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Minimal Energy Efficiency Indicators for Poultry Industries

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Abstract. This paper discusses the behaviour of energy efficiency in thermal processes of chicken slaughterhouses in Brazil, as they are large consumers of electricity and have few indicators to system monitoring. The work addresses some indicators that are monitored by the slaughterhouse, the main factors affecting the cooling circuit and the technologies that are available in the market for equipment manufacturers. The article proposes measurements in the refrigeration circuit to implement indicator that monitors the power consumption expended to generate the system's cooling capacity and also check and eliminate factors that affect the cooling system to reduce the power consumption. Energy consumption between two slaughterhouses indicates a 49.27% difference. The disclosure of efficiency comparison information may help the national industry to become more efficient and competitive.

Key words

Energy efficiency, Indicators, Power Consumption, Chicken Slaughterhouses, Refrigeration.

1. Introduction

Brazil is one of the major food producers in the world, because the national food industry is an important segment of economic activity in the country with great dynamism in manufacturing, exporting and technical progress in the production chain. According to [1], in recent years its turnover has grown, reaching approximately US$ 197.25 billion in 2012, compared with revenues of 2011, which was US$ 175 billion, increased by US$ 22.2 billion, corresponding to 11.26% of gain.

The state of Paraná led the poultry slaughter in 2012 with 29.7%, followed by the states of Santa Catarina with 17.7%; Rio Grande do Sul, 14.4%; and São Paulo, 12.7% [2]. The occupation of the region west and southwest of Paraná, according to [3] until the 20s was quite poor due to lack of interconnection with major centres. The decision to install the agroindustry in Paraná was due to the majority of cooperative members are owners of small farms (up to sixty acres), favouring the integration process. Thus, it is emphasized that the location of an agribusiness can be influenced by the market and, or, the raw materials origin proximity, customers, depending on the minimized sum of the costs of distribution and storage. As estimated by [4], 2012 data show that the United States lead the production of chicken meat with 19.79 million tonnes, followed by China with 18.51 million, 12.55 million in the European Union and Brazil with 11.3 million. Figure 1 illustrates the top producers of chicken meat in the world.

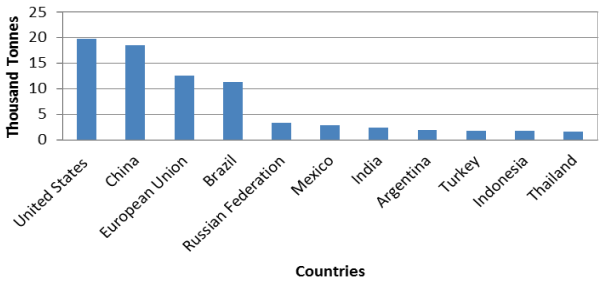

Fig. 1. Poultry production by country [4].

Faced with growing production of chicken meat in Brazil, one of its consequences was the increase in electricity consumption, so the industrial sector was the Brazilian great energy consumer in 2012 with 41%, followed by 26% households, 18% commercial and 15% others, as illustrated in Figure 2, with a total consumption of 448 GWh [5].

One of the key factors for chicken slaughterhouses to avoid waste, and minimize cost of electricity its the industrial refrigeration control. The cold chain comprises the whole process of storage, preservation, distribution, transportation and handling of products with controlled low temperature. Any failure in this chain can compromise product quality, by the speed of chemical reactions, biochemical and microbiological characteristics are directly related to temperature, influencing the health, nutritional quality and sensory quality of chilled products. Therefore, maintaining the cold chain intact, operating at

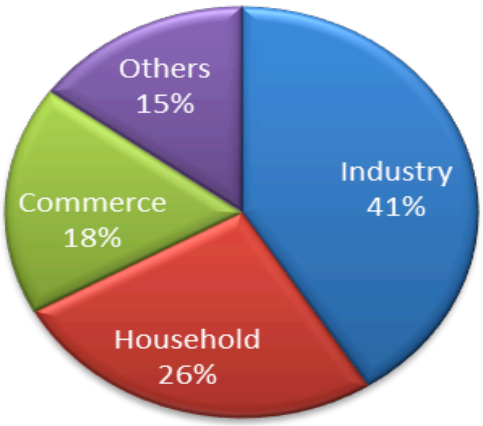

Fig. 2. 2012 Electricity Market in Brazil [7].

proper temperatures from the producer to the final consumer, is essential [6].
The numbers involved in this segment are very high. The electric bill for large industries are an amount between US$ 365.600,00 and US$ 685.500,00 per month, and the cooling sector corresponding to between 60-75% of the electric bill [8].

Thus, one of the characteristics faced by this industry is the high consumption of electrical energy that is concentrated in the cooling system and the engine compressors are the responsible of this consumption. Still, to reduce energy consumption the Brazilian Ministry of Mines and Energy, is developing energy efficiency programs that refer to various kinds of actions to culminate in reducing the energy needed for society's energy services demands in the form of light, heat, cold, activation, transport and use in processes. In short, the objective is to suit the needs of savings with lower primary energy use and therefore less impact on the nature [9].

Projects are being carried out with the objective of promoting energy efficiency actions aiming at medium and large industries, through partnerships with industry federations of states, to train technicians and engineers who work in industry, education and services, aiming at the establishment of energy efficiency actions in industrial motor systems [10].

Energy efficiency has become a central topic in several countries and also for the Europe production industries, as Romania's example. Saving energy is on the companies and public institutions agenda. Recently, there have been only policies influencing the implementation of industry energy efficiency, however the prices of electricity, oil and gas in Europe have continuously rising over the last 10 years. EE can be controlled and systematized using a power management system based on ISO 50001 standard, which allows companies and other institutions to reach a sustainable energy reduction [11].

The use of indicators is a very important tool to highlight the system conditions, paths of their respective evolutions, for purposes of developing policies, they have the property of separating the important aspects of a wide range of information and thus can assist in decision-making processes. Therefore, indicators are needed in the process of monitoring, evaluation and diagnosis of the systems studied.

The act of measurement is intrinsic to the human being, because of the interest in understand the environment around. In order to perform such task, important questions arise: what to measure, appropriate measuring instruments and their aim [12].

Some indicators are monitored by slaughterhouses as the total consumption of electricity, cost per unit, generated financial value and annual savings. But they have few indicators to monitor the cooling system, since it consumes most of the power. Other important elements that must be checked are the factors that affect the efficiency of the cooling circuit and the technologies available for the equipments. Measuring the cooling system is possible to implement energy efficiency indicator called specific energy consumption represented by kWh per TR (tonnes of refrigeration), it determines the system efficiency (including management, maintenance and operation) in terms of income and monitors the system power consumption, its high rates points to excessive heat gain in the cooling system.

2. Industry Structure

Talking about the industry, this paper analyses only the chicken slaughterhouses need for refrigeration, due to its high power consumption. The refrigeration system cooling circuit uses vapor-compression, where ammonia is used as coolant, as it can reach extremely low temperatures and pressures required by the system. The sketch of Figure 3 shows a typical multi-pressure industrial cooling system, two-stage vapor-compression, where may be seen the main components: compressor, condenser, evaporator, expansion valve, liquid separators.

3. Minimal Indicators

Firstly, to pursue EE, a survey of the energy situation of the organization (energy review) should be done. That is the baseline used to compare with the situation after implementations of any EE measure. The picture of the organizational energy situation can be made using some indicators, defined by the organization. Although, Brazil do not have many references to define their indicators.

This paper defines five minimum indicators for the first step towards an energy efficiency management for chicken slaughterhouses and these indicators turns the industry more competitive. The first, equation (1) represents the total electrical consumption (TEC) in a period of time (kilo Watts hour per month). It is present in every industry as the electrical bill easily obtains it.

$$TEC = \frac{kWh}{month} \quad (1)$$

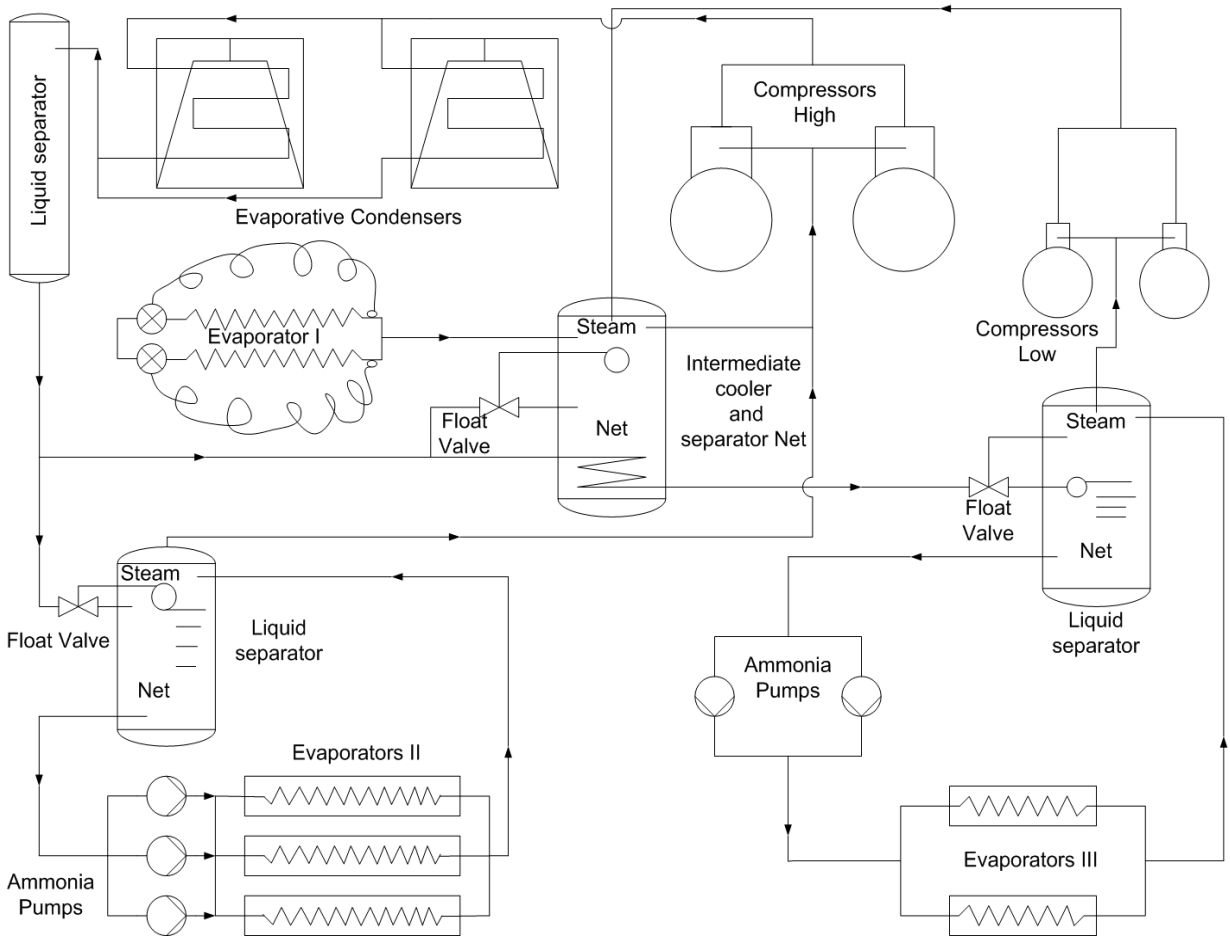

Fig. 3. Vapor-compression cooling system [13].

The second most important indicator of EE for slaughterhouses is related to the production due to industry need of production measurements. Comparing to production data there is the electricity consumption by total chicken meat production to obtain the unit cost (UC), in equation (2), represents the kilo Watts hour consumed per produced chicken meat kilograms). If there is other sources of energy than electricity, their units must be converted to a common one and added up to calculate this indicator.

$$UC = \frac{kWh}{kg} \tag{2}$$

One of the key factors to chicken slaughterhouses avoid waste and minimize the cost of electricity, is the control of industrial refrigeration. The numbers involved in this segment are very high. So it becomes important to use a specific electrical energy panel (secondary panel) for the refrigeration sector. The equation (3) represents the specific energy consumption of the cooling sector (SEC) in kilo Watts hour by the installed capacity (tonnes of refrigeration, TR). Reinforcing that if another sources of energy are used in this sector they have to be included in this equation, in kWh. Equations (2) and (3) will be discussed further.

$$SEC = \frac{kWh}{TR} \tag{3}$$

The described indicators are important for industry EE management and controlled by the technical supervisor, however, the business owners are more interested in capital gain. The generated financial value (4), represents the transformation of values, from the total energy costs over the generated product income in monetary value.

$$GFV = \frac{input\ energy\ value\ (\$)}{output\ production\ value\ (\$)} \tag{4}$$

Finally, to complete the picture of some minimal EE management, the organization's annual reviews on total energy consumption. The annual savings in equation (5) consists on comparing energy consumption from one year to another, in kilo Watts hour.

$$AS = kWh_{year\ 1} - kWh_{year\ 2} \tag{5}$$

4. Methodology

One of the adopted procedures to pursue energy efficiency in slaughterhouses units is to monitor energy flows, the diagram in Figure 4 illustrates the electricity flow.

Through this monitoring is possible to obtain this namely indicators:

1) Electricity consumption by total chicken meat production, equation (2);
2) Electric energy consumption of the cooling sector by the installed capacity (tonnes of refrigeration), equation (3).

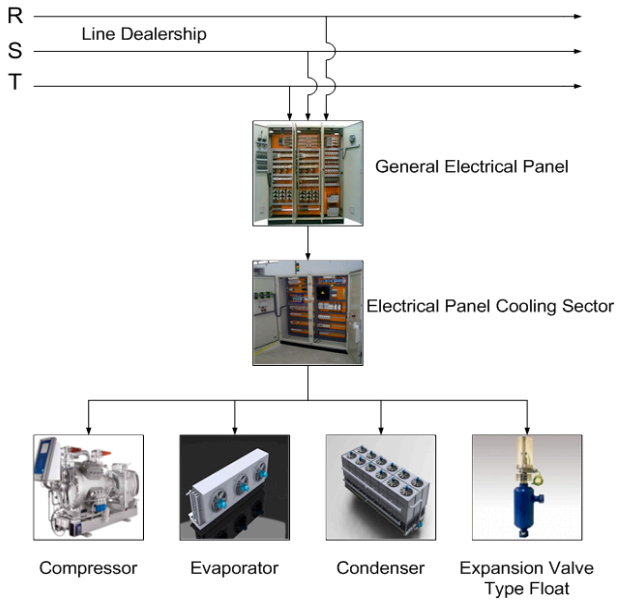

Fig. 4. Electricity flows of poultry slaughterhouses.

The first indicator is currently monitored by industry, because it provides the total electricity consumption per slaughtered chicken kilogram.

To obtain this indicator, energy consumption is measured in the overall input power panel (or the electric bill) and also production data of chicken meat. They already have systems for electrical energy measurement and control demand, giving priority to peak hours and correcting the power factor. This system uses meters and controllers that communicate over cables and send this data over the Internet to a central and thus can generate graphs and reports for managers surveillance.

The second describes the aim of this paper: to check the actual consumption of the refrigeration sector (kWh) to produce a TR (tonne of refrigeration) in cold storage and other equipment, i.e., the micro indicator measures the performance of the refrigeration equipment system in terms of throughput, further the design of the system itself, since elevated levels of this indicator may mean excessive heat gain in pipes and dirt presence on condenser, among others. To obtain values in kWh is necessary:

1) Check the existence of a general panel that feeds only the refrigeration sector;
2) Check the maximum power of general power panel for the refrigeration sector;
3) Check instrumentation to perform the measurement;
4) Perform measurement of electricity consumption in the refrigeration sector.

The measurements are performed using a portable electricity quality analyser. In case of permanent monitoring, the ideal is to install a digital fixed power meter to a data acquisition system. One way to quantify the refrigerating capacity (TR) for each compressor can be performed by measurements on the cooling system, manufacturer manual and thermodynamic equations. It should be collected information about the temperature and pressure at the input (suction) of the alternative or screw compressors, temperature and pressure of liquid separator.

In addition to these measurements, there are other important factors to be checked that affect the electricity consumption. Factors that lead to inefficient cooling system that are in a fishbone diagram of Figure 5.

5. Industry Available Technologies

Advances in component technology, such as electronic controllable expansion valves and variable speed control of compressors and fans, make possible to apply more advanced control systems that achieve better performance, in addition, better EE [14]. The industry has at its disposal

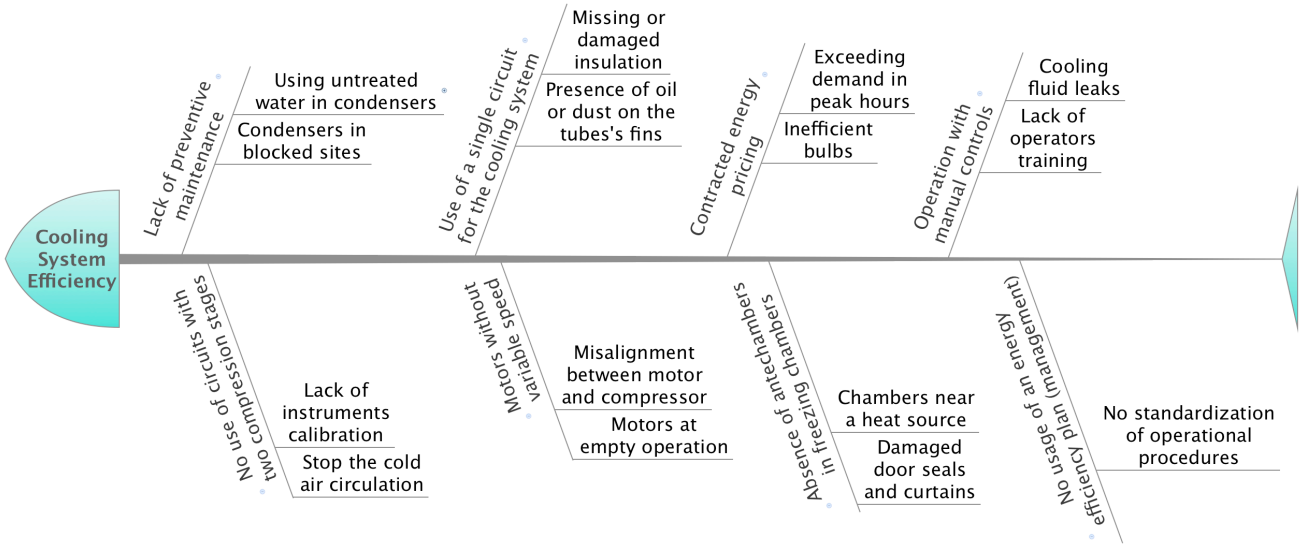

Fig. 5. Factors that lead to inefficient cooling system, in a fishbone diagram.

sensor systems technology for the cooling circuit with sensors supply voltages from 0 to 5 volts or 4 to 20 mA. The sensors used to measure the temperature are called thermistors (NTC or PT100), pressure measurements are made by ratiometric order pressure transducers, level sensors are also used and flowmeters can be used too. Software are also available for ammonia refrigeration system, to monitor and control the system, with tools to manage energy efficiency, graphs and spreadsheets.

6. Results

Some studies were made to verify the high energy consumption, [15] found that energy consumption in a chicken slaughterhouse "A" located in the State of São Paulo, Brazil, with a slaughter capacity of 16,000 chickens per day, thus being its UC of 0.15 kWh/kg of chicken and with a 97% of energy consumption in refrigeration sector.

Another study conducted in the state of Paraná, Brazil, named "B", slaughter 180,000 chickens per day. Having a power consumption total of 38,650.36 kWh/day. Its refrigeration sector consumes 32,084.38 kWh/day, representing 83% of all energy consumed, the UC being 0.1652 kWh/kg of chicken, data from [16].

According to [17] another chicken slaughterhouse ("C") in the same state slaughter an average of 2,779.9 tonnes of chicken meat (two years average). Its average electricity consumption in 2011 and 2012 was about 622,429.9 kWh and refrigeration sector consumed a total of 12,100,038 kWh in those years, corresponding to 81% of total consumption. Its UC is 0.2239 kWh/kg of chicken.

The described studies don't address the refrigeration sector energy consumption by cooling capacity (SEC). Not being possible to identify the degree of system inefficiency.

7. Conclusion

Publications about the results of these indicators are scarce in the national scenario, industries do not disclose the information to protection from competitors, and also, the government does not have access to this information to perform comparisons between electricity consumption data and determine an ideal indicator of efficiency.

Therewith, the country loses because if these data were transmitted and disseminated every slaughterhouse could obtain indicators with more efficient levels and reduce the processes electricity consumption and be more competitive among each other and the external market.

Comparing the slaughterhouse "A" and "C", may be noticed that the last consumes almost a half more energy to produce the same product, a difference of 49.27%. The question still lies in knowing what will be the ideal value of UC, given that the data are not divulged. The proposal is to reach the energy efficiency of the refrigeration sector it should implement the indicator SEC, because through it can be checked the quantity of energy spent to produce all the refrigeration capacity and eliminating the inefficient factors that affect the cooling circuit to obtain maximum system's efficiency.

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