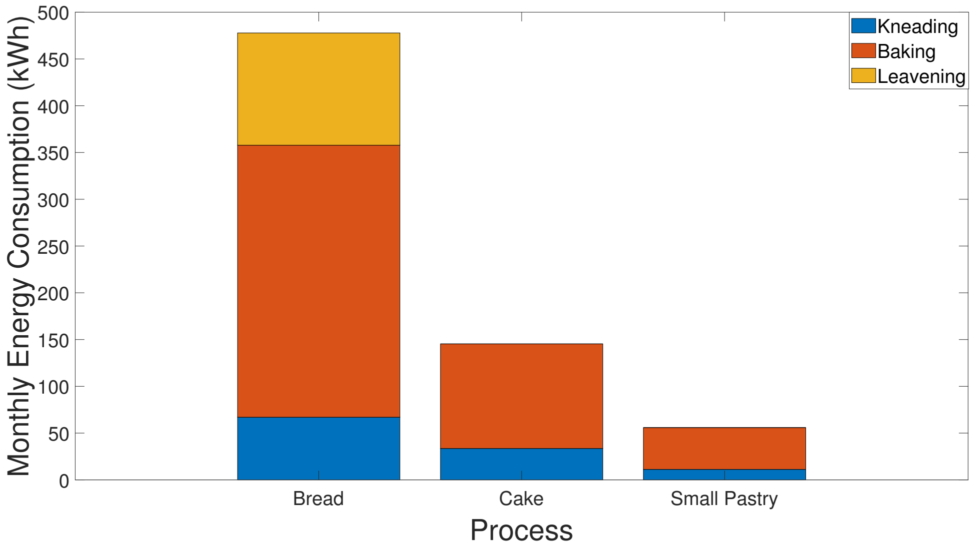

Figure 7. Share of Energy Consumption by Process from Bakery 2.

4.4. Higher Consumption Activities

Each bakery was divided according to their activities into production, refrigeration, lighting, and other activities. These activities were determined based on the function that they fulfill within the bakery and considering the energy consumption. The values of each bakery are shown in Appendix I. Figure 8 illustrates the share of each consumption activity in bakery 2. It was observed that the production activity is the highest value of electrical energy used, representing 46% of the entire bakery with 679 kWh. Subsequently, the refrigeration activity consumes 626 kWh of the total, because the refrigeration equipment is frequently on for the sale of products. Besides, at least one refrigeration equipment is on 24 h a day because it fulfills a preserving function all foods present, such as the products necessary for bakery, dairy products, sausages, or other foods. Lighting consumes 91 kWh, and the other activities 76 kWh, representing a small share of the total energy consumption.

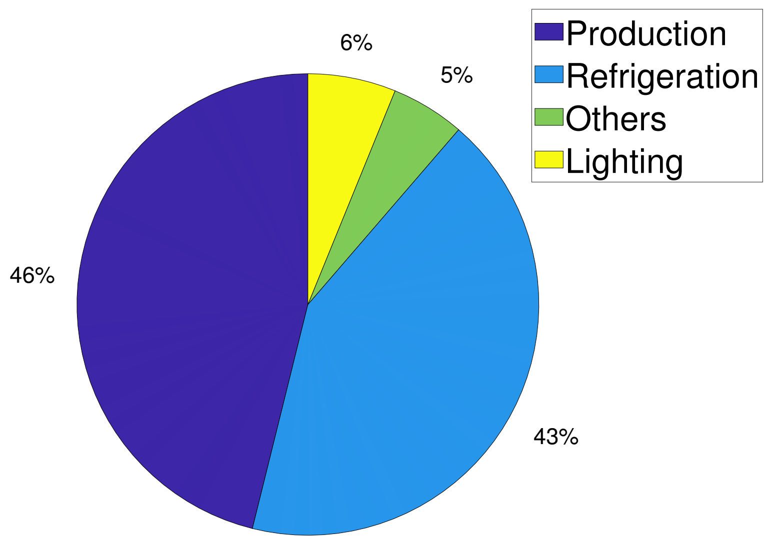

Figure 8. Share of Energy Consumption of the Bread Process per activity from Bakery 2.

4.5. Proposals for the Improvement of Energy Efficiency

After analyzing the energy audit, once the bakery processes and activities with the highest consumption have been identified, improvement activities and actions are proposed. They cover general logistics needs, habits of use, economics, and electric reduction consumption. They are detailed below. This section analyzes bakery 1, since the primary process in all bakeries is to make bread, and this bakery has the worst performance.

- A change of equipment was proposed for the kneading process. Table 3 shows data of old and new proposal. The proposed equipment has a higher capacity for dough processing, with 10 kg per cycle, which will reduce the processing time from 120 h in a month to 36 h. Moreover, the proposed equipment has less power with 750 W, and the energy-saving will be 105 kWh/month. NPV and IRR were calculated with a rate of discount of 6.94% taken from the Central Bank of Ecuador, and an average cost of investment of $636.96 for the kneader after analyzing three different models with the same characteristics, and an annual profit of $ 163.8 for the reduction in the energy bill. The NPV for this proposal after ten years was $555.04 and IRR of 22%.

Table 3. Kneaders comparison data of bakery 1.

Kneaders	Power W	Capacity kg/cycle	Cost $
Old	1100	3	121.03
New Option	750	10	636.96

- For the fermentation chamber, better process management was proposed since the fermentation chamber was partially used due to the limitations of the kneading process. This action will reduce the time of use from 300 h in a month to 96 h, with an energy saving of 102 kWh/month.
- The oven was also partially used due to constraints in the kneading process, and better process management will reduce the time of use with savings of 200 kWh/month.
- The refrigeration activity has a poor performance since the heat emission from ovens is quickly gained by refrigerators. It is recommended to improve thermal isolation in all bakeries. The heat gained by refrigerators was not measured, since it is a secondary bakeries activity, and it should be analyzed in future studies.
- Lighting and minor equipment were not analyzed in detail, since they represent 11% of the whole energy consumption. However, the time of use of this equipment could be reduced with staff training.

In total, 407 kWh/month could be reduced in bakery 1, which represents 39% of the energy saving.

After analyzing all bakeries' data, it is determined that bakeries with low mass processing capacity, like bakeries 1, 4, and 6, have the highest energy indicators. These bakeries have similar problems, like bakery 1, such as the equipment's capacity is not appropriate for the production, which is too small or too big. Therefore, equipment with inadequate capacity limits the following processes, and some equipment is partially used, which causes a waste of energy.

5. Conclusions

This paper presents energy efficiency proposals for bakeries in Quito, Ecuador. Based on the energy audits that were carried out, energy consumption and payment values were determined to reaffirm the relationship between the real payment value and obtained during the investigation. It can be concluded that bakery 2 presents the best energy indicators, since its total production requires a lower amount of electrical energy than others. Besides, bakery 2 shows the best energy performance in all of its production processes, since it works at its optimum capacity. On the other hand, bakery 4 presents the worst energy consumption indicators, since it presents energy losses due to the subutilization of equipment.

Within the bakeries that were located north of Quito, it was established that the process with the highest energy consumption is baking for bread, since the equipment used in this process has the longest usage time per day. Moreover, the high energy consumption is represented by the leavening process, since it is performed daily, as is the baking process, and the equipment's energy consumption is high. The refrigeration equipment has a high energy consumption, since the heat emission from ovens is gained by refrigerators.

The energy indicator of 0.204 kWh/kg in the bakeries in the city of Quito shows an efficient process in general, since the bakeries do not have room heating systems or air conditioners since they are not necessary due to weather conditions. In addition, the equipment presents greater efficiency because the processes are more straightforward for bread and its derivatives. For this reason, the energy indicator shows an average consumption that was lower than other bakeries in developed countries, such as a case study of Germany, where the energy indicator was 0.383 kWh/kg for the source of electricity [22]. This is primarily because bakeries in Quito are artisans and they employ labor to shape, design, and flavor products. Other developed countries are governed to use more equipment, machinery, and less labor force.

The main limitation of this work is that energy consumption values were provided by the invoices of the stores, since this information is available for all consumers, and they do not have an additional cost. Moreover, there were some restrictions in measuring equipment's energy use due to safety protocols that were implemented during the COVID-19 pandemic restrictions. Thus, it could be essential to obtain real measurements of energy consumption in future work through an energy monitoring system.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

HVAC	Heating Ventilation and Air-Conditioning
IRR	Internal Rate of Return
NPV	Net Present Value

Appendix A. Survey of Behavior

This survey analyzes schedule of operation and activities developed in bakery.

Questions	Answers					
	Bakery 1	**Bakery 2**	**Bakery 3**	**Bakery 4**	**Bakery 5**	**Bakery 6**
Monday through Friday, how many hours does the facility operate daily?	15	12	12	12	13	12
How many hours does the facility operate daily on weekends?	15	12	12	12	13	12
What kind of activities does he fulfill? You can choose from several options.	kneading baking decoration sales -	kneading baking decoration sales administration	kneading baking decoration sales -	kneading baking decoration sales -	kneading baking decoration sales administration	kneading baking decoration sales -
In the course of your workday do you have a break?	yes	yes	yes	yes	yes	yes
How long is your break?	30 min	30 min	30 min	30 min	30 min	30 min
When you leave your workday or break, do you leave electrical equipment or appliances on?	yes	yes	yes	no	yes	no
Which appliances or equipment remain on?	refrigeration equipment	oven	refrigerator cash register machine	none	refrigeration equipment	none
Do you unplug the cables of electrical equipment or appliances that you do not use?	yes	yes	yes	no	yes	no
What are the electrical equipment or appliances that you disconnect?	fan television radio baking machine	mixer oven hand mixer	refrigerator cash register machine	none	mixer oven hand mixer	none
How do you consider the operation and condition of the electrical equipment?	regular	good	good	regular	good	good

Appendix B. Survey of Equipment

This survey analyzes the power of each equipment and time of use.

Questions	Answers					
	Bakery 1	Bakery 2	Bakery 3	Bakery 4	Bakery 5	Bakery 6
How many mixers or kneaders does the facility have?	1	1	1	1	1	1
What is the brand of the equipment?	Bomman KM	6010 CB Imepa CF-16500	Eisenbach1 200	Eisenbach1 200	Kneader AR-50	Hornipan
What is the nominal power in (W)?	1100	500	1200	1200	1100	745.7
Time of daily use between week?	4	10	4	4	5	3
Time of daily use on weekend?	4	10	3	4	5	3
How many leavening chambers does the facility have?	1	1	1	1	1	1
What is the brand of the equipment?	Imepa CF-16	Sopan 2C2P	Nova	Imepa	Nova	Adeucarpi
What is the nominal power in (W)?	500	500	450	500	500	1100
Time of daily use between week?	10	8	8	9	7	5
Time of daily use on weekend?	10	8	8	9	7	5

How many electric oven do you have in the facility?	1	2	1	1	2	1
What is the brand of the equipment?	Ecua hornos	(a) Hornipan (b) Hornipan	Inox (Harpia H pro-10)	Hornipan	(a) Ecua hornos (b) Ecua hornos	Inox
What is the nominal power in (W)?	745.7	(a) 745.7 (b) 745.7	1000	745.7	(a) 745.7 (b) 745.7	850
Time of daily use between week?	15	(a) 10 (b) 10	12	13	(a) 9 (b) 9	12
Time of daily use on weekend?	15	(a) 10 (b) 10	12	13	(a) 9 (b) 9	12
How many refrigerators does the facility have?	2	3	2	2	3	2
What is the brand of the equipment?	(a) IMBERA (b) Midea HS-411SN -	(a) IM6 (b) IM6 (c) MABE	(a) Midea HS 5C13707 (b) Induram VFV-520 -	(a) MABE (b) IMBERA VR-19 -	(a) MABE (b) WAL 1F15759171 (c) Midea HS-411SN	(a) Midea HS 5C13707 (b) Induram VFV-520 -
What is the nominal power in (W)?	(a) 380 (b) 450 -	(a) 745.7 (b) 745.7 (c) 372,85	(a) 450 (b) 670 -	(a) 372.85 (b) 559.27 -	(a) 372,85 (b) 80 (c) 450	(a) 450 (b) 670 -
Time of daily use between week?	(a) 24 (b) 6 -	(a) 7 (b) 7 (c) 24	(a) 24 (b) 8 -	(a) 24 (b) 8 -	(a) 24 (b) 24 (c) 13	(a) 24 (b) 8 -
Time of daily use on weekend?	(a) 24 (b) 6 -	(a) 7 (b) 7 (c) 24	(a) 24 (b) 8 -	(a) 24 (b) 8 -	(a) 24 (b) 24 (c) 13	(a) 24 (b) 8 -

Have any changes been made to appliances or equipment in the last year?	no	no	yes	yes	no	yes
What devices or equipment have been changed?	-	-	refrigerator	oven	-	mixer
Approximately how long ago was the change in the last year?	-	-	12 months	6 months	-	12 months
What equipment or appliances do you run on a daily ?	refrigeration equipment	refrigerator	refrigerator	refrigerator	refrigerator and cooler	refrigeration equipment
How many hours are turn on this equipment?	24	24	24	24	24	24

Appendix C. Survey of Lighting

This survey analyzes the power and time of use of lighting.

Questions	Answers					
	Bakery 1	**Bakery 2**	**Bakery 3**	**Bakery 4**	**Bakery 5**	**Bakery 6**
How many hours per day are the luminaires on, by area?	Production: 15 h Sales: 15 h	Production: 12 h Sales: 12 h	Production: 12h Sales: 12 h	Production: 13 h Sales: 13 h	Production: 13 h Sales: 13 h	Production: 12 h Sales: 12 h
Do you turn off the lights you are not occupying?	yes	yes	yes	yes	yes	yes
How many lights do you have in the facility?	5	9	7	6	7	7
What is the nominal power in (W)?	10	28	60	18	32	32

Appendix D. Survey of Production

This survey analyzes the mass used for each product in the bakeries.

Questions	Answers					
	Bakery 1	Bakery 2	Bakery 3	Bakery 4	Bakery 5	Bakery 6
Approximately how much flour is used daily in (kg)?	80	400	300	120	350	170
Approximately how much flour is used Monday through Friday in (kg)?	400	2000	1500	600	1750	850
Approximately how much flour is used on weekends?	200	800	600	220	600	320
Approximately how many loaves of bread are produced daily?	2500	6000	5000	4000	5000	3000
Approximately how many loaves are produced from Monday to Friday?	12,500	30,000	25,000	20,000	25,000	15,000
Approximately how many loaves are produced on weekends?	5000	12,000	10,000	8000	8000	6000
Approximately how many cakes are produced from Monday to Friday?	15	100	50	40	40	30
Approximately how many cakes are produced on weekends?	6	40	20	16	10	15
How many (cookies, chocolates, nougats, truffles, alfajores, brownies, etc.) approximately are produced daily?	50	200	150	130	180	150
How many (cookies, chocolates, nougats, truffles, alfajores, brownies, etc.) approximately are produced from Monday to Friday?	250	1000	750	650	900	750
How many (cookies, chocolates, nougats, truffles, alfajores, brownies, etc.) approximately are produced on weekends?	100	400	300	260	360	300

Appendix E. Survey of Maintenance

This surveys analyzes maintenance of equipment and energy savings measures in the bakeries.

Questions	Answers					
	Bakery 1	Bakery 2	Bakery 3	Bakery 4	Bakery 5	Bakery 6
Have you performed maintenance on electrical installations and equipment?	yes	yes	yes	yes	yes	no
What electrical facilities or equipment have been maintained?	oven	-	mixer	oven	oven	oven and refrigerator
How often is the maintenance or renewal of the machines performed?	1–2 years	-	1–2 years	1–2 years	1–2 years	1–2 years
Do you know about the energy consumption used by electrical installations and equipment?	yes	yes	yes	no	yes	no
Does the facility have an energy plan?	no	no	no	no	no	no
Have you ever performed an energy consumption diagnosis of the facilities?	no	no	no	no	no	no
Have you ever implemented any energy saving measures?	no	unknown	no	no	no	unknown

Appendix F. Energy Indicator for Bread Production by Bakery

Process	Bakery 1 [kWh/kg]	Bakery 2 [kWh/kg]	Bakery 3 [kWh/kg]	Bakery 4 [kWh/kg]	Bakery 5 [kWh/kg]	Bakery 6 [kWh/kg]
Kneading	0.032	0.008	0.013	0.035	0.015	0.013
Leavening	0.058	0.047	0.042	0.052	0.037	0.064
Baking	0.096	0.036	0.042	0.070	0.039	0.057
Total	0.186	0.091	0.096	0.158	0.091	0.134

Appendix G. Energy Indicator for Cake Production by Bakery

Process	Bakery 1 [kWh/kg]	Bakery 2 [kWh/kg]	Bakery 3 [kWh/kg]	Bakery 4 [kWh/kg]	Bakery 5 [kWh/kg]	Bakery 6 [kWh/kg]
Kneading	0.044	0.014	0.020	0.061	0.029	0.017
Baking	0.103	0.047	0.035	0.132	0.053	0.085
Total	0.147	0.061	0.055	0.192	0.082	0.102

Appendix H. Energy Indicator for Minor Pastry production by bakery

Process	Bakery 1 [kWh/kg]	Bakery 2 [kWh/kg]	Bakery 3 [kWh/kg]	Bakery 4 [kWh/kg]	Bakery 5 [kWh/kg]	Bakery 6 [kWh/kg]
Kneading	0.050	0.007	0.019	0.051	0.011	0.012
Baking	0.056	0.029	0.037	0.096	0.030	0.046
Total	0.106	0.036	0.056	0.147	0.041	0.058

Appendix I. Energy Use by Activities

Process	Bakery 1 [kWh/kg]	Bakery 2 [kWh/kg]	Bakery 3 [kWh/kg]	Bakery 4 [kWh/kg]	Bakery 5 [kWh/kg]	Bakery 6 [kWh/kg]
Production	618	679	600	570	662	538
Refrigeration	382	626	485	403	382	485
Others	28	76	59	49	66	51
Lighting	23	91	151	42	87	81
Total	1050	1472	1295	1063	1197	1155

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