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Electric energy consumption and economic feasibility of led lighting system in broiler house

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This study aimed to compare the performance of incandescent lamps and LED lamps, regarding the consumption of electricity and the economic viability of these lighting systems in broiler houses in western Paraná State, Brazil. The study was conducted to compare the power consumption in two broiler houses of the dark house type in São Miguel do Iguaçu, Paraná, Brazil; one lighting system with incandescent lamps and the other one with LED lamps. The power consumption was measured in the two lighting systems, using meters of electrical quantities Landis Gyr+ during the housing period of a batch of poultry corresponding to 43 days. Then, the energy consumption was calculated per bird housed, by mass of live chicken and aviary unit area. With the electricity tariff values for rural consumers, there was an evaluation of the economic viability of lighting systems by the method of net present value (NPV) method and the discounted payback. The main results showed that throughout the period of broiler chickens housing, in the aviary with incandescent lamps 1,768 kWh in lighting was consumed, while the aviary with LED lamps consumed 221 kWh. The economic feasibility analysis showed that the use of LED lamps presented greater economy, and has a return on investment within a period of 21 months.

Key words: Energy consumption, lighting systems, broiler house.

INTRODUCTION

The Brazilian poultry industry is responsible for thousands of integrated producers, processing companies and exporters. The poultry sector employs over 3.6 million people directly and indirectly, and accounts for almost 1.5% of the national gross domestic product (GDP) (UBABEF, 2014).

The national poultry industry uses imported tech-nologies temperate climates, using adaptations without considering the growing concern for the rational use of energy in relation to the environment (Bonn, 2010). As this activity is dependent on electricity, mainly due to commercial-scale productivity, energy consumption in the production

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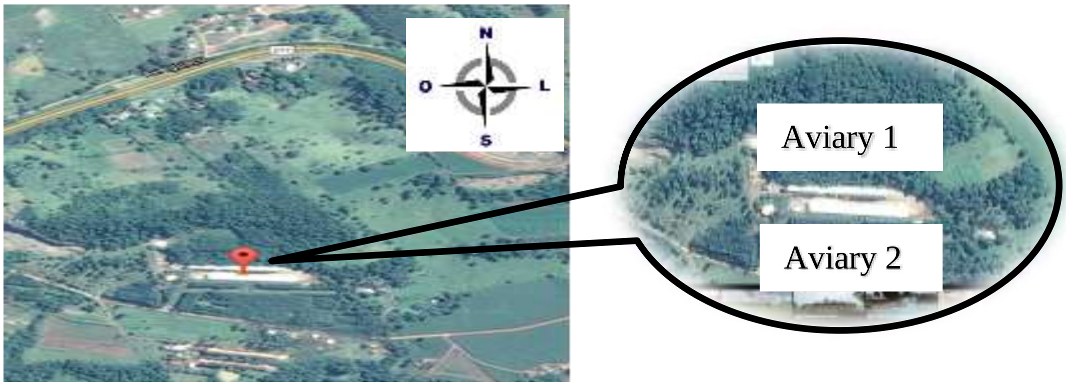

Figure 1. Location of aviaries 1 and 2 of the study (Google maps, 2015).

becomes limiting, making the poultry sector seek increased energy efficiency. According to Saidur (2009), this reduction in power consumption, can constitute a simple replacement of inefficient light bulbs with more efficient light bulbs.

According to Simpson et al. (2014), regarding the poultry industry, the light is an important aspect and is presenting developments in lighting systems in aviaries during the past years. Until 2007, the production of broiler chickens depended almost entirely on incandescent lamps. From 2008, producers began to replace incandescent lamps with spiral compact fluorescent lamps not dimmable, for laying chickens, and for termination, used to dimmable CFLs. This process resulted in an annual electricity bill reduction of US$ 1,000 for aviaries of 1,800 m².

Santos et al. (2015) and Simpson (2008), report that incandescent lamps produce light by heating the tungsten filament. For this reason, the luminous efficiency is in the range 10-20 lm/W. Depending on its construction and the filament operating temperature, the rated life of these lamps is approximately 1,000 h. According to Brunner et al. (2010), incandescent lamps are considered inefficient light sources, because 95% of the consumed electrical energy is dissipated as heat. According to Reynolds et al. (2012), despite the fact that cost of the incandescent lamp is much less, in the long run, the cost may be increased due to the high consumption of electricity. As stated by MME (2011), according to the Ministry of Mines and Energy of Brazil, the incandescent lamp is inefficient and through an interministerial decree No. 1,007 of December 31, 2010, which sets minimum levels of energy efficiency for incandescent lamps, prohibits marketing and imports from June 30, 2016.

FUPAI (2006) reported that LED lamps are composed of semiconductors that convert electrical current into visible light in a solid state. The main advantage is its small size and technological development, making it an interesting alternative to the replacement of incandescent lamps. According to Osram (2014), the LED lamp has energy efficiency of about 100 lm/W in the white light illumination. Simpson et al. (2014) comments that, from 2008, new light-emitting diodes (LED), became available.

Abreu and Abreu (2011) reported that the aviaries type dark house, can possess light protection and natural ventilation, held by Curtain sider sealing black polyethylene on one side and reflective on the other or use steel plates insulated with rigid foam polystyrene (XPS) for sealing. The aviary type dark house provides greater control of lighting and thermal conditions inside the aviary. As stated by Nowicki and Butzge (2011), in this type of aviary, the birds are subjected to totally artificial light and controlled light program, ventilation and relative humidity as well. This combination of controlled ventilation and light makes the broiler become quieter and consume less energy for their development.

In order to show the possibility of power consumption reduction in aviaries and demonstrate the economic viability, this article compared the performance of conventional incandescent lamps with the performance of LED lamps based on their energy consumption in their final use in two broiler houses type dark house in São Miguel do Iguaçu city, western Paraná, Brazil (Figure 1).

MATERIALS AND METHODS

The aviary 1 was built about 8 years ago, works in the system dark house and has the capacity to house 23,000 broilers. Its dimension is 12 x 150 m (total area of 1,800m2) and ceiling height of 2.60 m. The sides are insulated with polyethylene sheeting and coverage with fiber cement tiles with 6 mm.

The aviary 1 lighting system is composed of 3 rows of 22 incandescent 60 W lamps of 127 V, a total of 66 lamps installed. The control of the illumination system is done by means of a panel with a Fan control dimmer equipment (Figure 2).

The aviary 2 which was built about 2 years ago works in the system dark house and has the capacity to house29,000 broilers. Its dimension is 14 x 150 m (total area of 2,100 m2) and ceiling height of 2.45 m. All lateral walls were sealed through a system of double aluminum plates, expandable polystyrene (EPS) coated, filling the heart of this system is through the use of extruded polystyrene (XPS). The doors also have insulation with aluminum. The external side of the aviary is painted in white.

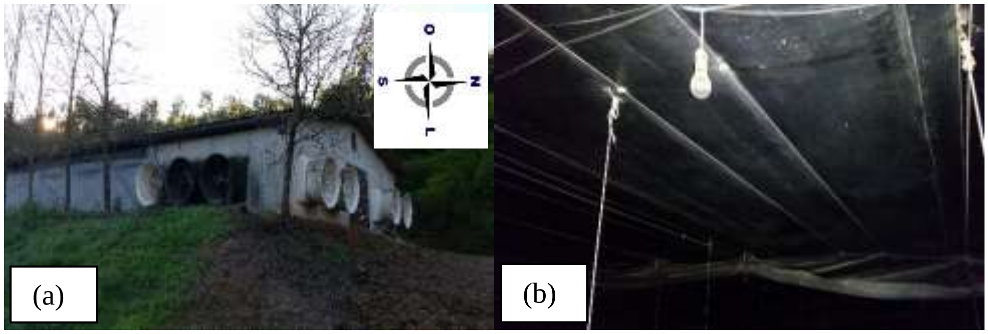

Figure 2. (a) Aviary 1, dark house system without thermal insulation. (b) Lighting with incandescent lamps in aviary 1.

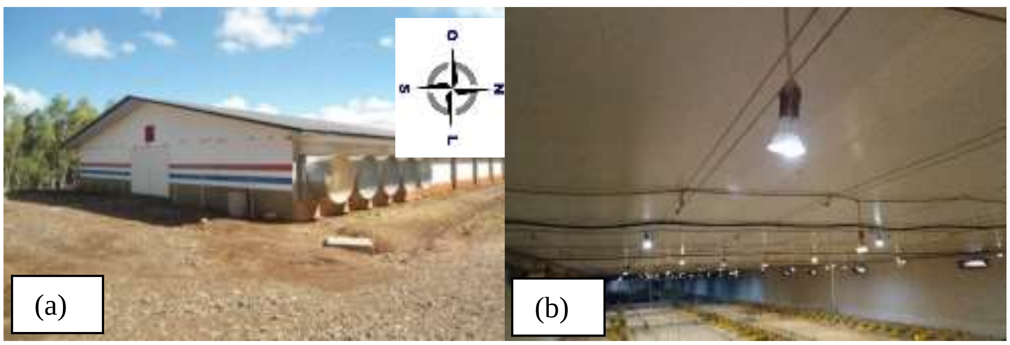

Figure 3. (a) Aviary 2 with thermal insulation and lining with thermal blanket. (b) Lighting with LED lamps in aviary 2.

Figure 4. Measuring instruments installed in the scenarios 1 and 2.

The aviary 2 lighting system consists of 3 lines of thirty-three 5W LED lamps, for a total of 99 lamps installed. The control of the illumination system is done by means of an Avilamp panel, which has a converter 220V/24 V to power the system (Figure 3). The authors used the brand meters Landis Gyr+ ZD318 model, that store the active power consumption for net connection in 3-phases, 4-wires; 2-phase, 3-wire; connected in 120 or 240 V, 50 or 60 Hz and currents up to 120 A. It has standard optical interface ABNT (brazilian standard); diode (LED) test and its reading is recorded every 1 Wh/pulse (Figure 4).

Initially, there was the technical inventory of the two aviaries lighting system. Also, broiler chicken production information, housing area, density of broiler/m² and total output weight of the broiler in each aviary were collected (Table 1).

To perform the measurement of electricity consumption, the brand meters Landis Gyr+ Z.D.318 model was used. In aviary 1, an equipment Landis Gyr+ was installed in order to collect data from electric power consumption of 66 power incandescent lamps of 60 W. In aviary 2, other equipment Landis Gyr+ was settled to measure the electric power consumption of 99 LED lamps of 5 W.

The data generated by the meters were collected daily. The beginning of the data collection took place on June 18, 2015 (date

Table 1. Technical characteristics of the aviaries.

Description	Aviary 1	Aviary 2
Aviary area (m²)	1,800	2,100
Input housed broiler (un.)	23,000	29,000
Slaughter output broiler (un.)	21,698	27,334
Density of broiler (broiler/m²)	12.78	13.81
Output total live broiler weight (kg)	60.732,70	72.571,77

Table 2. Electric energy consumption of lighting systems on each aviary.

Description	Aviary 1	Aviary 2
Total eletric energy consumed (kWh)	1,768.00	221.00
Eletric energy consumed (kWh /housed broiler)	0.0815	0.0081
Eletric energy consumed in lighting (kWh/m²)	0.9822	0.1052
Eletric energy consumed (kWh /kg of live broiler)	0.0291	0.0030

of housing broiler) and ended on July 31, 2015 (date of transport of broiler for slaughter). The electrical quantity measured was the active energy (kWh), collection of data of total consumption, consumption during normal business hours (6:30 to 21:30) and consumption on schedule (NRR) with nocturne rural rate (21:30 to 6:30). The property works with conventional charging rural B2 group with nocturne reduced rate.

To calculate the electric energy consumption in kWh/housed broiler, the energy consumption in kWh/m² and electricity consumption in kWh/kg of live broiler, the following equations were used:

$$EECHB=TEEC/(\text{housed broiler amount}) \quad (1)$$

$$EECAU=TEEC/(\text{aviary area}) \quad (2)$$

$$EECBLM=TEEC/(\text{total weight of live broiler}) \quad (3)$$

Where, EECHB = Electric energy consumption by housed broiler, kWh/housed broiler; EECAU = Eletric energy consumption by area unit, kWh/m²; EECBLM = Electric energy consumption by live broiler weight, kWh/kg of broiler live; TEEC = Total electric energy consumption, kWh.

To perform the economic feasibility analysis of incandescent lamps as compared to LED lamps, the calculation of net present value (NPV) and discounted payback were used considering interest of 5% per year, taking into consideration the following information:

Aviary 1: Lifetime of incandescent lamps (1,000 h), the cost per kWh, the initial cost of buying the bulbs and the cost of exchanging all the bulbs when they reach the rate life (every 60 days).

Aviary 2: Lifetime of LED lamps (50,000 h), the cost per kWh, the initial cost of buying the bulbs and control panel and the cost of exchanging all the bulbs when they reach the rate life (6th year).

RESULTS AND DISCUSSION

In this study, two aviaries type dark house with different building systems were evaluated, in São Miguel do Iguaçu city, Paraná, Brazil. With the data collected by the equipment Landis Gyr+, it was possible to know the total consumption of electricity in the two aviaries (Table 2). The variation in the consumption between the aviaries was considerably high. The aviary 2 showed consumption difference of 8 times lower for aviary 1.

The lighting program was the same for both aviaries using 4 to 12 days 100% of illumination, 13 to 20 days 80%, 21 to 30 days 60% and 31 days before slaughter 45% lighting. Comparing the consumption of aviary 1, which was 0.0291 kWh/kg of broiler live (incandescent lamps) with the aviary 2, the power consumption was 0.0030 kWh/kg live chicken (LED lamps); it may show that the electricity consumption of aviary 2 was more cost-effective (Table 2).

This is confirmed in the study of Rajaniemi and Ahokas (2015) with the electricity consumption in lighting by using 84 fluorescent tube lamps of 36W, in an aviary of 1,600 m² in size and capacity of 28.000 housed broiler. Rajaniemi and Ahokas (2015) obtained on average 606 kWh per lot or 0.013 kWh/kg of broiler live which makes the aviary 2 with LED lamps even more energetically attractive.

As shown in Figure 5, the highest consumption for the two aviaries was in the beginning of the accommodation, as from the second week, the lighting program begins. According to López et al. (2007), Nascimento (2011) and Abreu and Abreu (2011) when the light program is correctly applied, it is one of the factors that contribute to the efficiency of the production lot.

In the first week, there was a sudden drop in temperature reaching 7°C. As stated by Brunner et al. (2010) and Pan (2015), incandescent lamps turn up to95% of the energy used into heat, which is energetically inefficient. As the aviary 1 is laterally closed with polyethylene tarpaulins and this has many air intakes, it hindered the room heating; however, benefited from this inefficiency of incandescent lamps to assist in adjusting

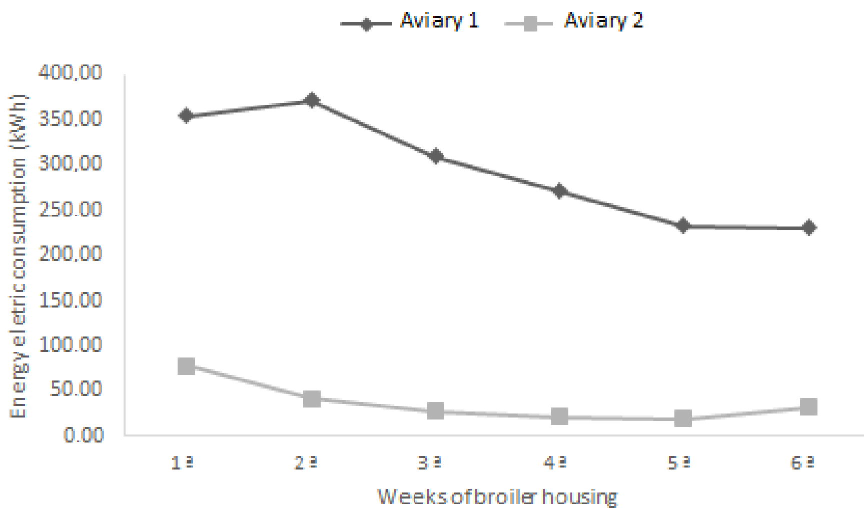

Figure 5. Eletric energy consumption (kWh) of the lighting system in the aviaries 1 and 2, during the six weeks of broiler housing.

Table 3. Electric energy consumption of the aviaries (kWh) working in the nocturne light program.

Nocturne light program	%	Work hours	Aviary 1		Aviary 2	
			Daytime (kWh)	Nocturne (kWh) **	Daytime (kWh)	Nocturne (kWh)**
1 and 12	100%	288	287	206	36	26
13 and 20	80%	134,4	263	66	33	8
21 and 30	60%	129,6	247	164	31	21
31 and 43	45%	324	241	294	30	36
Maintenance*	100%	84	144	0	18	0
Total		960	1182	730	148	91

*Empty aviary for maintenance, 7 days a week with 12 h worked during regular hours. **NRR– nocturne reduced rate.

Table 4. Energy electric cost in the aviaries 1 and 2.

Description	Aviary 1		Aviary 2	
	Consumption (kWh)	R$	Consumption (kWh)	R$
Daytime rate consumption	1,182	R$404.31	148	R$54.08
Nocturne rate consumption	730	R$101.31	91	R$14.06
Energy eletric cost in 60 days		R$505.62		R$68.14

the internal temperature. This generated a peak in electricity consumption as shown in Figure 5.

To perform the economic feasibility analysis of incandescent lamps in relation to the LED lamps, the values collected were used, days of the light program and its percentage and days in the aviaries were empty for cleaning as shown in Table 3. To calculate the NPV, it was considered the replacement of incandescent lamps every 60 days and LED lamps every 6 years.

In Table 4, it is shown, the total electric energy consumption and the cost of aviaries 1 and 2, considering the values provided by the dealership tariff in regular time, R$0.342030 and nocturne rural rate (NRR), R$0.138808.

The information and annual total cost of the implementation of each light bulb model are shown in Table 5.

Table 5. Total investment cost in relation to rate life.

Description	Incandescent*	LED**
Rate life of lamps (hours)	1,000	50,000
Quantity (un.)	66	99
Cost per unit	R$2.00	R$39.60
Panel cost	R$0.00	R$1,644.60

*Incandescent lamp: 60 days until replacing; **LED lamp: 6 years until replacing.

The calculation of net present value (NPV) and discounted payback period were used, considering an interest rate of 5% per year. The NPV lighting system with incandescent lamps was R$19,260.09 and NPV lighting system with LED lamps was R$7,620.76. Therefore, by the NPV, it is concluded that the system with LED lamps showed a lower investment cost. The investment analysis of the discounted payback indicates that the LED lamps system achieves a return on investment in 21 months.

Conclusion

The results of this study showed that in the period of June 18, 2015 to July 31, 2015, the aviary 1 consumed in lighting system, equivalent of 1,768 kWh and aviary 2, consumed 221 kWh. In financial terms, this LED lamps system obtained a saving of R$437.48 and analysis shows that an average of 6 lots per year can be achieved with savings of R$2,624.00 yearly.

Through the NPV calculation, the aviary 2 showed lower cost considering 72 months of investment and with the calculation of the discounted payback, this initial investment has its return in 21 months.

It is concluded that with the electricity consumption and also the economic viability calculation (NPV and discounted payback), the LED lighting system is an efficient energy and economically viable as compared to incandescent lighting system in this case.

Conflict of interests

The authors have not declared any conflict of interests.

REFERENCES

Abreu VMN, Abreu PG (2011). Os desafios da ambiência sobre os sistemas de aves no Brasil. Rev. Bras. Zootec. 40:1-14.

Bonn J (2010). Estudo de diferentes tecnologias, métodos e processos para eficientização energética de sistemas de iluminação de aviários. Dissertação apresentada como requisito à obtenção do grau de Mestre, no Programa de Pós-graduação em Desenvolvimento de Tecnologia (PRODETEC), do Instituto de Tecnologia para o Desenvolvimento (LACTEC), e Instituto de Engenharia do Paraná (IEP), com ênfase na linha de Pesquisa Geração e Transferência de Tecnologia.

Brunner EJ, Ford PS, McNulty MA, Thayer MA (2010). Compact fluorescent lighting and residential natural gas consumption: testing for interactive effects. Energy Policy 38:1288-1296.

Fupai (2006). Conservação de energia: eficiência energética de equipamentos e insltalações. 3. ed. Itajubá 596 p.

López CAA, Baião NC, Lara LJC, Rodrigues SV (2207). Efeitos da forma física da ração sobre a digestibilidade dos nutrientes e desempenho de frangos de corte. Arq. Bras. Med. Vet. Zootec. 59:1006-1013.

MME (2011). MINISTÉRIO DE MINAS E ENERGIA. Consultoria jurídica. http://www.mme.gov.br/documents/10584/904396/Portaria_interministral+1007+de+31-12-2010+Publicado+no+DOU+de+06-01-2011/d94edaad-5e85-45de-b002-f3ebe91d51d1?version=1.1

Nascimento LAB (2011). Análise Energética na Avicultura de Corte: Estudo de Viabilidade Econômica para um Sistema de Geração de Energia Elétrica Eólico-fotovoltaico Conectado a Rede. 2011, Dissertação (Mestrado em Engenharia Elétrica) - Universidade Tecnológica Federal do Paraná, Pato Branco, Brasil.

Nowicki R, Butzge E, Otutumi LK, Júnior RP, Alberton LR, Merlini LS, Mendes TC, Dalberto JL, Gerônimo E, da Silva Caetano IC (2011). Desempenho de frangos de corte criados em aviários convencionais e escuros. Arquivos de Ciências Veterinárias e Zoologia da UNIPAR. 14(1):25-28.

OSRAM (2014). Manual Luminotécnico Prático, 2014a, 28 p. Disponível em:http://www.iar.unicamp.br/lab/luz/ld/Arquitetural/manuais/manual_luminotecnico_praticos_osram.pdf

Pan KF (2015). Avaliação de sistemas de iluminação de aviários dark house, com e sem isolamento térmico: um estudo de caso na região de Palotina – Pr. dissertação apresentada à universidade estadual do Oeste do Paraná, como parte das exigências do programa de pós graduação em engenharia de energia na agricultura, para obtenção do título de mestre. Março 2015.

Rajaniemi M, Ahokas J (2015). Direct energy consumption and CO2 emissions in a Finnish broiler house – a case study. 24:10-23.

Reynolds T, Kolodinsky J, Murray B (2012). Consumer preferences and will- ingness to pay for compact fluorescent lighting: Policy implications for energy efficiency promotion in Saint Lucia. Energy Policy 41:712-722

Saidur R (2009). Energy consumption, energy savings, and emission analysis in Malaysian office buildings. Energy Policy 37:4104-4113.

Santos TSD, Batista MC, Pozza SA, Rossi LS (2015). Análise da eficiência energética, ambiental e econômica entre lâmpadas de LED e convencionais. Eng. Sanit. Ambient. 20(4):595-602.

Simpson G, Brothers D, Campbell J, Donald J (2014). Poultry Engineering, Economics & Management. Update: LEDs for Broiler House Lighting. Auburn University College of Agriculture. http://www.aces.edu/main/

Simpson RS (2008). Lighting Control—Technology and Applications. Focal Press.

UBABEF (2014). Relatório anual. União brasileira de avicultura.