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Electricity Consumption in the Pork Production Chain From the Western Region of Paraná State, Brazil

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Abstract

The development of swine farming resulted in the specialization and transformation of the productive chain with direct impact on the agroindustry. The intensive swine production is representative, with relevant performance in the international scenario, with an expressive increase in volumes and values produced and exported, contributing significantly to the performance of the Brazilian trade balance. This performance is due to the technological and organizational advances of the last decades. The constant changes and advances that swine farming has been undergoing promote the search for new ways of raising pigs. There is a constant incorporation of new technologies and an uninterrupted reorganization in the production systems in the industry, aiming to follow the industrial progress with greater cost reduction and increased profitability. In this context, the objective of this study was to evaluate the consumption of electric energy in the productive process of pig termination in rural properties in the western region of Paraná. The study was conducted in three pig farms, where data were collected on the consumption of electricity in the production, slaughter and processing of pigs. The average specific energy consumption in the production of pigs in the termination stage was 0.0058 kWh kg^{-1}, accounting for 1% of the process, while at slaughter it was 0.22 kWh kg^{-1}, responsible for 38.22 kWh kg^{-1} % of consumption and processing of 0.35 kWh kg^{-1}, accounting for 60.78%. Thus, results showed that the processing stage consumes the most energy within the pig meat production chain.

Keywords: swine breeding, energy consumption, Paraná

1. Introduction

Brazilian pig farms, like other agribusiness production chains, have grown significantly in recent years. This growth is observed when analyzing the various social and economic indicators, such as participation in the worldwide market, number of direct and indirect jobs, volume of exports, among others. Pork breeding from the past has also evolved in the technique and model of coordination of activities between inputs suppliers, rural producers, agro-industries, wholesale, retail and consumers (Roppa, 2002; Rodrigues et al., 2011).

According to the Paraná Association of Swine Farmers (APS, 2009), swine farming in Paraná is of fundamental importance in the socioeconomic context of the State, generating multiplier effects on income and jobs in all sectors of the economy, intensifying the demand for agricultural inputs and the expansion and modernization of the marketing and agro-industries sectors.

The Panorama of Pig Herd in Paraná (2016) is 7,131,132 heads, representing 17.8% of the national total that is 39,950,320. Paraná has become one of the largest swine herds in Brazil (IBGE, Municipal Livestock Research 2016). In 2017, the State of Paraná slaughtered 9,203,619 heads and produced 826,131,095 (IBGE, Quarterly Survey of Animal Slaughter/Year 2011 to 2017).

In the city of Toledo, in the western region of the State of Paraná, swine farming contributes to economic development by creating jobs and generating income, leveraging other sectors of the economy. As a result of this

scenario, there is an increase in the consumption of agricultural inputs, as well as in the expansion and modernization of the processing and marketing segments. In smallholdings, it is a predominant activity, responsible for the significant employment of family labor, making possible an important source of income and social stability in the countryside, positively reflecting on the urban environment (Roesler & Cesconeto, 2003).

According to the State Secretariat for Agriculture and Food Supply (SSAFS) and the Department of Rural Economy (DRE) (2016), the participation of regional pig production in the period from 2011 to 2014 was centered in the city of Toledo, representing 44.7% of the Gross Value of Production (GVP). While the regional center of Cascavel corresponds to 16.4%, Ponta Grossa represents 12.9% and Francisco Beltrão, 6.2%. Pig farming accounts for 6.2% of the gross value of the production from Paraná, corresponding to R$ 4.4 billion. Compared to 2013, pig farming increased its representation in the gross value of production by 1.1 percentage points, however, the gross value of production increased by 24.4%. There are about 30,000 commercial producers in Paraná and 105,000 occasional producers, that is, those that produce for subsistence. The swine farming influences the productive chains of corn, soybean and of genetic advances in the animal species, aiming at its strengthening.

In Brazil, the pork production chain has one of the best economic performances in the international scenario, with a significant increase in volumes and values 2produced and exported. It is tied to the technological and organizational advances of the last decades (Velarde, & Dalmau, 2018). The southern region is the main producer and processor of pork, and the State of Paraná is the 3rd in the national ranking. In Paraná, the producers work in the integrated or cooperative system, via contracts with the meat processing industries and have a technified swine industry. Production is focused on supplying the domestic market as well as exporting (Filho et al, 2005).

According to the Department of Economic Research and Studies (DEPEC, 2017) meat production in Brazil is divided into: chicken meat (50.6%); beef (35.9%) and pork (13.5%). The consumption of chicken, beef and pork is 46.8; 38.6 and 14.5%, respectively, while worldwide these values are 34.6; 22.5 and 42.9%, respectively.

The Brazilian Association of Pig Farmers (ABCS, 2017) stated that in the first four months of 2017, 198 thousand tons of fresh pork were exported, beating the historical record. Brazil is responsible for generating 1 million direct and indirect jobs and for the production of 3.7 million tons of meat per year, one of the reasons why pig farming is gaining ground in the country's economic scenario (ABIPECS, 2016).

The southern region of the country has the largest expression in pork production, accounting for 60% of the technified headquarters located in Brazil. The Southeast, with a population of 381,000 households, is the second largest producer region. However, due to the conditions associated to the proximity of grain production areas, water abundance and favorable climate, the production of the central-west region has increased significantly, and in the next few years, it is expected to surpass the southeastern region (Santos et al., 2016).

Considering this scenario, the study of the energy used in agricultural systems, their flows, distribution and conversion, constitute an important instrument for the evaluation of the sustainability of these systems, especially considering the possible crises in the energy sector. This procedure allows the determination of the processes, materials and equipment of higher energy consumption, indicating economical options (Teixeira et al., 2005; Ramírez, Patel, & Blok, 2006; Lee & Chang, 2007; Mobtaker et al., 2010; Shahamat et al., 2013).

The objective of this study was to evaluate the specific energy consumption in the production, slaughter and processing of pigs in the western region of Paraná, in Brazil, considering, during breeding, the termination stage, period in which the animal remains until reaching the ideal weight of approximately 25 kg before being taken to slaughter.

2. Materials and Methods

2.1 Description of Evaluated Properties

The experiment was carried out in three pig farms, a pig slaughterhouse and a pork processing industry to produce sausages, through data collection of electricity consumption, during the period from January to December 2017.

The pig farms were located in Novo Sobradinho, at latitude 24º38′27.99″ S and longitude 53º44′16.98″ W, in the district of Toledo, western region of Paraná.

In property 1, the area of the shed was 1500 m^2 and installed capacity for 1500 pigs, divided into 60 bays, with capacity for 25 animals.

In property 2, the area of the shed was 2430 m^2 and installed capacity for 2000 pigs, divided into 80 bays, with capacity for 25 animals.

In property 3, the area of the shed was 3000 m^2 and installed capacity for 2500 pigs, divided into 100 bays, with capacity for 25 animals. In the three properties the shed was built in masonry, covered with ceramic tiles on a wooden structure.

The slaughterhouse was located in Santa Terezinha de Itaipu, Paraná. The slaughterhouse was built in masonry with an area of 10.000 m^2 (100 m × 100 m) and a roof made of corrugated fiber cement tiles. On average, 80 pigs and 100 cattle were slaughtered on a daily basis. The average monthly slaughter was 1509 pigs, totaling 135,810 kg of meat.

The pork processing industry for sausage production was located in Céu Azul, Paraná, at the geographical coordinates of latitude 24º57′21″ S, longitude 53º27′19″ W and elevation 781 m. The industry area was 80.000 m^2 (800 m × 100 m), with a right foot of 2 m, cover of clay tiles, featuring side walls with 75 cm height, with lining and side curtains.

2.2 Characteristics Evaluated in Properties

For the evaluation of the specific energy consumption in the production, slaughtering and processing of pigs, the electricity bills and monthly production information of each place were used, provided by the managers of the establishments. Based on the information collected, a general analysis of the energy consumption (kWh kg^{-1}) in the pork production chain in the western region of Paraná in Brazil was carried out.

With the data of electric energy consumption of the properties, worksheets corresponding to the consumption of electric energy were elaborated. From the total consumption of electric energy, the average daily consumption of electricity (in kWh) was calculated.

The three pig farms evaluated developed a system of production of termination, which consisted of the phase after day care until reaching slaughter weight, which was approximately 110 days of life. The residence time of the pigs in the farms was from 110 to 120 days.

3. Results and Discussion

3.1 Evaluation of the Electricity Consumption of Pig Farms

Table 1 presents the values of the average consumption of electricity for the production of pigs in each rural property.

Table 1. Average electricity consumption in the three rural properties

Properties	Average Number Of Pigs Housed (Kg $Month^{-1}$)	Average Electricity Consumption (Kwh $Month^{-1}$)	Average Specific Energy Consumption (Kwh Kg^{-1})
1	159,669	1273	0.0080
SD	7,154	209.3	0.0013
VC (%)	4	16	16
2	214,474	1150	0.0054
SD	10,240	195.1	0.0009
VC (%)	5	17	17
3	268,827	1070	0.0040
SD	9,406	167.2	0.0006
VC (%)	3	16	16

Note. Standard Deviation (SD); Variation Coefficient (VC).

The average specific energy consumption per kilogram of pork in the pig termination process at properties 1, 2 and 3 were 0.0080, 0.0054 and 0.0040 kWh, respectively (Figure 1).

Grando et al. (2013), also observed that the average specific consumption of electricity in the termination phase was 0.0053 kWh kg^{-1} of meat produced, when they evaluated the energy consumption in a pig farms with 900 animals, in the municipality of Palotina-PR. While, Souza et al. (2009) observed an average consumption of 0.0054 kWh/kg of energy required, in a production system with 500 pigs.

Rovaris (2015) evaluated the consumption of electric energy in two dark houses aviaries, with different construction systems. The results showed that 0.0743 kWh kg^{-1} and 0.0518 kWh kg^{-1} live chicken, respectively, were consumed during the housing period of broilers. The difference in energy consumption between the dark aviaries and the pig farms studied can be explained by the housing of these animals (lighting, exhaust system and misting system).

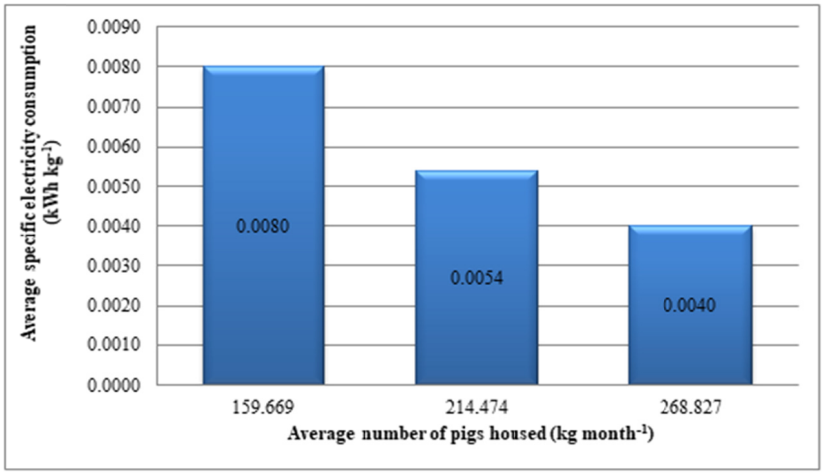

Figure 1. Average specific electricity consumption (Kwh Kg^{-1}) by the average number of pigs housed

3.2 Evaluation of the Consumption and Cost of Electricity of the Swine Slaughter House

The results for the average electricity consumption of the pig slaughterhouse are shown in Table 2.

Table 2. Average electricity consumption of pig slaughtering in the western region of Paraná-Brazil

Property	Average amount of carcass (kg $mês^{-1}$)	Average electricity consumption (kWh $month^{-1}$)	Average specific energy consumption (kWh kg^{-1})
Slaughterhouse	135,810	29,370	0.22
SD	22,464	2,329	0.02
VC (%)	16	8	9

Note. Standard Deviation (SD); Variation Coefficient (VC).

The consumption of thermal energy used in the slaughterhouse for sterilization and cleaning in the form of steam and hot water was not analyzed in this work, only the electric consumption was taken into account. The average specific electricity consumption in the pig slaughterhouse studied was 0.22±0.02 kWh kg^{-1}. The use of electric power is due to the operation of machines and equipment, mainly for refrigeration, besides lighting, ventilation and production of compressed air.

According to the United Nations Environment Program (UNEP), Danish Environmental Protection Agency (DEPA), and Consulting Engineers and Planners (COWI) (2000) it is estimated that energy consumption (thermal and electric) in pig slaughterhouse is 0.33 to 1.39 kWh per kilogram of pig. Approximately 80 to 85% of the total energy needed in a slaughterhouse is thermal energy (steam and hot water) and 15 to 20% is electricity, from which the greatest consumption occurs in the refrigeration operation.

The energy consumption in pig slaughter found in this work was 54.40 kWh for 155 kg of pork. While Larry, Bernard, & Bruce (1996), observed that the energy consumption used in the slaughter process in each unit operation was 84.22 kWh for 155 kg of meat.

3.3 Evaluation of the Electricity Consumption in the Pork Processing Industry

The values presented in Table 3 were obtained based on the evaluation of average data generated in the period from January to December of 2017, related to the average electricity consumption of the pork processing industry for the production of sausages.

Table 3. Average electricity consumption of the pork processing industry for sausage production in the western region of Paraná-Brazil

Property	Average amount of production (kg mês^{-1})	Average electricity consumption (kWh month^{-1})	Average specific energy consumption (kWh kg^{-1})
Industry	38,978	13,679	0.35
SD	1,002	2,041	0.05
VC (%)	3	15	14

Note. Standard Deviation (SD); Variation Coefficient (VC).

For the processing industry, the average specific electricity consumption was 0.35±0.05 kWh kg^{-1}. Energy consumption corresponded to the illumination of the facilities and the equipment required for the production of sausages, such as: meat chopper, meat mixer, filling machine, cold rooms, vacuum packer, freezer chamber and electronic scale. The freezing chamber was the one that consumed the most energy. The freezing chamber and the cold room are on 24 hours a day for 30 days of the month.

According to Ramirez et al. (2006), the specific energy consumption related to the meat production process was 1,625 MJ ton^{-1} (0.45 kWh kg^{-1}), a value close to that found in the present study. Zorzela (2013), in his work on the economic and technical feasibility study for the implantation of a sausage industry in Santa Maria - RS, analyzed the consumption and the cost with electric energy for the equipment needed for the production of sausages. The results were for an industry with capacity for 35,000 to 40,000 kg month^{-1} and consumption and cost with the illumination of the facilities was not included. The energy consumption found by the author was 0.20 kWh kg^{-1}. For calculations it was considered that the freezing chamber and the cold room would be turned on 24 hours a day during the 30 days of the month and the other equipment would operate at most 8 hours a day during the 21 working days of the month.

According to Vanni (1998), coefficient of variation greater than 35% indicates that the series is heterogeneous, and the mean has little meaning. Therefore, it was observed that for all the coefficients of variation evaluated there was high experimental precision and that the data series was homogeneous. Also, according to the classification proposed by Warrick and Nielsen (1980), it can be concluded that the values found in the study are considered low C.V. (< 12%) and average C.V. (12 to 24%).

3.4 Evaluation of the Share of Electricity Cost and Consumption in the Pork Chain in the Western Region of Paraná

With the data obtained in Tables 1, 2 and 3, the specific consumption of electricity (kWh/kg) for the pork chain in the western region of Paraná was calculated (Table 4).

Table 4. Average specific energy consumption for the pork production chain

Stages	Average specific energy consumption (kWh/kg)
Termination phase (average of properties)	0.0058
Slaughter of pigs	0.22
Processing of pork	0.35
Total	0.5758

Figure 2 shows the percentage of the share of electricity consumption in the pork chain from the western region of Paraná.

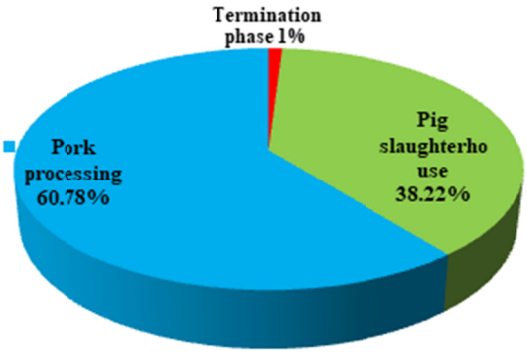

Figure 2. Percentage share of electric energy consumption in the pork chain from the western region of Paraná

The termination phase within the production chain presented 1% of the energy consumption. At this stage, the highest expenditure corresponds to feed consumption. According to Avanci et al. (2012) the highest proportion of input energy is feed consumption which corresponds to 79.13% of all input energy. Water consumption and human labor are the ones with the lowest embedded energy (0.010% and 0.049%, respectively). Regarding energy consumption and buildings, the built-in energy is 1.29% and 19.51% respectively. The results of Rohenkohl (2003) confirm the link between feed costs and total termination costs. The costs of feeding found by the author represent around 50% of the total costs of production of termination.

Pig slaughter had a 38.22% share of electricity consumption. According to the United Nations Environment Program (UNEP), Danish Environmental Protection Agency (DEPA) and Consulting Engineers and Planners (COWI) (2000), approximately 80 to 85% of the total energy required at a slaughterhouse is thermal energy (steam and hot water), produced by burning fuels in the boilers of the industrial unit. The same authors also state that the electricity consumed in a slaughterhouse is 15 to 20%, whose distribution occurs as follows: refrigeration (59%), boiler room (10%), by-product processing (9%), slaughter area (6%), generation of compressed air (5%), deboning area (3%) and others (8%), and that the cooling operation is the one that demands greater energy consumption in the process.

The processing of pork consumed 60.78% of the electricity. In this type of industry, electricity is mostly used for refrigeration. However, it has also been used for the production of compressed air, lighting and ventilation systems, among others. According to the Food and Agriculture Organization of the United Nations (FAOSTAT, 2014) report, refrigeration accounts for between 45% and 90% of the total final energy consumption during the daytime work period and about 100% during the night period. According to Ramírez, Patel, and Blok (2006), the electricity consumption related to the different stages of the meat production process is divided into: 40% for cutting and mixing, 40% for refrigeration, 10% for packaging and 10% for lighting.

4. Conclusion

The average specific energy consumption in pig production in the termination phase, slaughter and processing was 0.0058, 0.22 and 0.35 kWh kg^{-1}. The highest consumption occurred in the processing stage.

Electricity consumption in the termination phase accounted for 1%, slaughtering by 38.22% and processing by 60.78% of electric power consumption within the pork chain in the West of Paraná.

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