TECHNICAL NOTE

Energy Evaluation of ¨Rómulo Padrón¨ Feed Factory Based on the General Consumption of the Plant

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Evaluación energética a fábrica de piensos ¨Rómulo Padrón¨ a partir del consumo general de la planta

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ABSTRACT: The production of concentrated foods with high-energy efficiency indicators is currently a challenge in Cuba. Therefore, in this research, the objective is to carry out an energy evaluation of ¨Rómulo Padrón¨ Feed Factory based on the general consumption of the plant. For this, a diagnosis of the factory is carried out, the main tools that evaluate energy efficiency in this type of industry are determined and an improvement plan is presented. The results show average monthly values of production, energy consumed and the consumption index of 4589.4 t; 35,117 kWh and 7.56 kWh/t, and 108.13 t daily for the month of March; 802.93 kWh and 7.42 kWh/t, respectively. In addition, it was determined an unstable behavior of the energy consumed based on production (monthly and daily), with correlation coefficient values of 0.88 and 0.81, respectively.

Keywords: Concentrated Food, Diagnosis, Efficiency, Consumption Index, Production.

RESUMEN: La producción de alimentos concentrados con elevados indicadores de eficiencia energética constituye un reto en Cuba actualmente. Por lo que en la presente investigación tiene como objetivo, realizar una evaluación energética a la UEB Fábrica de Piensos ¨Rómulo Padrón¨ a partir del consumo general de la planta. Para ello se realiza un diagnóstico de la fábrica, se determinan las principales herramientas que evalúan la eficiencia energética en este tipo de industria y se presenta un plan de mejoras. Los resultados muestran valores mensuales promedio de producción, energía consumida y el índice de consumo de 4589,4 t; 35117 kWh y 7,56 kWh/t, y diarios del mes de marzo de 108,13 t; 802,93 kWh y de 7,42 kWh/t, respectivamente. Además, un comportamiento inestable de la energía consumida en función de la producción (mensual y diaria), con valores de coeficiente de correlación de 0,88 y 0,81, respectivamente.

Palabras clave: alimento concentrado, diagnóstico, eficiencia, índice de consumo, producción.

INTRODUCTION

Energy problems are becoming more important in the world, based on the accelerated development of some countries, which has led to intense competition for control of oil reserves. Energy efficiency is one of the main areas of opportunity to reduce costs, protect the environment and increase the competitiveness of industries (Monteagudo-Yanes, 2004; Monteagudo-Yanes & Gaitan, 2005). It seeks to achieve a more efficient use of energy without reducing production levels, without reducing the quality of the product or service, or affecting safety or environmental standards. It is characterized by the ability to achieve production objectives, using **the** least amount of energy possible, that is to achieve a production level, with the quality requirements established by the client, with the lowest energy consumption and expenditure and the lowest associated environmental pollution (Borroto-Nordelo *et al.*, 2005; Borroto-Nordelo, 2009; Bustos-Burgos & Chiquito-Sánchez, 2017; Ruiz & Hall-Mitre, 2017).

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Energy management benefits the industry, helping to guarantee product quality, reducing production costs and increasing its competitiveness. It benefits the country by postponing financing requirements for energy infrastructure, promoting new technologies and the modernization of the industrial sector and reducing the import of capital goods for energy development. And finally, it benefits the society by conserving resources for future generations, reducing polluting emissions to the environment and contributing to the formation of an energy and environmental culture (Borroto-Nordelo *et al.*, 2005; 2006; Borroto-Nordelo & Aldersey-Williams, 2006; Bravo-Hidalgo & Martínez-Perez, 2016).

On the other hand, in industrial development, knowledge has been expanded based on improving animal nutrition, reaching high levels of development since progress in genetics and health have partially influenced an improvement in production results, achieving by simply changing the formulation of food, an increase in production volumes. Balanced feed is a necessity not only for the animal but also for the producer, because it allows storage for long periods, provisioning in times of scarcity, saving time in preparation and ease of handling when feeding animals (BPFA-ICA, 2020). The same (feed) play a leading role in the global food industry, by allowing the economic production of animal products throughout the world (Cartaya, 2017).

The commercial production or sale of manufactured feed is carried out in more than 140 countries and more than 30,000 feed factories; this world production has risen 14% in the last 5 years. The total world quantity produced of compound feed in 2016 is slightly above 1,032,000 m, which represents an increase of 3.7% compared to last year, despite the decrease in the number of factories by 7% (BPFA-ICA, 2020). Feed manufactured in industrial plants is used to develop and maintain animals for human consumption, animals that produce meat, milk, eggs, wool, leather, and other products under a wide range of production conditions. Concentrated foods are nothing more than mixtures of foods that provide primary nutrients, which contain less than 18% crude fiber, high values of energy and they are manufactured from previously prepared and scientifically qualified recipes (Cartaya, 2017). The technological process for obtaining concentrated food is made up of 3 fundamental stages (Reception of Raw Material, Production and Marketing) within which there are different tasks that must be controlled according to the CA that is desired to obtain the required quality. The production process of the industries dedicated to the preparation of concentrated foods generates high consumption of energy, regardless the characteristics with which the raw materials arrive, mills and mixers demand a great amount of energy and because of that, they are called key posts. Therefore, it is necessary to carry out an energy evaluation of agro-industrial plants. Hence, the objective of this research is to evaluate energetically ¨Rómulo Padrón¨ Feed Factory from the general consumption of the plant.

MATERIALS AND METHODS

For the energy evaluation of the factory, a working group is created made up of specialists who are part of the research project for the integral evaluation of it; conceived by four professors, the energy specialist and five students. During the selection of the working group, age, sex, years of work related to the subject, educational level and, in the case of university graduates, the specialty in which they were trained, have been taken into account.

Determining Information Needed for Diagnosis

The information necessary for the diagnosis in this type of research is determined from the theoretical foundations. The factory will be characterized in terms of its electrical infrastructure and all sources of energy consumption, its main activities, those associated or not to production, as well as daily, monthly and annual reports of energy consumption and production values. The most recent data corresponding to the first quarter of 2019 are analyzed, with the aim of obtaining the relationship between energy, production and the consumption rate of the plant.

Selection of Areas and Equipment to be Diagnosed

Once the characterization of the plant and its main energy consumption areas has been carried out, as well as the conditions of the electrical installations that influence losses, a selection of the areas and equipment to be diagnosed is made. Information about daily, monthly and annual reports of the factory to the National Electrical Union (UNE) and the periodic conciliations the factory carries out with it, as part of its control to establish consumption plans, are used to evaluate the relationship between consumption and production of concentrated food.

Compilation of the Necessary Quantitative and Qualitative Information

For the collection of the necessary information, the following methods will be used: observation, photography (digital camera, Cannon Powershot 348, 7.2 megapixels) and interview. On the other hand, the factory's energy database will be used, where the daily consumption appears since January 2019 according to the record of the meter-counter clock, an equipment established in Cuba for monitoring energy consumption throughout the infrastructure of the country, both state and private. The consumption plan assigned by the UNE according to the expected production volumes will be also considered. In addition, there will be data on the daily production values of the factory during the four-month period-analyzed (January-April) obtained from the entity's production department, in the same format as the previous ones. The values of the total energy consumed are obtained through the sum of the daily values of the reading offered by the meter:

$$E_m = \sum_{i=1}^{n} E_1 + E_2 + E_3 + \ldots + E_i; kWh \quad (1)$$

where:

E_m energy consumed monthly;

E_1, E_2, E_3, E_i = energy consumed daily;

Similarly, the value of daily production is recorded to obtain a total monthly production as shown:

$$P_m = \sum_{i=1}^{n} P_1 + P_2 + P_3 + \ldots + P_i; t \quad (2)$$

where:

P_m = monthly production

P_1, P_2, P_3, P_i = daily production

Field Measurements, Data Collection and Filtering

The data obtained will be reviewed and filtered using the Microsoft Excel 2010 tool, which will be also used to statistically analyze the dependence established between energy consumption and the consumption index vs. production from obtaining the coefficient of determination. This tool will be used to obtain the models that correspond to said behavior. In this stage, the following actions will be carried out:

- The energy consumption (E) and production (P) values associated with them are recorded in periods of time (T) (day, month, year, etc.), and the graph E - P is obtained as a function of T.
- The above analysis makes it possible to compare the production variation trends in each period (from one day to the next, from one month to another, etc.) with the consumption variation trends and the periods where abnormal variations occur are identified.
- Using the linear regression method, the coefficient of determination between E and P is established, the line that best fits the points located on the diagram or trend line is drawn, and the model with the best fit is obtained.
- The consumption index of the factory IC=f (P) is determined from the expression E=f (P). The actual data (E/P, P) of the E and P data records used to make the E vs P plot are determined, and the IC vs P plot and the IC vs T plot are obtained.

RESULTS AND DISCUSSION

Results of the Energy Evaluation of the Plant

Rómulo Padrón¨ Feed Factory with Spanish technology was built in 1961. It is located in Jaruco Municipality, Mayabeque Province between 23° north latitude and 82° west longitude, subordinated to the Western Feed Company belonging to the Ministry of Agriculture. The feed factory constructively has the capacity to produce 19.2 t (9.6 for each line) of feed per hour, taking into account that each work line grinds 2.4 t per 15 min and has two production lines. At the end of 2019, , it was possible to produce a real of 60,655.67 t from a 67,000 t plan, for a non-compliance of 6,344.33 t (90.5%). Table 1 shows the average values of production (4,589.4 t), energy consumed (35,117 kWh) and the consumption index (7.56 kWh/t) during the months analyzed.

Figure 1 corresponds to the E-P vs T graph, which shows the simultaneous variation of the energy consumption of the grinding section of line two with the production carried out over time. A tendency to instability can be seen in the first two months of the year and then, to the increase in the months of March and April, which as a positive element shows production values above those of consumption.

The abnormal behavior of the variation in energy consumption with respect to the variation in production in the months of January and February is because there is energy consumed that is not directly related to production. The fundamental causes, according to the interviews carried out, were related to the lack of raw material, breakages in the weighing system and a breakage in one of the two mills. Also in the month of February, there were effects on the electric power for approximately 35 hours. It was also found that on working days, when there was no production due to the above causes, the work of the offices, the repairing workshop and the night public lighting were maintained. Night public lighting is kept on daily for security reasons and it consumes approximate 48 kWh in 12 hours (16 mercury lamps, consumption 250 Wh). During the analysis of the linearity between the energy consumed and the average production for the analyzed period of January-April (Figure 2), a determination coefficient of R^2 = 0.77 was obtained. The dependence between both variables was obtained through the correlation coefficient r = 0.88. It shows a strong direct relationship between both variables and that the values

TABLE 1. Monthly production, energy consumption and consumption index

Parameters	January	February	March	April	Average
Production (t)	4229.0	4204.7	4944.,9	4978,9	4589.4
Energy Consumed (kWh)	34650	31320	36708	37790	35117
Consumption Index (kWh/t)	8.19	7.45	7.42	7.59	7.56

of energy consumed correspond 88% to the production carried out. This value is considered adequate for this type of analysis according to Borroto-Nordelo & Monteagudo-Yanes (2002) (r≥ 80% adequate, although the closer to 100% the better) taking into account that all factory , in addition to the energy consumption that is used directly to fulfill its corporate purpose, carries collateral expenses produced by all the supporting processes.

To represent the amount of energy consumed per ton (kW/t) in Figure 3, the consumption index is calculated. In the specific case of this parameter, it is recommended that the lower it is, the more energy efficient the entity is. According to the study carried out, ¨Rómulo Padrón¨ Feed Factory was more efficient in March. It corresponds with what Borroto-Nordelo & Monteagudo-Yanes (2002) and Chacón-Cordero (2015) describe, also taking into account the mechanical characteristics of the factory and the nature of the technological process to maintain production values and energy expenditure that guarantee a consumption rate that does not exceed 7.42 kWh/t.

When analyzing the linearity between the average consumption index (CI) and production (P) parameters for each month (Figure 4), a determination coefficient of R^2 = 22 was obtained. The dependence between both variables was obtained through the correlation coefficient r = -0.48 that shows a weak inverse relationship between both variables and that the values of the consumption index correspond in 48% with the production carried out in each month. This result is obviously given by the energy values (E) and production (P) so deficient obtained in January and the irregularities that were previously mentioned in February as shown in Figure 4.

When analyzing the behavior of the E-P diagram vs work days in March, (Figure 5) some instability is observed during the course of the days, however, it is also possible to observe correspondence between both parameters analyzed. The production value equal to zero on day 9 corresponds to a failure in the weighing system and low production values on days 6, 12 and 14 caused by interruption in the electrical supply. In the same way, it is possible to verify that when the factory works at full capacity, for example on days 16, 26 and 30, it can become efficient in the use of energy. The graph also shows greater instability in production values than in energy consumption, so it is necessary to review organizational problems that could be influencing this behavior.

During the analysis of the linearity between the energy consumed and the average production for each day in March (Figure 6), a determination coefficient of R^2 = 66 was obtained. The dependence between both variables was obtained through the coefficient of correlation r = 0.81 that shows a slightly strong direct relationship between both variables and that the values of energy consumed correspond in 81% with the

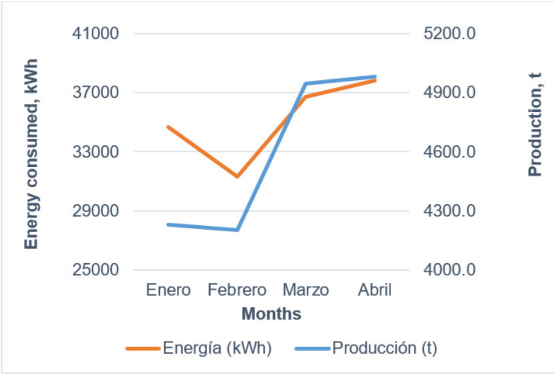

FIGURE 1. Graph Energy Consumed -Production vs. Time.

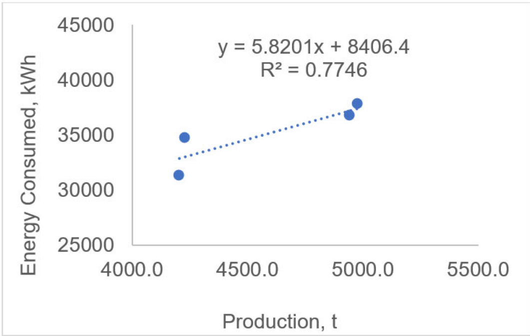

FIGURE 2. Dispersion diagram obtained from the statistical analysis of Energy Consumed vs. Production.

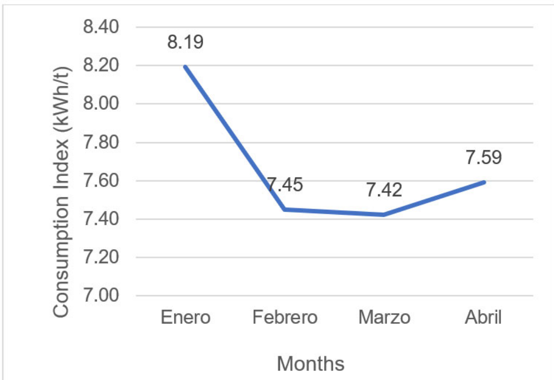

FIGURE 3. Diagram of Consumption Index vs. Months.

production carried out. This value is considered adequate for this type of analysis, according to Borroto-Nordelo & Monteagudo-Yanes (2002) (r≥ 80% adequate, although the closer to 100% the better), taking into account that all factory, in addition to the energy consumption that is used directly to fulfill its corporate purpose, carries collateral expenses produced by all supporting processes.

Figure 7 shows the kWh/t consumption index during March, which also demonstrates an unstable

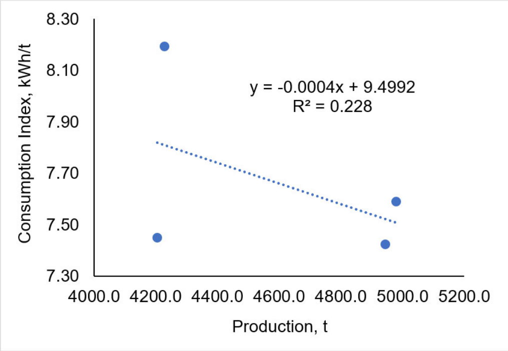

FIGURE 4. Dispersion diagram obtained from the statistical analysis of the Consumption vs. Production Index of the months evaluated.

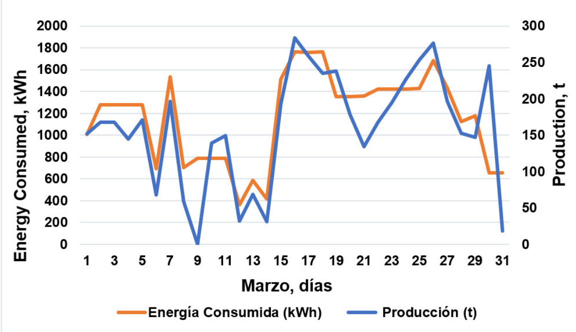

FIGURE 5. Graph Energy Consumed-Production vs Time in the month of March.

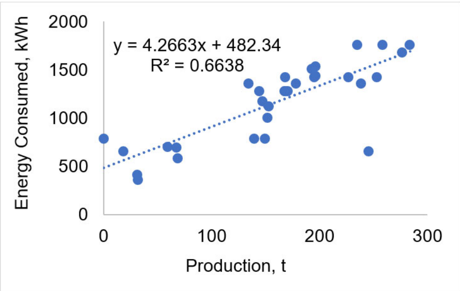

FIGURE 6. Dispersion diagram obtained from the statistical analysis of Energy Consumed vs. Production.

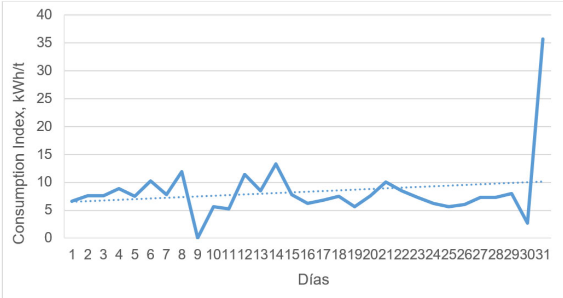

FIGURE 7. Diagram of Consumption Index vs. Days of March.

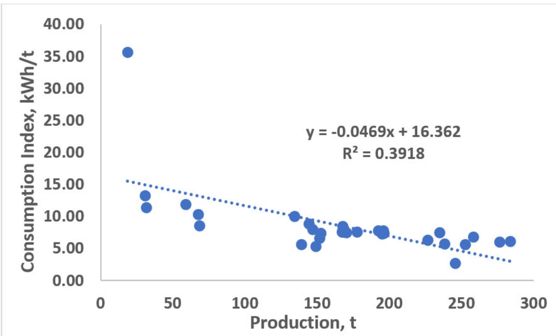

FIGURE 8. Dispersion diagram obtained from the statistical analysis of the Consumption vs. Production Index.

behavior characterized by peaks and depressions that correspond to the causes described in Figure 5.

During the linearity analysis between the consumption index and the average production for each day of March (Figure 8), a determination coefficient of $R^2 = 39.1$ was obtained. The dependence between both variables was obtained through the correlation coefficient r = -0.62, which shows an inverse relationship between both variables and that the values of the consumption index correspond 62% to the production carried out in each month.

The results obtained ratify the partial fulfillment of the hypothesis in which it was assumed that the Energy Consumed-Production relationship with respect to the months and days of the month of March analyzed would show a stable behavior with strong dependence between them given by correlation coefficients higher than 0.85. The behavior for both, months and days, was unstable but showed a strong correlation between both parameters when the monthly behavior is analyzed, described by coefficient r= 0.88. However, when analyzing the relationship between both parameters in the days of the month March, a slightly strong correlation between them is reached, given by a value of r= 0.81 lower than the expected value of 0.85.

TABLE 2. Plan of measures to improve the energy efficiency of ¨Rómulo Padrón¨ Feed Factory

Classes	Measure	Responsible	Date
Infrastructure	• Request the preparation of an investment project for the capital repair of the factory • Place the plastic protection of the connectives and splices	• Administration • Maintenance staff and electrician	• September 2018 - approve it in 2019 • According to availability of inputs
Technical and Technological	• Replacement of electric motors for ones with a lower rated power • Evaluate the rest of the factory engines • Monitor electricity consumption at night and when the factory is not producing • Determine the causes that lead to the existence of considerable energy consumption that is not directly associated with production.	• Administration and technical staff in charge of the activity	• According to investment • Period September 2018 to March 2019 • According to monthly schedule • quarterly basis
Organization	• Train technical staff in energy functioning • Properly signal everything related to electrical installations and design the plans if they do not exist • Periodically protect and clean the places where the electrical conductors and energy sources are located until they are repaired.	• Admin. from the Feed Factory and UNAH • Administration and technical staff in charge of the activity • Administration and personnel trained for that	• Second semester of 2018 • Second semester of 2018 • Monthly.

Proposed Action Plan

From the results obtained in the diagnosis, the energy evaluation and the analysis of the operation of the motors, a group of recommendations are derived that will be specified as established by the methodology applied for the energy evaluation of the factory, in the improvement plan that is proposed below (Table 2).

CONCLUSIONS

- The diagnosis carried out made it possible to identify 9 problems that affect the energy efficiency of the factory, defining their causes and the effect they produce.
- The average monthly values of production, energy consumed and the consumption index reached values of 4,589.4 t; 35,117 kWh and 7.56 kWh/t, while the daily figures for the month of March were 108.13 t; 802.93 kWh and 7.42 kWh/t, respectively.
- The Energy Consumed - Production relationship with respect to the months and days of the month of March shows an unstable behavior with a strong correlation between both parameters when the monthly behavior is analyzed, described by coefficient r= 0.88, while the relationship between both parameters on the days of the month of March are considered slightly strong given by a value of r= 0.81.
- Among the main causes of the unstable behavior of the E-P ratio over time, both monthly and daily, are identified: lack of raw material, breaks in the weighing system, a break in one of the two mills and affectations in the electrical fluid, among other factors.
- Inverse and weak correlation between CI and P with coefficient values r regarding months and days of -0.48 and -0.62, respectively.

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