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A CASE-STUDY VISION

# Description of industrial processes energetically critical factors in cocoa production in Santander

## *Descripción de los procesos industriales energéticamente críticos en la producción de cacao en Santander*

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ABSTRACT

The objective of this research paper is to describe the energetically critical processes in cocoa production in Santander due to the growth of industrial activities that have generated a higher energy consumption. Additionally, a descriptive methodology with a quantitative approach was proposed through the data analysis technique that seeks to identify the processes with the highest consumption within the production lines. Subsequently, a description of the processes involved in cocoa production was made considering the technical data and operation of the equipment, the calculation was proposed for the operation of the same equipment for 24 hours and 30 days for power factors of 0.75 and 0.95. Finally, through analysis, calculations, and the application of the Pareto methodology, it was found that the energy potential with the highest consumption of active, reactive, and apparent energy is in the cocoa refining process.



**Palabras clave:**
Consumo
Eficiencia
Energía
Procesos Industriales

RESUMEN

Este artículo de investigación tiene como objetivo describir los procesos energéticamente críticos en la producción de cacao en Santander a causa del crecimiento de las actividades industriales que ha generado un mayor consumo de energía. Adicionalmente, se plantea una metodología descriptiva con enfoque cuantitativo mediante la técnica de análisis de datos que busca identificar los procesos con mayor consumo dentro de las líneas de producción. Posteriormente, se realiza la descripción de los procesos involucrados en la producción de cacao teniendo en cuenta los datos técnicos y funcionamiento de los equipos, el cálculo se planteó para el funcionamiento de estos equipos durante 24 horas y 30 días para factores de potencia de 0.75 y 0.95. Finalmente, mediante el análisis, la realización de cálculos y la aplicación de la metodología de Pareto se encontró que el potencial energético de mayor consumo de energía activa, reactiva y aparente se localiza en el proceso de Refinado de cacao.

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## 1. Introduction

Colombia is a country with great geo-climatic conditions that allow the development of the agricultural sector. Additionally, it stands out for its biodiversity and the great variety of microclimates that generate great potential for the cultivation of different species. However, the agricultural sector has been experiencing production, economic, and sales problems for the last four years, the central axis of the crisis being the fall in prices and the income of small growers, who are unable to cover even the costs of production. Departments such as Santander, Antioquia, Tolima, and others are the largest producers of cocoa [1].

The Department of Santander contributes 47% of national cocoa production, with 16% destined for export and 84% for the domestic market. Low crop productivity was also identified due to difficulties in post-harvest methods. The cocoa sector has in its production line different types of industrial machinery and purely manual techniques to obtain cocoa products after planting. [2]

The industrial equipment involved in cocoa processing generates energy consumption that in parallel causes environmental impacts (atmospheric pollution, acid rain, global warming, etc.) that must be reduced. However, there is no complete specification of the energetically critical industrial processes in cocoa production. Accordingly, it is stated that all production processes require energy for their operation, some with higher or lower consumption, which generally depends on the capacity and efficiency of the associated equipment. Thus, knowing the distribution of this consumption within the organizations becomes a starting point for the identification of areas and processes with critical energy consumption [3]. Similarly, it is possible to propose action plans that will help to mitigate environmental impacts in various industrial processes [4] and comply with the ISO 50001 standard [5-7]. In this order of ideas, the present work seeks to identify the processes that are energetically critical in the production of cocoa, based on processes for which it was necessary to build a documentary base of all the processes of cocoa production, classify the industrial processes separating them from the natural processes, make a description of the industrial processes from their principles of operation and technical characteristics to finally calculate the theoretical consumption of each equipment to determine the processes that can be energetically critical in the production of cocoa. The mechanisms and results of the present study are described below research.

## 2. Methodology

The development methodology was based on descriptive research, with a quantitative approach and the use of the deductive method [8-9]. The information search was exploratory, using different databases. On the other hand, the description of the processes was based on the classification of technical characteristics of the equipment and functional characteristics. Finally, the theory of electrical circuits was used to determine the consumption parameters of the equipment and the Pareto analysis was used to establish the criticality of the processes from the point of view of energy consumption.

### *2.1. Review and organization of bibliographic information.*

Different bibliographic sources were consulted that provided information on the subject contributing to the development of the research project. In this search, it is taken as a reference that the selected source has some relation with the terms related in table 1.

### *2.2. Description of the industrial equipment associated with cocoa production*

To describe the industrial equipment associated with cocoa production, it was necessary to identify and classify the processes to be carried out in cocoa production, separating the natural from the artificial or industrial ones. Figure 1 shows the entire cocoa production chain.

**Table 1.** Topics of the searches and organization of the information

| TOPICS | SOURCE TYPE | METHODOLOGICAL CHARACTERISTICS |
|---|---|---|
| *Cocoa industrial* processes | Sources found: Magazine, Book, Document virtual, ETC. | Description of the methodological characteristics of the document. |
| *Critical equipment in* production *lines* | Sources found: Magazine, Book, Document virtual, ETC. | Description of the methodological characteristics of the document. |
| *Energy consumption* | Sources found: Magazine, Book, Document virtual, ETC. | Description of the methodological characteristics of the document. |
| *Processes energetically critics* | Sources found: Magazine, Book, Document virtual, ETC. | Description of the methodological characteristics of the document. |
| *Pareto Methodology* | Sources found: Magazine, Book, Document virtual, ETC. | Description of the methodological characteristics of the document. |

Source: own.

**Figure 1.** Cocoa production process.


Source: own.

In addition, Table 2 shows the list of equipment and processes in cocoa production.

**Table 2.** List and description of the processes and equipment involved in cocoa production.

| PROCESS | DESCRIPTION | TEAM |
|---|---|---|
| **Harvesting and Shelling** | This process consists of opening and removing the seed with its slime from the cob and should be carried out when the fruit ripens, which is recognized by the coloration of the fruit and occurs every 165180 days from the fertilization of the flower. To avoid the predominance of diseases such as brown spots and moniliasis, it is suggested to harvest weekly. | Industrial scissors |
| **Fermented** | It is a process of great importance that has a direct relationship with the quality of the beans, since, having a biochemical change in the bean will develop in the seed the best possible chocolate flavor, it takes approximately 3-6 days with process removal at temperatures 4045°C to achieve changes in color, flavor, and odor. | Wooden boxes |
| **Drying** | The purpose of this process is to reduce the moisture content of the grain at the end of the fermentation stage to a maximum moisture content of 7% to guarantee the quality of the grain and prevent the appearance of fungi in its commercialization. | Cocoa Dryers |
| **Cleaning** | The process of segregating any material or object other than the cocoa bean (metals, stones, pieces of wood, among others) ensures that only the raw material enters the production process. | Industrial cocoa cleaner, use vibrators and sieves for eliminate any material other than cocoa. |
| **Pre-toast** | This process consists of roasting the cocoa for a few minutes to loosen the shell. | Industrial Pre-toaster |
| **Roast** | Process of chemical changes of free amino acids and reducing sugars where the best aroma and characteristic flavor of chocolate is obtained, additionally, it seeks to darken the color, facilitate the detachment of the shell and eliminate any type of microorganism. | Industrial Toaster |
| **Shelling** | The process consists of segregating the husk and the grain through the difference in density. | Descaler Disconnectors |
| **Alkalinization** | Cocoa beans undergo a process called alkalinization, usually with potassium carbonate, to increase the intensity of the flavor and color of the final product. | Industrial Mixers |
| **Grinding** | The cocoa is subjected to compression and friction forces, the bean is transformed into mass, liquor, or cocoa paste, which in its liquid form contains a bitter taste. | Pin mill<br>Mill Blades |
| **Pressing** | The cocoa paste is subjected to extreme pressure to separate its solid part “Cocoa” from its liquid part “Cocoa Butter”. | Industrial Press |
| **Formulation** | Using a homogeneous mixture of cocoa liquor with other ingredients such as sugar gives rise to what we know as chocolate in its paste presentation. | Industrial mixer |
| **Refined** | Through high pressures generated in steel rollers, the granulometry of solid particles, especially cocoa and sugar, is reduced to about 25 microns, thus generating a greater fineness of the paste. | Rolo Refiners |
| **Conchado** | The chocolate is subjected to a temperature of 80°C, during the process the cocoa paste is stirred and kneaded through powerful stirrers to obtain a better taste of the paste and the necessary properties, in this phase the caramelization reaction occurs, likewise, the volatile acids are eliminated and the humidity remaining in the chocolate is evaporated, excluding undesired flavors in the product and obtaining a suitable emulsion. | Industrial mixers with blades |
| **Tempering** | It consists of reducing the temperature to which the chocolate was subjected, ensuring the crystallization of a minimum amount of butter, this process is performed to ensure the resistance of chocolate to any type of heat subjected. | Industrial tempering machine |
| **Molding and Packaging** | The liquid cocoa mass is poured into molds and the necessary complements are added to the final product. The molds are then sent to a cooling tunnel at low temperatures that give the product the texture and hardness with which it will be marketed. Finally, the product is taken by a conveyor belt to packaging machines that give it its final presentation. | Cooling tunnels and packing machine |

Source: own.

Considering the above, a description of the industrial equipment is made, extracting the most relevant technical information in each process, Tables 3-14.

- **DRYING**: Machine that has the function of distributing heat between the cocoa beans, exchanging heat vertically first to the top and then to the bottom, obtaining uniform drying.

**Table 3.** Dryer technical data

| TECHNICAL DATA DRYERS | | | | |
|---|---|---|---|---|
| **MODEL** | G20 | AS-15 | SGV | SLH 2-6 |
| **POWER** | 1.93 KW | 3,728 KW | 5.21 KW | 5.59 KW |
| **PRODUCTIVITY** | 500 Kg/h | 1150 Kg/h | 1000 Kg/h | 300 Kg/h |
| **VOLTAGE** | 220 V | | | |

Source: own.

- **CLEANING:** Machine used to separate stones and other foreign objects from the raw material, air distribution control, and minimum noise.

**Table 4.** Technical Data Scraper

| TECHNICAL DATA OF THE DESTONERS | | | | |
|---|---|---|---|---|
| **MODEL** | B. CLEANER | CPFBNR 1X | NA-1 | NA-3 |
| **POWER** | 0.45 KW | 4.10 KW | 3.72 KW | 5.21 KW |
| **PRODUCTIVITY** | 200 Kg/h | 2000 Kg/h | 1000 Kg/h | 3000 Kg/h |
| **VOLTAGE** | 220 V | | | |

Source: own.

- **TOAST:** Poly functional machine used to roast cocoa, peanuts, cereals, and grains of various products, it has 5 LPG (Liquid Propane Gas) points for the heating point, additionally, it has temperature control. Finally, it has a compartment that allows one to take samples of the product**.**

**Table 5.** Technical data Toaster.

| TECHNICAL DATA TOASTER | | | | |
|---|---|---|---|---|
| **MODEL** | FISCHER | TD-50 | ROASTY 70 | TCV-30 |
| **POWER** | 0.37 KW | 1.11 KW | 2.2 KW | 2.23 KW |
| **PRODUCTIVITY** | 500 Kg/h | 200 Kg/h | 70 Kg/h | 30 Kg/h |
| **VOLTAGE** | 220 V | | | |

Source: own.

- **SCRAPPING:** Machine that separates the cocoa husk after cocoa processing roasting process, removing the husk without causing any damage to the bean. For ease of operation and maintenance, it has a corrugated rubber roller to avoid damaging the cocoa, which is built in ISO 304 stainless steel, it has a motor reducer and a fan**.**

**Table 6.** Technical Data Shelling Machine.

| TECHNICAL DATA SHELLER | | | | |
|---|---|---|---|---|
| **MODEL** | WINDCRACKER | DESC-100 | DCV-30 | PEL-4 |
| **POWER** | 5.25 KW | 2.05 KW | 2.93 KW | 4.10 KW |
| **PRODUCTIVITY** | 200 Kg/h | 100 Kg/h | 600 Kg/h | 200 Kg/h |
| **VOLTAGE** | 220 V | | | |

Source: own.

- **ALKALINIZATION AND FORMULATION:** Machine is in charge of making a homogeneous mixture without any type of agglomeration, it is built in stainless steel 316L and 304, and it has a hygienic seal on the mechanical shaft.

**Table 7.** Technical data Mixer.

| TECHNICAL DATA FOR MIXERS | | | | |
|---|---|---|---|---|
| **MODEL** | MHV-500 | MHV-100 | CHOCOMIX 30 0 | CHOCOMIX 50 0 |
| **POWER** | 5.59 KW | 11.18 KW | 4 KW | 7.5 KW |
| **PRODUCTIVITY** | 500 Kg/h | 1000 Kg/h | 300 L | 500 L |
| **VOLTAGE** | 220 V | | | |

Source: own.

- **MILLING:** Machine is in charge of grinding dry cocoa beans and other derivatives homogeneously, preventing the beans from sticking to the equipment, maintenance and operation.

**Table 8.** Technical data mil.

| TECHNICAL DATA OF GRAIN MILL | | | | |
|---|---|---|---|---|
| **MODEL** | MUV60-60 | PICAMOL300 | INOX 3 | MTC 250 |
| **POWER** | 29.82 KW | 5.59 KW | 7.45 KW | 3.72 KW |
| **PRODUCTIVITY** | 400 Kg/h | 250 Kg/h | 350 Kg/h | 250 Kg/h |
| **VOLTAGE** | 220 V | | | |

Source: own.

- **PRESSING:** Machine in charge of exerting high pressure on the cocoa beans to separate the solid part from the liquid, has a cylinder that works for hot or cold pressing and also has a piston that is responsible for putting pressure on the content.

**Table 9.** Technical data hydraulic press

| TECHNICAL DATA OF HYDRAULIC PRESS | | | | |
|---|---|---|---|---|
| MODEL | 6YYY-260 | AMEO-100T | 6YZ-400 | DTC-CAPR |
| POWER | 2.2 KW | 2 KW | 3 KW | 4 KW |
| PRODUCTIVITY | 600 Kg/h | 30 Kg/h | 25 Kg/h | 200 Kg/h |
| VOLTAGE | 220 V | | | |

Source: own.

- **REFINING:** Machine used to refine the cocoa paste through five rollers, it also has temperature control and a hopper to load cocoa. Stainless steel construction.

**Table 10.** Technical data refiner mil.

| TECHNICAL DATA OF COCOA REFINING MILL | | | | |
|---|---|---|---|---|
| MODEL | MONTY 3000 | MONTY 2000 | MOLROD 500 | MUV 60-60 |
| POWER | 55 KW | 37 KW | 3.72 KW | 29.82 KW |
| PRODUCTIVITY | 3000 L | 2000 L | 300 Kg/h | 400 Kg/h |
| VOLTAGE | 220 V | | | |

Source: own.

- **CONCHADO:** Machine is in charge of eliminating unwanted acetic acids in the cocoa paste already refined utilizing an extractor and an agitation process that takes place inside the machine. It maintains the liquid state of the chocolate through a system composed of a thermal jacket, resistances, electrovalves, and temperature control.

**Table 11.** Technical data of the conching mill

| COCOA CONCHING MILL TECHNICAL DATA | | | | |
|---|---|---|---|---|
| MODEL | ROCKY 40 | CHOCOMILL1000 | CRV-20-I | MONTY 500 |
| POWER | 1.5 KW | 11 KW | 2.23 KW | 15 KW |
| PRODUCTIVITY | 40 L | 1000 L | 30 L | 500 L |
| VOLTAGE | 220 V | | | |

Source: own.

- **TEMPERING:** Machine that performs the functions of tempering, molding, and vibrating of chocolate, works through a heat induction system, additionally, an automatic gas cooling system which reduces the cooling time.

**Table 12.** Technical data Tempering machine.

| COCOA TEMPERING MACHINE TECHNICAL DATA | | | | |
|---|---|---|---|---|
| MODEL | THERMINAT OR-3 | CHOCO-TEMP | CHOCO-TEMP | CHOCO-TEMPER24 |
| POWER | 2.5 KW | 4.75 KW | 7.5 KW | 3 KW |
| PRODUCTIVITY | 120 Kg/h | 100 Kg/h | 250 Kg/h | 24 Kg/h |
| VOLTAGE | 220 V | | | |

Source: own.

- **MOULDING AND PACKAGING:** Tunnel cooling is mainly used to cool the chocolate after the molding process, it is composed of a belt inside a thermally insulated enclosed compartment to which the conveyor is injects cold air.

**Table 13.** Cooling tunnel technical data

| COOLING TUNNEL TECHNICAL DATA | | | | |
|---|---|---|---|---|
| MODEL | FRIGOBELT100 | LST | YC-T-C800 | SJP-400 |
| POWER | 2.23 KW | 14 KW | 36 KW | 16 KW |
| PRODUCTIVITY | - | - | - | - |
| VOLTAGE | 220 V | | | |

Source: own.

On the other hand, for packaging it is used in various forms in aluminum foil, it is made of 100% aluminum.

**Table 14.** Technical Data Packer

| PACKER TECHNICAL DATA | | | | |
|---|---|---|---|---|
| MODEL | BOMBOM-PACK | PACKER 300 | CHOCOPOT 5000 | CHOCO-POWDER 2000 |
| POWER | 0.746 KW | 1.6 KW | 1.3 KW | 4 KW |
| PRODUCTIVITY | - | - | - | - |
| VOLTAGE | 220 V | | | |

Source: own.

## 3. Results

Based on the aforementioned technical data, we proceed to calculate the theoretical energy consumption based on the operation of a cocoa production plant 24 hours a day for 30 days.

Theoretical calculation: A table was used to calculate the theoretical energy consumption, identifying the areas with the highest consumption, using power factors of 0.95 and 0.75 as a reference.

For the tables 15 and 16 below, items 1, 2, 3, and 4 represent the models of the machines mentioned above and the AVERAGE item is the result calculated from the sum of 1, 2, 3, and 4 divided by 4.

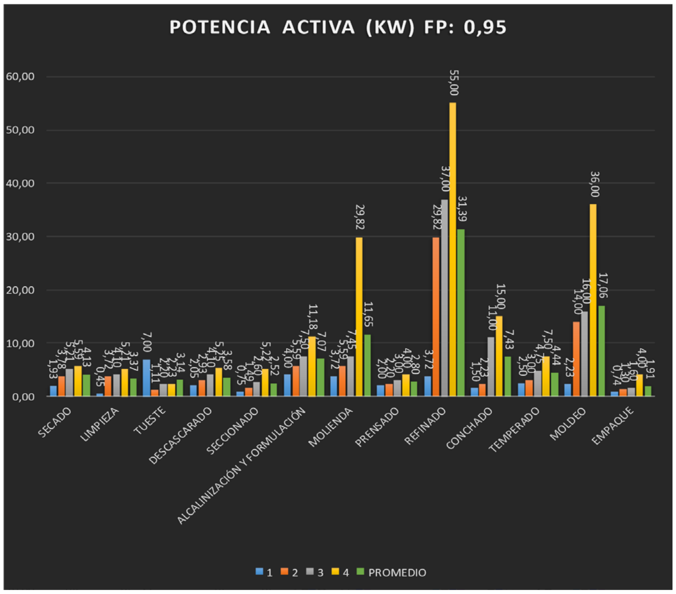
**Table 15.** Active Power for a Power Factor of 0.95

| PROCESS | ACTIVE POWER (KILOWATTS) | | | | | VOLTAGE (VOLTS) | FACTOR OF POWER | CURRENT (AMPERES) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | AVERAGE | | | 1 | 2 | 3 | 4 | AVERAGE |
| DRYING | 1,93 | 3,78 | 5,21 | 5,59 | 4,13 | 220 | 0,95 | 9,23 | 18,09 | 24,93 | 26,75 | 19,75 |
| CLEANING | 0,45 | 3,72 | 4,10 | 5,21 | 3,37 | 220 | 0,95 | 2,15 | 17,80 | 19,62 | 24,93 | 16,12 |
| TOAST | 7,00 | 1,11 | 2,20 | 2,23 | 3,14 | 220 | 0,95 | 33,49 | 5,31 | 10,53 | 10,67 | 15,00 |
| SCRAPPED | 2,05 | 2,93 | 4,10 | 5,25 | 3,58 | 220 | 0,95 | 9,81 | 14,02 | 19,62 | 25,12 | 17,14 |
| SECTIONING | 0,75 | 1,49 | 2,60 | 5,22 | 2,52 | 220 | 0,95 | 3,59 | 7,13 | 12,44 | 24,98 | 12,03 |
| ALKALINIZATION AND FORMULATION | 4,00 | 5,59 | 7,50 | 11,18 | 7,07 | 220 | 0,95 | 19,14 | 26,75 | 35,89 | 53,49 | 33,82 |
| MILLING | 3,72 | 5,59 | 7,45 | 29,82 | 11,65 | 220 | 0,95 | 17,80 | 26,75 | 35,65 | 142,68 | 55,72 |
| PRESSING | 2,00 | 2,20 | 3,00 | 4,00 | 2,80 | 220 | 0,95 | 9,57 | 10,53 | 14,35 | 19,14 | 13,40 |
| REFINING | 3,72 | 29,82 | 37,00 | 55,00 | 31,39 | 220 | 0,95 | 17,80 | 142,68 | 177,03 | 263,16 | 150,17 |
| CONCHADO | 1,50 | 2,23 | 11,00 | 15,00 | 7,43 | 220 | 0,95 | 7,18 | 10,67 | 52,63 | 71,77 | 35,56 |
| TEMPERATE | 2,50 | 3,00 | 4,75 | 7,50 | 4,44 | 220 | 0,95 | 11,96 | 14,35 | 22,73 | 35,89 | 21,23 |
| MOLDING | 2,23 | 14,00 | 16,00 | 36,00 | 17,06 | 220 | 0,95 | 10,67 | 66,99 | 76,56 | 172,25 | 81,61 |
| PACKAGING | 0,74 | 1,30 | 1,60 | 4,00 | 1,91 | 220 | 0,95 | 3,54 | 6,22 | 7,66 | 19,14 | 9,14 |

Source: own.

Figure 2 shows the graphical representation of the calculations performed, corresponding to table 15; and Figure 3 shows the graphical representation of the calculations performed, corresponding to table 16.

**Figure 2.** Active Power for a Power Factor of 0.95



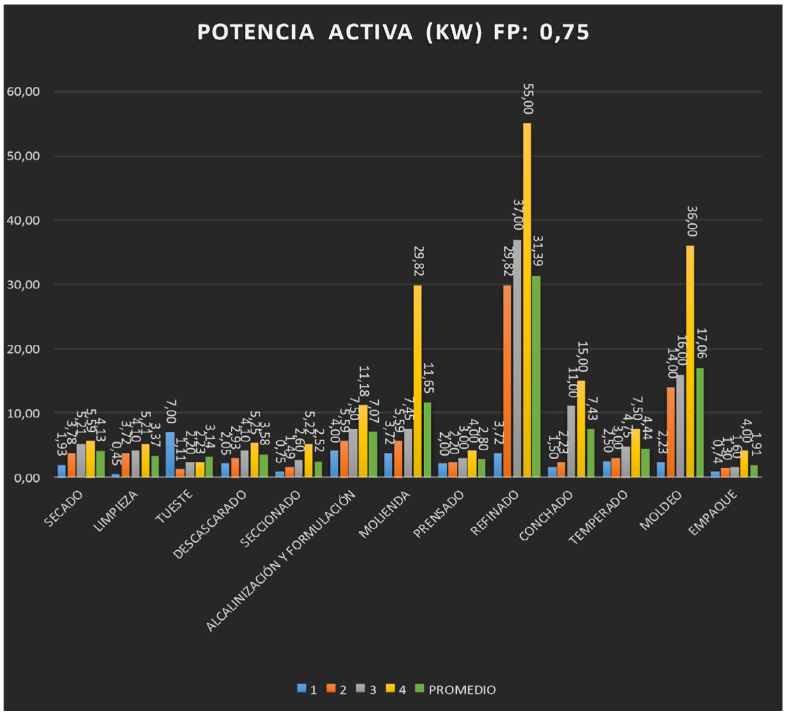

Source: own.

**Table 16.** Active Power for a Power Factor of 0.75

| PROCESS | ACTIVE POWER (KILOWATTS) | | | | | VOLTAGE (VOLTS) | FACTOR OF POWER | CURRENT (AMPERES) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | AVERAGE | | | 1 | 2 | 3 | 4 | AVERAGE |
| DRYING | 1,93 | 3,78 | 5,21 | 5,59 | 4,13 | 220 | 0,75 | 11,70 | 22,91 | 31,58 | 33,88 | 25,02 |
| CLEANING | 0,45 | 3,72 | 4,10 | 5,21 | 3,37 | 220 | 0,75 | 2,73 | 22,55 | 24,85 | 31,58 | 20,42 |
| TOAST | 7,00 | 1,11 | 2,20 | 2,23 | 3,14 | 220 | 0,75 | 42,42 | 6,73 | 13,33 | 13,52 | 19,00 |
| SCRAPPED | 2,05 | 2,93 | 4,10 | 5,25 | 3,58 | 220 | 0,75 | 12,42 | 17,76 | 24,85 | 31,82 | 21,71 |
| SECTIONING | 0,75 | 1,49 | 2,60 | 5,22 | 2,52 | 220 | 0,75 | 4,55 | 9,03 | 15,76 | 31,64 | 15,24 |
| ALKALINIZATION AND FORMULATION | 4,00 | 5,59 | 7,50 | 11,18 | 7,07 | 220 | 0,75 | 24,24 | 33,88 | 45,45 | 67,76 | 42,83 |
| MILLING | 3,72 | 5,59 | 7,45 | 29,82 | 11,65 | 220 | 0,75 | 22,55 | 33,88 | 45,15 | 180,73 | 70,58 |
| PRESSING | 2,00 | 2,20 | 3,00 | 4,00 | 2,80 | 220 | 0,75 | 12,12 | 13,33 | 18,18 | 24,24 | 16,97 |
| REFINING | 3,72 | 29,82 | 37,00 | 55,00 | 31,39 | 220 | 0,75 | 22,55 | 180,73 | 224,24 | 333,33 | 190,21 |
| CONCHADO | 1,50 | 2,23 | 11,00 | 15,00 | 7,43 | 220 | 0,75 | 9,09 | 13,52 | 66,67 | 90,91 | 45,05 |
| TEMPERATE | 2,50 | 3,00 | 4,75 | 7,50 | 4,44 | 220 | 0,75 | 15,15 | 18,18 | 28,79 | 45,45 | 26,89 |
| MOLDING | 2,23 | 14,00 | 16,00 | 36,00 | 17,06 | 220 | 0,75 | 13,52 | 84,85 | 96,97 | 218,18 | 103,38 |
| PACKAGING | 0,74 | 1,30 | 1,60 | 4,00 | 1,91 | 220 | 0,75 | 4,48 | 7,88 | 9,70 | 24,24 | 11,58 |

Source: own.

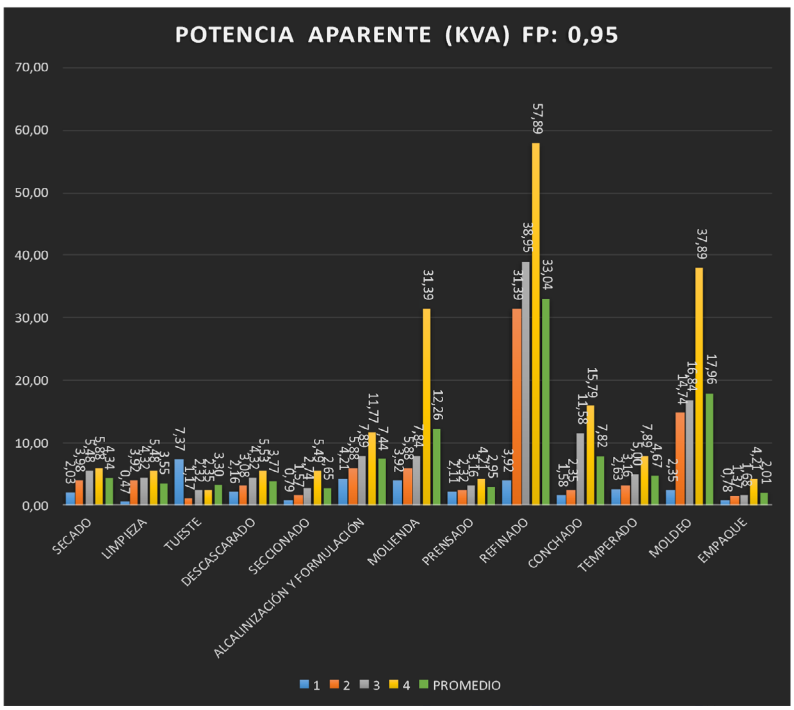
**Figure 3.** Active Power for a Power Factor of 0.75




Source: own.

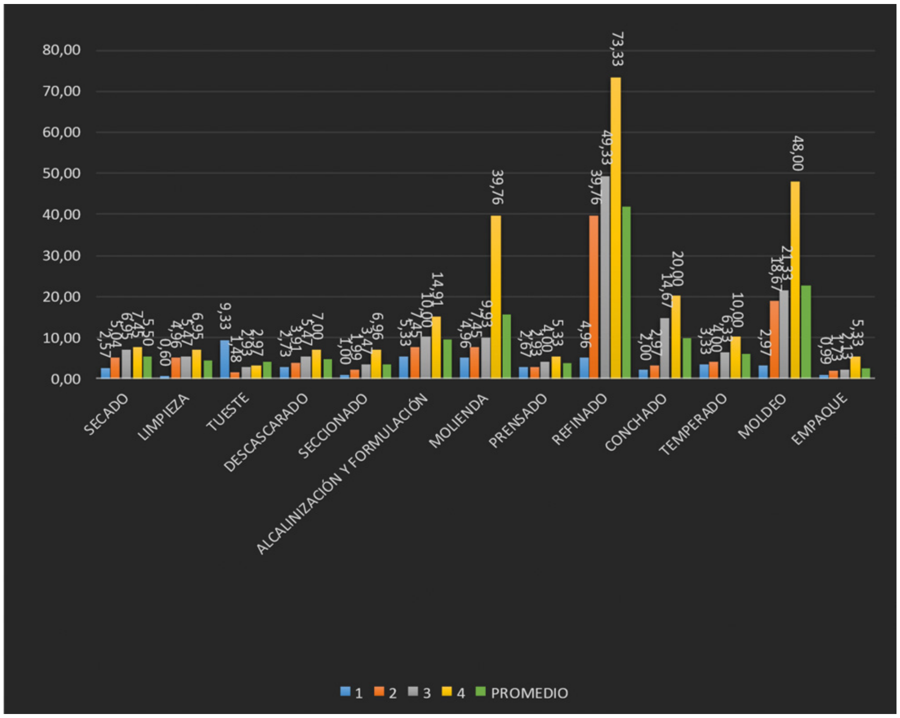
The same was done for apparent power and reactive power. Finally, the result of the Pareto analysis is shown, where the processes with the highest energy consumption at different power factors are identified (Figures 4-13).

**Figure 4.** Apparent Power for a Power Factor of 0.95



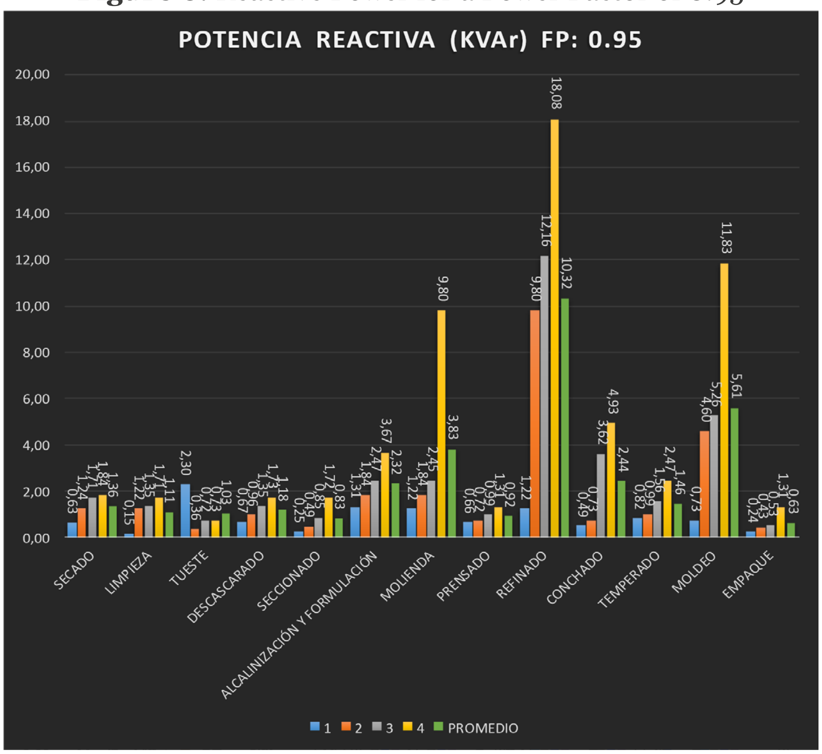

Source: own.

**Figure 5.** Apparent Power for a Power Factor of 0.75




Source: own.

**Figure 6.** Reactive Power for a Power Factor of 0.95




Source: own.

**Figure 7.** Reactive Power for a Power Factor of 0.75

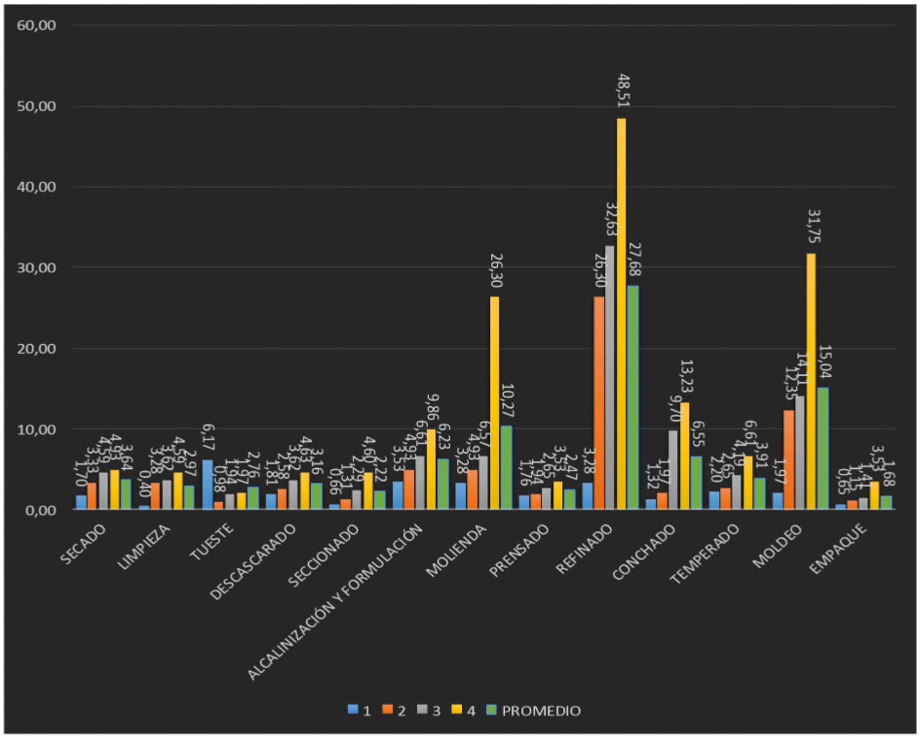



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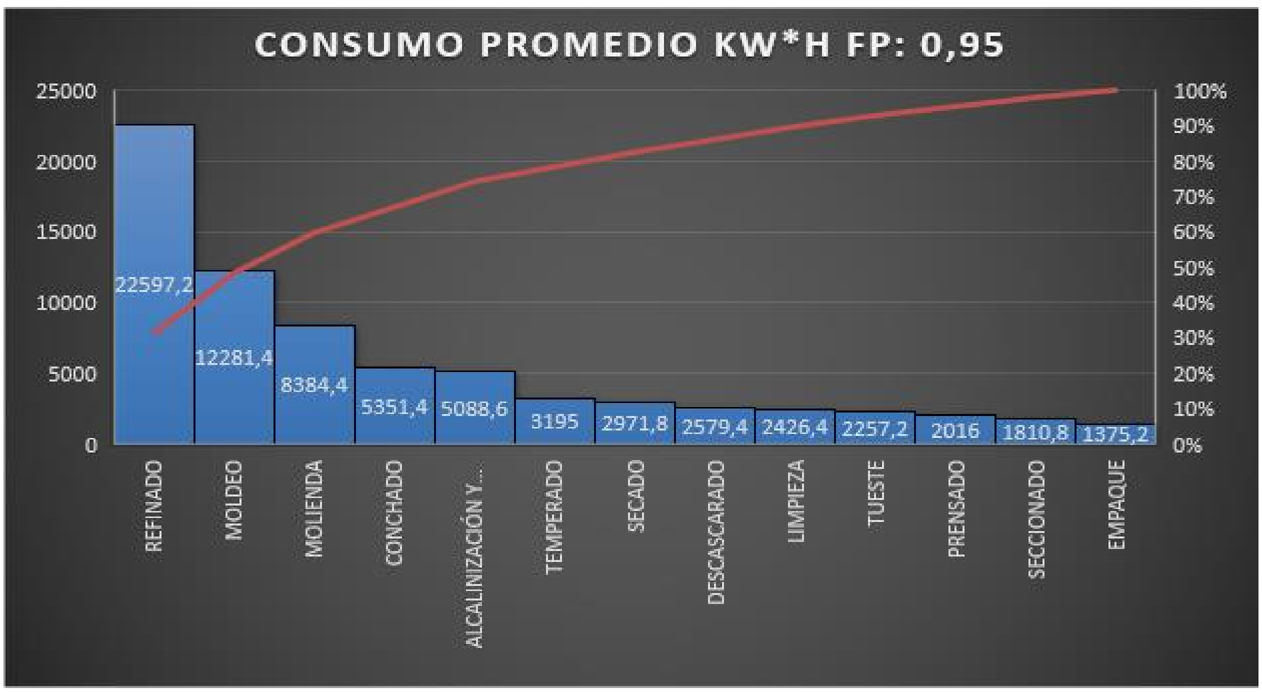
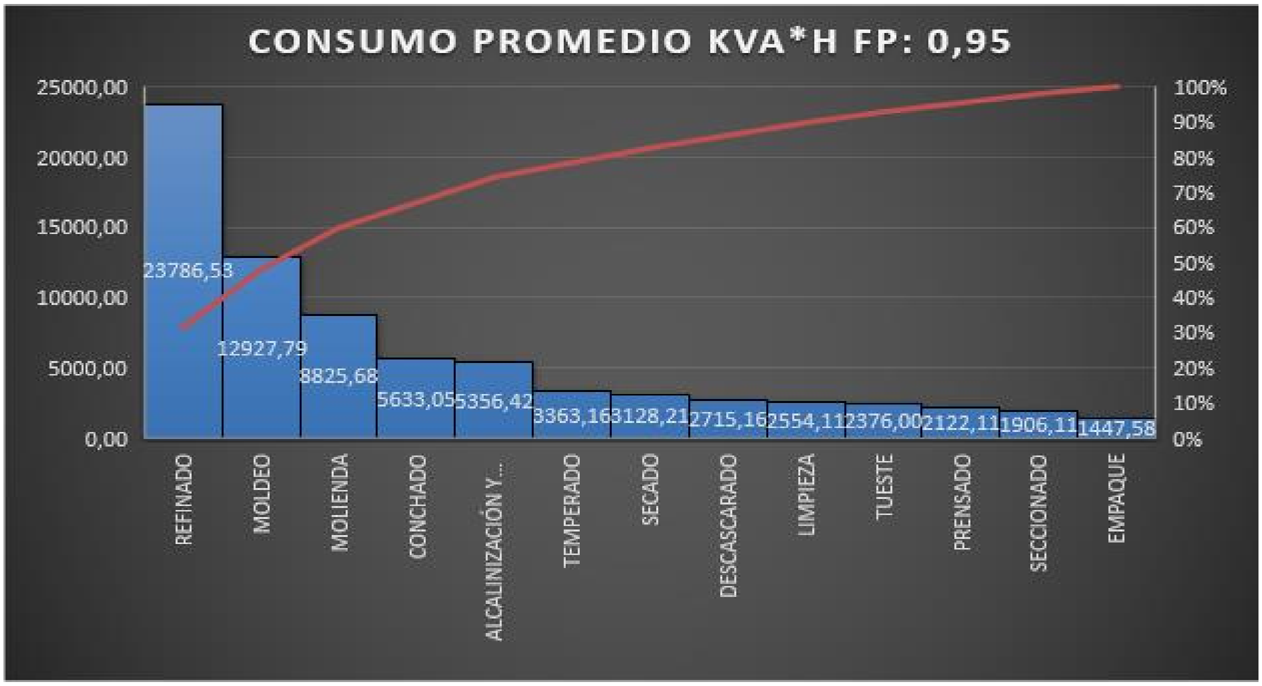
**Figure 8.** Average Power Kw*h for a Power Factor of 0.95



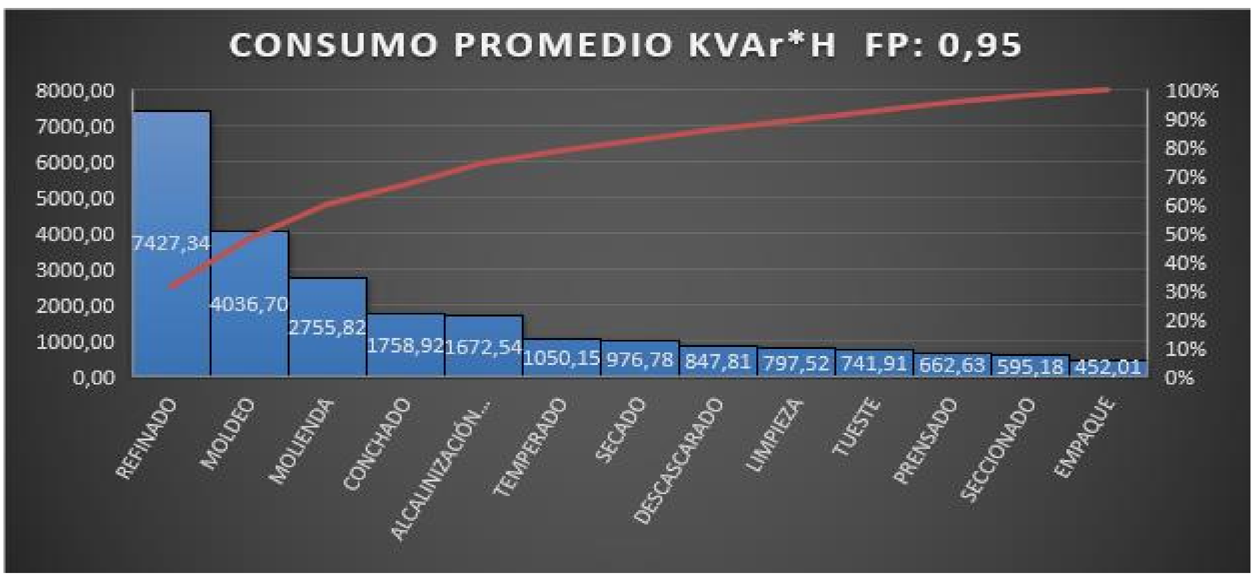

Source: own.

**Figure 9.** Average Power KVA*h for a Power Factor of 0.95



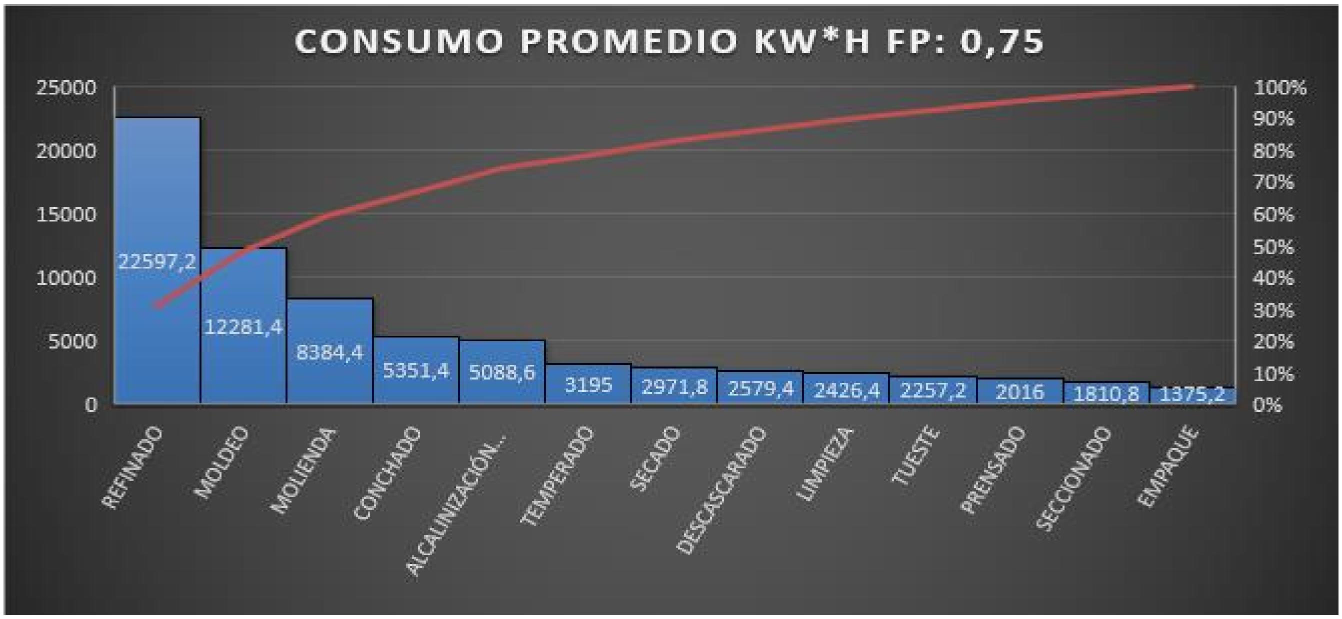

Source: own.

**Figure 10.** Average Power KVAr*h for a Power Factor of 0.95



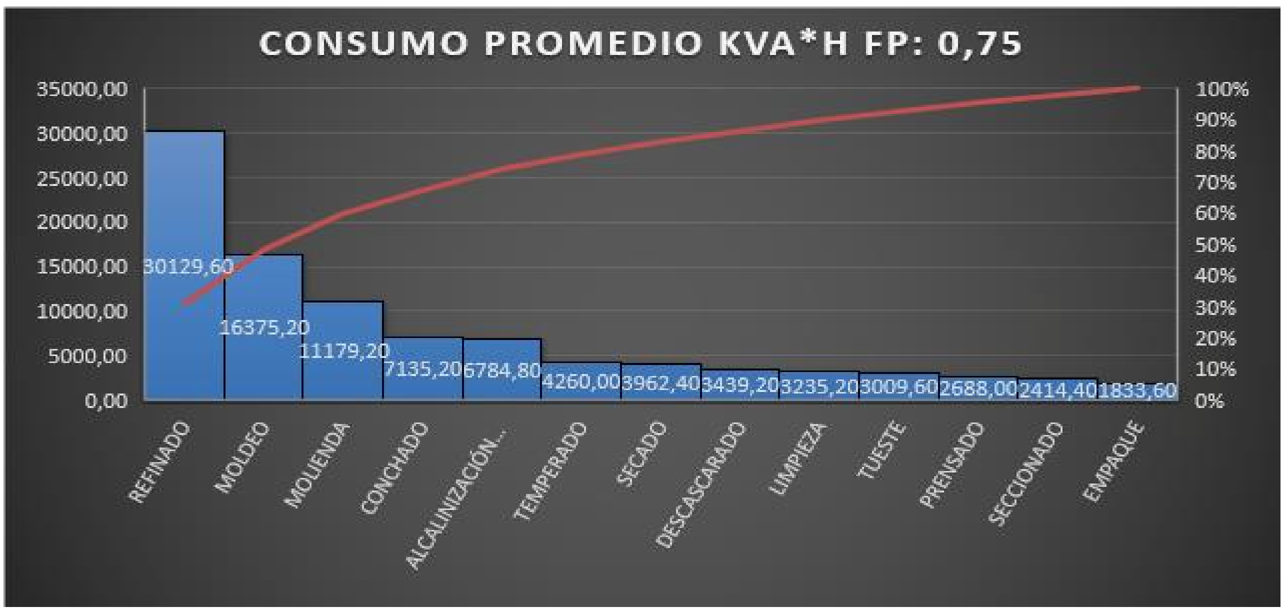

Source: own.

**Figure 11.** Average Power KW*h for a Power Factor of 0.75



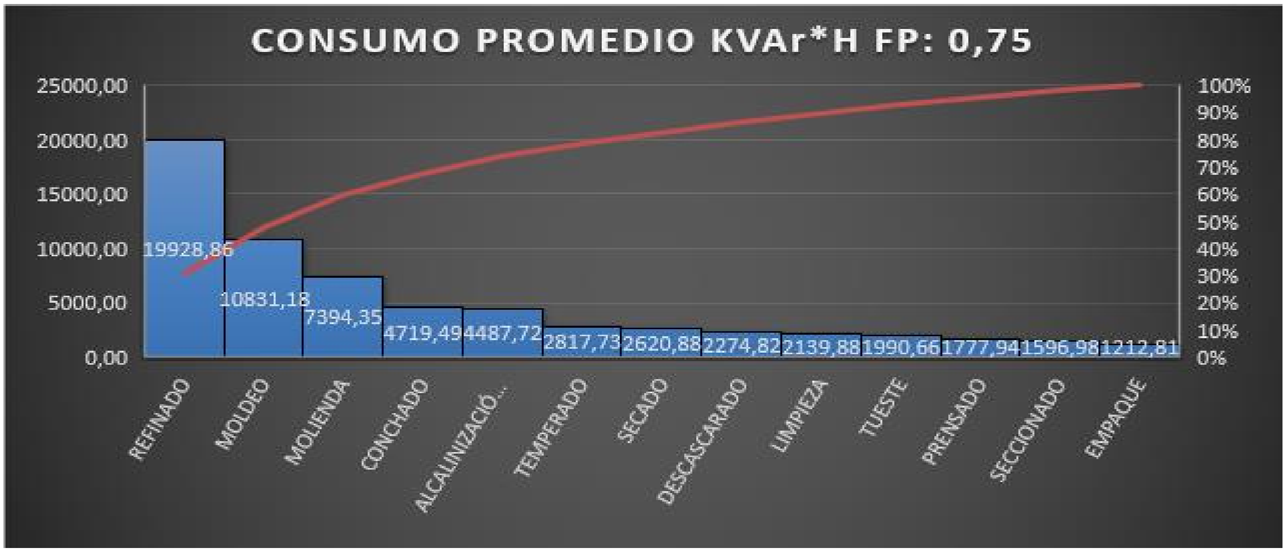

Source: own.

**Figure 12.** Average Power KVA*h for a Power Factor of 0.75




Source: own.

**Figure 13.** Average Power KVAr*h for a Power Factor of 0.75




Source: own.

## 4. Conclusions

From the graphs presented above, it can be concluded that for a power factor of 0.95 the area with the highest active, apparent and reactive energy consumption is the cocoa refining process. For a power factor of 0.95, the areas with the next highest active, apparent and reactive energy consumption are the cocoa molding and grinding processes. Similarly, for a power factor of 0.75, the area with the highest active, apparent and reactive energy consumption is the cocoa refining process. Finally, for a power factor of 0.75, the areas with the next highest active, apparent and reactive energy consumptions are the cocoa molding and grinding processes.

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