XVIIth World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

ELECTRICAL ENERGY USE IN DIFFERENT HEATING SYSTEMS FOR EARLY WEANED PIGLETS

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CSBE101133 – Presented at Section IV: Rural Electricity and Alternative Energy Sources conference

ABSTRACT Many technologies can be used to promote the welfare in pig production. In order to make them viable, it is necessary to develop research works to lower their costs and increase their practicality, enabling the sustainability of the process. Heating systems for piglets in nursery and farrowing may be improved to save energy, without affecting the animals welfare. There is little information in current literature and specific information about electricity in Brazilian swine farms. The objective of this research work was to compare the electrical energy use and thermal comfort conditions promoted by three heating technologies for piglets in nursery. The evaluation was performed in a commercial farm, located in Brazil, in a subtropical climate area. Each treatment allocated 150 weaned piglets at 21 days-old. The systems were designed to keep the piglets at 28 a 30°C, during fourteen days. The heating technologies studied were: TR - suspended electrical resistors, TP - heated floor and TA – convection heating. Electrical energy consumption (kWh), maximum power demand requirements (kW), specific consumption (kWh/kg of live produced body mass), efficiency of heating system (°C/m^3 air) and dry-bulb temperature (°C) were evaluated. The heated floor system was better under the aspect of electrical energy use. The electrical resistance heating system was the best regarding to the animals thermal comfort needs.

Keywords: swine production, pig nursery, energy saving, heated floor.

INTRODUCTION In order to meet the production quality and amount demands, the protein producer needs to invest in new technologies, searching for the sustenance on the swine meat market. This market becomes more competitive every day.

In Brazil, the competitive maintenance depends, mainly, on the product (animal and meat) quality maintenance and on the production cost reduction, especially in produced live pig.

Aiming to improve the product quality, carcass of better quality, new market demands, e.g. animals raised under welfare conditions and sustainability, are features commonly sought.

Energy saving procedures in the swine production is important to contribute to sustainability of the activity. If well used the energy saving procedures can contribute to economical feasibility, environmental practicability and animal welfare in the swine livestock.

Current and specific literatures about the energy use in Brazilian swine production are scarce. According to Girotto and Talamini (1998), the average consumption of the electrical energy per finished pig, in Brazil, in 1994, was 2.03 kWh/ finished animal. Talamini et al. (2006) estimated that the consumption of a swine farm is 150 kWh per housed sow.

Many procedures to reduce the energy consumption can be used. Even a simple temperature controller can be an interesting tool under energy saving aspects. This appliance allows correcting the management deficiencies of heat source and keeps the environment stable. It gets 30 to 50% energy savings when it is compared with a system that works without the thermostat (Bonett and Monticelli, 1997).

The heating of piglets is a procedure that demands great energy consumption. Thus, increase the efficiency of energy use is necessary. These actions should be carried out without harming the animal welfare strategies.

Xin et al. (1997) compared different lamps for piglets heating in farrowing and they concluded that the 175W energy-efficient heat lamps (Phillips PAR) instead of 250W infrared lamps, for suckling piglets, allowed an energy saving of 1.03 kWh per lamp per day. This economy meant the equivalent of $5,400 per year, in a swine farm with 1000 sows, considering the North America economical and cost conditions. Also, the energy-efficient heat lamp showed higher durability and has reduced mortality and increased weight gain of piglets.

Beshada et al. (2006) studied heated mats and heat lamps, for suckling piglets. The authors found no differences in the piglets performance, when the animals were submitted to both technologies. But, they reported an energy saving of 2.8 kWh per litter.

Because of the large number of diseases, behavioral problems and proven stressors that affect the weaned piglets (Merlot et al., 2004), it is necessary to develop more research works to mitigate the stress, mainly thermal one.

In this research work, it was aimed to compare the electrical energy use and thermal comfort conditions promoted by three heating technologies for piglets in nursery.

MATERIAL AND METHODS The analyses were performed on a commercial pig farm, in São Paulo State – Brazil. The farm is located 600m above the ocean level, at latitude 22º37’28.4”S and longitude 47º03’23”W. This farm has a livestock production, complete cycle, with weekly organization of production and hosts 1,000 sows from a worldwide recognized genetic company.

In each analysis, a group of 450 weaned piglets (19 days adjusted age) was allocated to three identical pens. Each treatment was located in a pen with 150 animals. The floor was composed by 1/3 of concrete (compact) and 2/3 of plastic (slatted). The density used was 5 piglets.m^{-2}. Although some authors state that large groups and high density are able to reduce the performance of piglets (Wolter et al., 2000), were respected managements conditions, accommodation and facilities already used in the farm.

The buildings were of masonry, covered with clay tiles. All pens are suspended and had 26m^2. Each pen was covered with polypropylene yellow ceiling, positioned 1.85m high, in order to reduce the area to be heated. The rooms have screened windows, in both sides. The handling of curtain is done manually. A handler opened the curtain in the morning and closed it in the afternoon.

The piglets were submitted to three treatments, different in the way of heating. Heating was conducted during 14 days. Two observational studies were performed, in June and July 2008.

The compared treatments were as follows:

TR (Suspended electrical resistors) was composed by 15 electrical resistors of 200W, uniformly distributed (Figure 1), and suspended 1m from the floor. The system aimed to warm the piglets by radiation. It was designed to maintain the air temperature between 28-30° C. The installed power for this system was about 3000W.

TP (Heated floor) comprises an area of 10.4 m^2, corresponding to 40% of the total area of the pen (Figure 1). The top half of the floor was made of cement mortar (Portland CP V ARI) and sand. The bottom half was made of cement mortar, sand and rice husk (insulation material), according to recommendations of Rossi et al. (2005). This system aims to supply heat to the piglet by conduction. It was designed to maintain the air temperature between 28-30° C. For the design of electrical resistance, we used the methodology described by Incropera and Dewitt (1998), based on the Law of Conservation of Energy. The floor was maintained at this temperature after previous preference test, observing the behavior of piglets. The installed power for this system was about 2400W.

TA (Convection heating) was composed by a commercial heat exchanger, which injected hot air coming from the electrical resistance, into the rooms. This procedure was performed using a fan. The air was distributed through a PVC pipe (15 cm diameter and 7 m long), with 3 evenly spaced airflow outlet. Thereby, the air can be inflated in the center of the facility (Figure 1). This system aims to supply heat to the piglet by convection. The system was designed to maintain the air temperature between 28-30°C. The total installed power considered for this system (fan + electrical resistance) was approximately 8830W.

All studied systems were controlled by temperature controllers.

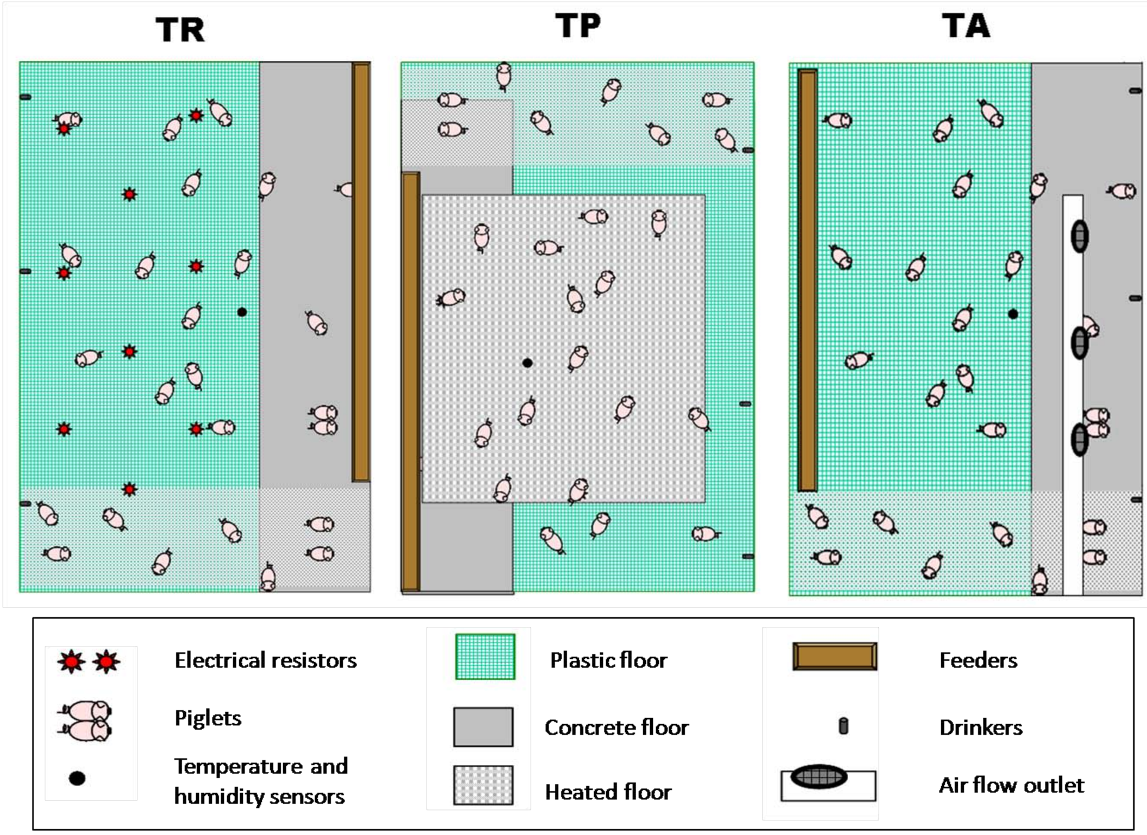

Figure 1. Layout of treatments.

Due to the large discrepancy found in the literature regarding the air temperature to which the pigs should be exposed, at 21 days-old, we tried to keep the piglets in the temperature range already used by the farm (28°C - 30°C). The criterion for this choice of temperature range, added to the recommendation of Brown-Brandl et al. (2003), presented in equation 1.

$$\text{Tideal} = 0.0015 \times wt^2 - 0.2969 \times wt + 30.537 \qquad (1)$$

Where,

Tideal – Ideal environmental temperature to the animal, °C, and

wt – mass, kg.

The electrical energy spent by equipments work was evaluated with individual electronic meters (Embrasul, model RE6081), installed in the circuits. These meters were coupled to a specific data logger. The variables were recorded every 15 minutes, 24 hours per day, during the experiment period. Electronic meters data were analyzed in specific equipment software.

To compare the treatments, the electrical energy variables were: maximum demand (kW) and energy consumption (kWh).

Power factor (relationship between active power and apparent power) indicates how the system is working regarding to the energy consumption. It shows how much power is actually used. However, in this case, the treatments TR and TP had installed capacity exclusively composed by electrical resistors. So the power factor was not considered.

The maximum demand indicates the highest value of energy demand, registered on the studied period. The demand is the electric energy delivered to or by a system (electric energy consumption divided by the measurement time). It was expressed in kW.

All parameters were considered for the complete system, including electronic components, LEDs, coolers etc.

The objective variable used for evaluating the animal performance was the gained body mass in the studied period. The animals were weighted in groups of 10 animals and the group weights were added within each treatment. The gained body mass was considered to compose the specific consumption.

To evaluate the energy efficiency of treatments, it was used the specific consumption. It was performed to analyze of consumption energy (kWh) for the generate product (kg of produced live body mass when the output of the nursery). This relationship is given by the equation 2:

$$Ces = \frac{CAi}{QPi} \qquad (2)$$

Where,

Ces – Specific consumption, kWh/kg of produced live body mass;

CAi – Energy consumption to rear a group of animals, kWh;

QPi – Amount of product yielded by the consumption unit (treatment) (kg of produced live body mass)

i - Index related to the swine reared group of animals, obtained by historic analysis of the data.

Even for the energy efficiency evaluation, Oliveira et al. (2006) determined the energy consumption per square meter of soil, in a study of a warmed greenhouse. In this work we calculated the amount of electricity consumed for the increase of 1ºC in 1m^3 of air in this building, to evaluate the heating systems efficiency. This calculation was performed based on the temperature difference between outside and inside the facilities.

In order to monitor the dry-bulb temperature (Tbs) into the studied environments and the external environment, temperature gauges with data loggers (BethaEletronica®, model UMMI) was placed in the center of the pens. Data were recorded every 15 minutes.

Analysis of variance and Tukey’s test were performed to compare the treatments.

RESULTS AND DISCUSSION Energy consumption is the recorded of how much energy was consumed during a certain time and, therefore, expressed in kWh. The table 1 presented the data of average daily electric energy consumption for each treatment in the studied period.

Table 1. Total electric energy consumption by different heated systems for nursery pigs, during two weeks of use.

	Electric Energy Consumption (kWh)		
	TR	TP	TA
Analysis 1	69.16	41.62	200.24
Analysis 2	115.32	44.8	278.14

TR= Electrical resistors, TP = heated floor, TA = Convection heating

The convection heating system consumed the highest energy amount, and therefore, it was the worst treatment in this aspect. The heating floor was the best one because it consumed less power. Xin and Zhang (1999) determined that the use of heated floor can offer 40 to 60% of energy savings, when compared with radiant lamps (including energy-efficient lamps). These data are similar to those found in this study when considering the comparison with the electrical resistances. In this study, heated floor provided savings of approximately 80%, compared with convection heating.

Data of the maximum demand recorded for each treatment and each period are shown in table 2.

Table 2. Maximum demand registered in different heating systems for nursery pigs.

	Maximum Demand (kW)		
	TR	TP	TA
Analysis 1	2.99	1.36	8.71
Analysis 2	3.14	0.88	8.56

TR= Electrical resistors, TP = heated floor, TA = Convection heating

The highest demand peak was recorded in the TA treatment. This is explained because of the greater installed electrical load on this system. It was observed that the maximum demand of TP treatment was the highest, considering the two analyses. It was 1.36 kW, considering these conditions of use, control systems and the weather.

In order to calculate the specific consumption, it was considered the total gained body mass. Table 3 shows the data on the total gained body mass in the end of the observational analysis.

Table 3. Total gained body mass of piglets submitted to heating systems, at the end of the analysis.

	Total gained body mass (kg)		
	TR	TP	TA
Analysis 1	526,5	732	924
Analysis 2	844,2	750,3	1081,2

TR= Electrical resistors, TP = heated floor, TA = Convection heating

TA treatment was able to produce higher absolute quantity of product. But the comparison of the systems efficiency was done by analyzing the specific consumption (Ces). Producing more is just countervailing, if the cost of production does not increase substantially, in order to become the production unfeasible.

Ces, in this case, was able to assess how much electricity was consumed to produce 1 kg of live pig weight. Table 4 displays the Ces values for each system studied, in the two tests in question.

Table 4. Specific consumption of different heating system for piglets nursery (kWh/kg of produced live body mass).

	Specific consumption (kWh/kg)		
	TR	TP	TA
Analysis 3	0.131	0.009	0.217
Analysis 4	0.068	0.003	0.129

TR= Electrical resistors, TP = heated floor, TA = Convection heating

Although the animals from TA gained more and the animals from TP gained less weight, the specific consumption of TA was the biggest (and therefore worst) and the TP specific consumption was the lowest (best). Thus, TP was the best system and TA was the worst system of the three treatments, when specific consumption was considered.

The amount of the electrical energy consumed for increasing 1°C per m^3 of air, in these studied conditions, is showed in table 5. Importantly, this data are specific to the location and facilities studied in this research work.

Table 5. Amount of electrical consumption (kWh) by different heating systems for piglets in nursery for increasing $1°C.m^{-3}$ of air in the facilities.

	Amount of the electrical consumption (kWh) for the increase $1°C.m^{-3}$ of air		
	TR	TP	TA
Analysis 1	0.14	0.11	0.26
Analysis 2	0.26	0.15	0.43
Average Analyses	0.20	0.13	0.35

TR= Electrical resistors, TP = heated floor, TA = Convection heating

In a comparative data analysis, presented in Table 5, it is necessary more kW to increase $1°C.\ m^{-3}$ of air, in the TA treatment. The most efficient system, according to the analysis of this index, is the TP system, because it needs less energy to raise $1°C.m^{-3}$ of air.

The comparison among the three proposed technologies showed that the average dry bulb temperature of the treatments was different ($p<0,05$), when treatments were compared with each other and with the external environment. These tests are presented in Table 6.

Table 6. Dry-bulb temperature average in nursery of piglets, using different heating systems

	Dry-Bulb Temperature (°C) – Tbs			
	TR	TP	TA	Text

Analysis 1	25.5 (±2,3)[a]	24.2 (±5,8)[c]	25.1 (±6,1)[b]	18.8 (±4,2)[d]
Analysis 2	26.2 (±2,4)[a]	24.0 (±5,2)[c]	25.3 (±2,6)[b]	20.0 (±5,2)[d]

[a,b,c,d] Averages followed by different letters in the same line are different (p<0,05) by Tukey's Test. TR= suspended electrical resistors, TP = heated floor, TA = convection heating, Text= external temperature (outside of the facilities).

No one treatment was efficient if we consider the optimum range between 28-30°C and the Tbs averages obtained. Therefore, it was verified, in both analyses, that all the systems were able to reach the maximum Tbs (30°C).

Evaluating the Tbs distribution during the analyses, it is possible to verify that TR treatment kept between 25 and 27°C, in most part of the time (42% of analyzed data). Same behavior was found in TA treatment. However, Tbs in TP treatment kept between 20 and 24°C, in most part of the time (about 49%). As a result TP was less efficient.

Pandorfi et al. (2004) studied heating systems for piglets in farrowing. The technologies studied were: heated floor (Rossi et al., 2005), incandescent lamps (200W), electrical resistors (200W) and infrared lamps (250W). The authors found that the heated floor was the most efficient considering the conduction heat change and it offered better comfort condition to the animals.

On the other hand, the study performed by Pandorfi et al. (2004) was performed inside of the creeps with volume of 0,53m^3. Sobestiansky et al. (1987) mentioned that the use of the creep gave a better environmental acclimatization to the piglets. But in this study the total volume of the facilities to be heated is about 80m^3.

This way, considering the treatments efficiency in view of the piglets thermal comfort, the suspended electrical resistors was the best, followed by the convection heating. The heated floor was the worst considering these aspects.

CONCLUSIONS The heated floor, used for the piglets in nursery, was the system that consumed less electrical energy, showed the lowest maximum demand value, had the best specific consumption and required less energy to heat the air, in these specific study conditions. However, it presented the worst air temperature conditions.

The heating convection system was the worst system considering to electrical energy saving, because it presented the highest electrical energy consumption, during the studied period. It presented the highest maximum demand value, the highest specific consumption and required more electrical energy to heat the air. So it got an intermediate performance in view of the piglets thermal comfort.

The suspended electrical resistors showed intermediate behavior, taking into account the electrical energy use, when it was compared with others systems. Besides, this system was the best for the piglets thermal comfort.

Acknowledgements. The authors acknowledge State of Sao Paulo Research Foundation (FAPESP) for the financial support and CNPq for PhD scholarship support.

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