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Analysis of energy consumption for artificial lighting of rooms for fattening of pigs

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Abstract. State aid for the implementation of voluntary commitments for human attitude toward pigs involves providing artificial light for 11 hours a day. This technological approach is associated with a further increase of energy consumption at farms. Therefore, relevant calculation methods for determination of the energy costs of providing artificial illumination by various types of lighting fixtures are proposed. This comparative analysis can be used by farmers to optimize the energy consumption in different categories of pigs.

Keywords: pig raising, artificial lighting, energy efficiency, human attitude toward pigs

Introduction

Pig raising is one of the most dynamic sectors of farm animal production and its development is largely dependent on opportunities for supply of feed, nature of the applied technologies and managerial decisions. The main problems that must be solved in the period until 2020 are production growth, sustainable development and obtaining of high-quality and safe produce at the lowest possible consumption of various resources. This is in line also with the implementation of the Second National Energy Efficiency Plan (developed on the basis of Directive 2006/32/EC) according to which energy savings in 2016 should represent 9% of the average final energy consumption for the period 2001 – 2005.

The purpose of this study is to make a comparative analysis of power ratings and consumption levels of various types of lighting fixtures to provide artificial light at daytime in production buildings for fattening of pigs. The analysis is within the context of the state aid for farmers to implement voluntary commitments for human attitude toward pigs and the related requirement to provide artificial light for 11 hours a day (3 hours more than required under the standard).

Material and methods

The object of study is the category of pig fattening up to 110 kg live weight, raised in a typical building. In Figure 1 the general appearance and main construction parameters of such a building are sketched. Group raising boxes are located in parallel to the feed alley (1 m wide) and at a floor area of 42 m² providing individual floor area of 0.76 m² per pig. The building (900 m²) has 20 boxes and at a capacity of 55 animals per box the total number of pigs is 1100.

The power performance of 7 types of lighting fixtures, the main parameters of which are shown in Table 1, were studied.

Table 1. Characteristics of lighting systems

<table>
<thead>
<tr>
<th>No</th>
<th>Type of lighting fixture</th>
<th>Relative power per unit luminous flux, lm/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Incandescent lamp</td>
<td>13 – 15</td>
</tr>
<tr>
<td>2</td>
<td>Fluorescent tube</td>
<td>69</td>
</tr>
<tr>
<td>3</td>
<td>Energy saving lamp</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>Halogen spot light bulb</td>
<td>20 – 30</td>
</tr>
<tr>
<td>5</td>
<td>Sodium low pressure lamp</td>
<td>100 – 200</td>
</tr>
<tr>
<td>6</td>
<td>Sodium high pressure lamp</td>
<td>43</td>
</tr>
<tr>
<td>7</td>
<td>LED</td>
<td>80 – 140</td>
</tr>
</tbody>
</table>

The luminous flux required to provide illuminance in compliance with the regulatory requirements is derived from the equation:

\[ I_e = S \cdot i \]  

(1)

where \( I_e \) is required luminous flux, \( lm \); \( S \) is indoor area of the room (building), \( m^2 \); \( i \) is illuminance rate required, \( lx \); \( i = 75 \cdot lx = 75 \cdot lm/m^2 \).

Figure 1. Scheme of a typical housing facility for fattening of pigs

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The electric power required to provide the necessary luminous artificial illumination in pig raising housing. The standing of the energy saving light alternatives with energy and financial costs of about 15% higher than that of fluorescent tubes, is similar.

The results in Table 3 illustrate the cost of transition from an 8-hour to and 11-hour artificial light a day. The ratio between the consumption and cost characteristics of the different types of lighting fixtures is similar to that of the data from Table 2. The transition in housing facilities which use a lighting system with incandescent, halogen and high pressure sodium lamps would be the most expensive. Low pressure sodium lamps, LEDs and fluorescent tubes are energy and financially viable.

The required illuminance for the pig fattening room can be achieved with a different number of lighting fixtures depending on

\[ N = \frac{P_e1000}{P_e} \]  

where \( N \) is total number of required lighting fixtures, pcs; \( P_e \) is unit power rating per type of lighting fixture, W.

The absolute energy consumption and its cash equivalent are respectively expressed by quotations (4) and (5)

\[ E = P_e \cdot T \cdot t, \text{kWh}, \]  
\[ B = E \cdot b, \text{BGN}, \]  

where \( E \) is absolute cost of electric energy for the entire production cycle, at 8 and 11 hour duration of artificial lighting, kWh; \( T \) is duration of production cycle, days \( (T=150); t \) is duration of artificial light day, h, \( (t = 8; 11); B \) is cost of consumed electric energy, at 8 and 11 hours; \( b \) is unit consumer price (VAT included) per unit consumed electric energy, BGN/kWh.

For the purpose of the comparative analysis between the various types of lighting systems, two relative indicators of the energy consumption and the corresponding financial resources were derived:

\[ OE = \frac{E}{N_p}, \text{kWh/pig}, \]  
\[ OB = \frac{B}{N_p}, \text{BGN/pig}, \]  

where \( OE \) is relative energy consumption for lighting provided per pig, kWh/pig; \( OB \) is cash resources spent for lighting provided per pig for the whole production cycle, BGN/pig; \( N_p \) is number of fattened pigs in the production cycle, pcs.

The comparison between the discussed parameters was made using the difference between the absolute values or relative values:

\[ DE = E_8 - E_11, \text{kWh}, \]  
\[ DB = B_8 - B_11, \text{BGN}, \]  

Results and discussion

The absolute electric energy consumption and its corresponding cash resources for each type of lighting fixture throughout the production cycle are presented in Table 2. Sodium low pressure lamps and light diodes (LEDs) display are the best indicators. Their cost characteristics in terms of energy and financial resources are approximately 2 times lower than the commonly used fluorescent tubes and nearly 10 times lower than the incandescent lamps. This comparison shows that high pressure sodium, halogen and incandescent lamps are conditionally unsuitable for providing artificial illumination in pig raising housing. The standing of the energy saving light alternatives with energy and financial costs of about 15% higher than that of fluorescent tubes, is similar.

initial investment, opportunities to ensure uniform illumination without shadows and reliability of the whole light system. Thus, it can be assumed to a certain extent that the most suitable are the LEDs and fluorescent tubes. Their number is respectively 610 and 28, which presumably implies uniform illuminance and good reliability even in the presence of single defects. The number of low pressure sodium lamps needed for the model room is only 6, which implies comparatively lower reliability of illumination in the event of single defects.

The information in Table 5 gives interpretation of energy consumption costs of the lighting fixtures in relative terms as compared to the number of raised animals. Low pressure sodium lamps, LEDs and fluorescent tubes give an advantage over the other...
alternatives. Costs for the illuminance of a pig throughout the fattening period is about 10 times lower in low pressure sodium lamps and LEDs as compared to incandescent lamps. The same comparison with fluorescent tubes highlights nearly 2 times lower lighting costs per pig if the system uses low pressure sodium lamps or LEDs.

Extension of the artificial light in daytime from 8 to 11 hours a day means a slight increase in the consumption of electric energy and the corresponding financial cost. For example, if fluorescent lighting fixtures are used for the artificial lighting of the room under study, the relative price for increase of the light in daytime would be only 0.08 BGN/pig. The relative lighting costs per pig when low pressure sodium lamps and LEDs were used are even lower, 0.03 and 0.05 BGN/pig, respectively. The insignificant amount of increase in energy and financial costs when switching to an 11-hour light a day definitely underlines the feasibility of extending the artificial lighting. This would increase the nutritional activity of pigs raised for fattening and result in better health and improved welfare.

The analysis of absolute and relative indicators of energy needs for the illumination in pig fattening showed that the use of LEDs is distinguished for its very low energy rate, while the relatively high number of lighting fixtures (Table 4) insures the uniform shadow-free illuminance and high reliability in the event of defects. There is a potential for the development of low energy pig farms with independent power supply from a “grid-off” type photovoltaic system mounted on the roof of the buildings. In this light, the large-scale deployment of lighting systems with LEDs and the development of mechanisms for financial incentives in the form of grants should become a priority of the professional organizations of pig farmers.

### Conclusion

Sodium low pressure lamp, LEDs and fluorescent tube fixtures used in pig raising have the lowest energy consumption and financial costs. Incandescent lamp, high pressure sodium lamp and halogen lighting fixtures are conditionally not suitable for artificial lighting in pig raising. Extension of artificial light in daytime from 8 to 11 hours is associated with a minor increase of energy consumption, while rise of costs is minimal. Large-scale use of LEDs for artificial lighting in pig raising is a real opportunity to minimize energy costs in the branch industry. Combining LED lighting with photovoltaic systems is a basis for the establishment of low-energy farms with relatively independent power supply.

Formation of expert groups for technological design of low-energy lighting systems in various production buildings in pig raising is required. Mechanisms for financial incentives and investment subsidies in the field of low-energy lighting in pig raising should be developed.

### References

- Veterinary Medicine Activity Act (The State Gazette, No 92, 2011)
- Farmers Aid Act (The State Gazette, No 15, 2013)
- Decree No 21 of 14 December 2005 on minimum requirements for the protection and human attitude in pig raising (The State Gazette, No. 64, 2006)
- Decree No 44 of 20 April 2006 on veterinary medicine requirements to animal raising facilities (The State Gazette, No 50, 2010)
- Decree No 49 of 10 August 1976 on artificial lighting in buildings (The State Gazette, No 64, 1976)
- Guidelines for the Support for Implementation of Voluntary Commitments for Human Attitude Toward Pigs 2013 state aid scheme. (Decision of the Managing Board of the State Farm Fund, Minutes No 47 of 27.02.2013)

### Tables

#### Table 4. Lighting systems by type, pieces

<table>
<thead>
<tr>
<th>Type of lighting system</th>
<th>Electric energy, kWh</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent lamp</td>
<td>100</td>
<td>48</td>
</tr>
<tr>
<td>Fluorescent tube</td>
<td>36</td>
<td>28</td>
</tr>
<tr>
<td>Energy saving lamp</td>
<td>24</td>
<td>47</td>
</tr>
<tr>
<td>Halogen spot light bulb</td>
<td>10</td>
<td>270</td>
</tr>
<tr>
<td>Sodium low pressure lamp</td>
<td>80</td>
<td>6</td>
</tr>
<tr>
<td>Sodium high pressure lamp</td>
<td>53</td>
<td>30</td>
</tr>
<tr>
<td>LEDs</td>
<td>1</td>
<td>610</td>
</tr>
</tbody>
</table>

#### Table 5. Relative indicators for energy consumption rate of lighting fixtures at artificial light day of different duration

<table>
<thead>
<tr>
<th>Type of lighting fixture</th>
<th>Electric energy, kWh/pig</th>
<th>BGN/pig</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 h</td>
<td>11 h</td>
</tr>
<tr>
<td>Incandescent lamp</td>
<td>5.26</td>
<td>7.23</td>
</tr>
<tr>
<td>Fluorescent tube</td>
<td>1.07</td>
<td>0.47</td>
</tr>
<tr>
<td>Energy saving lamp</td>
<td>1.23</td>
<td>1.70</td>
</tr>
<tr>
<td>Halogen spot light bulb</td>
<td>2.95</td>
<td>4.05</td>
</tr>
<tr>
<td>Sodium low pressure lamp</td>
<td>0.49</td>
<td>0.68</td>
</tr>
<tr>
<td>Sodium high pressure lamp</td>
<td>1.71</td>
<td>2.36</td>
</tr>
<tr>
<td>LEDs</td>
<td>0.67</td>
<td>0.92</td>
</tr>
</tbody>
</table>
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**Todorov N and Mitev J. 1995. Effect of level of feeding during dry period, and body condition score on reproductive performance in dairy cows, IX International Conference on Production Diseases in Farm Animals, Sept.11 – 14, Berlin, Germany, p. 302 (Abstr.).


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