Evaluation of the Behavior of Piglets in Different Heating Systems using Analysis of Image and Electronic Identification

H. Pandorfi[1] and I.J.O. da Silva[2]

[1] University of São Paulo, NUPEA - ESALQ/USP, Av. Pádua Dias, 11, PB 09, Cep. 13418-900, Piracicaba, SP – Brazil. E-mail: hpandorf@esalq.usp.br
[2] University of São Paulo, ijosilva@esalq.usp.br

ABSTRACT

The objective of this research was to evaluate the behavior of piglets in different heating systems using image analysis (IA) and electronic identification devices (EI). The experiment was conducted from June to August of 2002, in a commercial swine production farm, located in Elias Fausto city, state of São Paulo, Brazil. The research was developed in the farrowing house, with 80 newborn piglets distributed in eight studied creep heating. Four heating systems were studied: floor heating panel, standard heat lamp, electric resistance and infrared lamp. Dry, wet bulb and black globe temperatures, were measured inside and outside the creeps with T termocouples and recorded each 60 minutes in a datalogger. The thermal comfort indexes: black globe humidity index (BGHI), radiant heat load (RHL) and enthalpy (H) were calculated using the recorded climatic parameters. Piglets daily weight gain (DWG) and mortality were registered too. The behavior of the piglets was evaluated using the image analysis, electronic identification and geoestatistical techniques. The images were taken using video cameras that were installed in each creep, being recorded in a PC by an Image Capture Board. The EI devices consisted in a transponder that was injected inside the ear base of each piglet and antennas installed in each creep to record the transponder's signals. The results indicated the performance of the floor heating panel was superior than the other studied heat sources in function of its greatest occupation ratio and frequency of use. The image analysis associated with the geoestatistical technique, showed to be a better tool to study the piglets behavior in function of different thermal environments, than the animal electronic identification devices.

Keywords. Creep heating, animal behavior, electronic identification, imaging analysis.

1. INTRODUCTION

The modern swine industry has become specialized and farm sizes have grown as economies of scale are sought. Swine producers strive to minimize production costs while optimizing productivity and product quality while reducing environmental impact (waste and odor) and avoiding social impact on the community. On the other hand, within the industry, important issues regarding market usage and development are shaping the future of the swine industry. The main purpose of most livestock production enterprises is to satisfy the demands of the costumer, providing a product, which meets the customer's requirements that are becoming increasingly well defined.

New technologies for livestock monitoring are being developed, and making available increasing amounts of information about animal's behavior and their environment. With the development of these technologies, it becomes more important to develop systems that can collect, process and utilize the information. In this way, the producer can maximize the efficiency of the production system monitoring all its critical stages (Frost, et al, 1997).

One of the most important variables to be controlled on swine production is the thermal environment. It is well known that the thermal environment influences swine production performance, the welfare and health of pigs. In farrowing houses, the difficulty to solve the thermal environmental problems is higher, because the demands of the sow are different from the demands of newborn piglets that are metabolically immature, and have low insulation and thermo stability. While sows needs 16 – 20 °C to maintain constant body temperature (Connor, 1993), the piglets, during the first days after birth need 31 - 36 °C (Close, 1992).

To adjust the different thermal needs of sows and piglets, it is recommendable to keep low room temperatures, and to use a localized creep heating for the piglets. According to Xin, 1997 Heat lamps have been commonly used as creep heat source, while electrical heat mats are increasingly promoted as an energy-efficient alternative. Zhang & Xin (2000) observed that lamp heat is used significantly more than mat heat for small piglets (< 1.7 kg or 3.7 lb.) and its preference was influenced by the original heat source the piglets had been exposed to (Xin and Zhang, 1999). As piglets grew (2.4 to 5.3kg or 5.3 to 11.7 lb.), they showed a similar preference for lamp and mat heat. Further increase in body size (7.1 kg or 15.6 lb.) shifted the preference to mat heat.

According to Mount, 1968 and Van der Hel et al, 1986, pigs modify their postural behavior in function of their body heat loss in relation to the magnitude of thermal deviation from their thermoneutral zone. When they are feeling cold, they huddle and spread out when feeling hot. Xin and Shao, 2002, found that the best indicator to the environmental adequacy is animals themselves that integrate both external and internal factors. Animals exhibit thermal comfort level by displaying distinctive resting behaviors.
Within the pig industry, individual animal identification is becoming increasingly more important, with respect to health and quality assurance systems (Augsburg, 1990), but animal electronic identification is becoming important for the animal production research to. Several authors such as Artmann (1999), Caja et al. (1999), Kettlewell et al. (1997), Lacey et al. (2000) and Sowell et al. (1998) used transponders to study the behavior and the physiology of domestic animals.

The use of computer imagery, is being implementing the behavior-based approach of assessing and controlling thermal comfort of group-housed swine (Geers et al., 1991; Xin and Shao, 1997). Shao et al. (1997) demonstrated the feasibility of classifying thermal comfort state of young pigs using processed postural images of the pigs as input to a neural network (NN). Xin and Shao, 2002, developed an automated, real –time computer vision system that performs continuous assessment and control of group-housed pigs based on their resting patterns.

The goal of this research is to study the behavior of newborn piglets submitted to different creep heat sources, using different tools to behavior evaluation: electronic identification, imaging analysis and geoestatistical technique.

2. MATERIAL AND METHODS

2.1 Experimental Procedures

This trial was conducted on a commercial swine production farm located in Elias Fausto city, state of São Paulo, Brazil at a latitude of 22^o36'S, longitude of 47^o36W' and altitude of 532 m. The research was set at a farrowing housing, in wintertime, where a total of 80 newborn piglets (Landrace x Large Whirte x Duroc) were used in the study from birth to weaning, totaling 19 days of experiment.

Four creep heat systems were evaluated in this study: Treatment 1: floor heating panel or heated floor; Treatment 2: standard heat lamp; Treatment 3: electric resistance and Treatment 4: infrared lamp. The heated floor system consisted in three boards of vegetable-cement biomass each measuring 0.40 x 0.50 m. At 127V the heat output was 126 W, and the surface temperature of the panel was around 32°C. (Rossi, et al., 2002); The standard heat lamp had 200 W, and was fixed in one of the creep walls, 0.50 m far from the floor; The electric resistance had 200 W, and was fixed just as the heat lamps were; The infrared lamp, had 250 W, and was localized inside the creep like the other heat sources.

The creeps had 1.50 m long, 0.55 m wide and 0.65 m high. The floor of the creep was totally covered with wood bedding. The farrowing room had 23.0 m long, 13.5 m wide, and 2.8 m high. The roof had clay tiles, and was insulated with polystyrene boards. It has an opening area of 90m2, with curtains to close it.

A total of 16 sows were confined inside crates in the farrowing room that was divided in two rows by a central alley. The crates had 2.8m long, 1.7m wide and 1.2m high. Only eight pens were monitored, with ten piglets in each. The treatments, i.e., the different creep heat sources had two repetitions each, as can be seen in Figure 1.
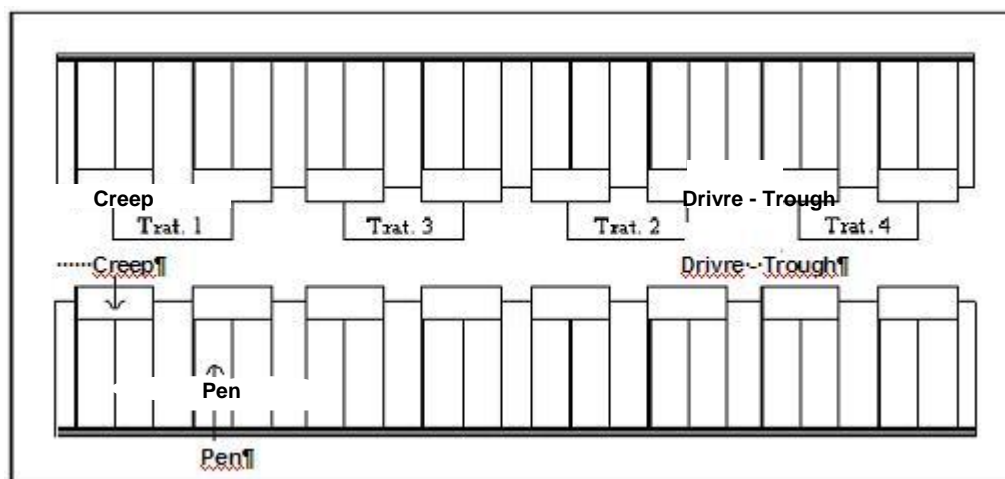
Figure 1. Schematic layout of the treatments in the farrowing house.

2.2 Climatic Variables

The following temperatures were measured: dry, wet bulb and black globe temperatures. They were measured inside and outside the creeps with T termocouples and recorded every 15 minutes on a data logging system. The thermocouples were fixed on the roof of the creeps, 0.55 m above the floor and to measure the climate variables of the farrowing houses, they were placed in the center of the house 1.33 m above the floor.

The surface temperature of the creep floor was taken with an infrared thermometer, in nine points of the floor represented in Figure 2. With these data, was possible to determine a temperature histogram of the creep floor.
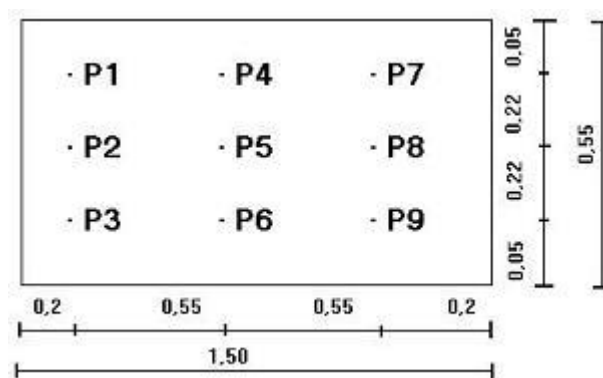
Figure 2. Dimensions of creep floor (in meters) and measurement locations of the floor surface temperature.

Air velocity (VV) data was monitored with a thermal-anemometer (Testo, model 405-V1), hourly, 24 hours a day. Heat load (RHL) and enthalpy (H) were calculated using the following equations:

a) Black globe humidity index (BGHI), according to Buffington et al. (1981):

$$BGHI = Bgt + 0.36Dpt - 330.08$$

Where:

BGHI = black globe humidity index;
Bgt = black globe temperature (K);
Dpt = dew point temperature (K);

b) Radiant heat Load (RHL), developed by Esmay (1979):

$$RHL = \tau(TMR)^4$$

$$TRM = 100\left\{\left[2.51(VV)^{0,5}(Bgt - Dbt) + \left(\frac{Bgt}{100}\right)^4\right]^{0.25}\right\}$$

Where:

RHL = radiant heat load (W/m^2);
TRM = average radiant temperature (K);
VV = air velocity (m/s);
Bgt= black globe temperature (K);

Dbt = dry bulb temperature (K);

$\tau = 5.67 * 10^{-8}$ K^{-4}.W.m^{-2} (Stefan-Boltzmann constant).

c) entalphy (kJ/kg dry air), developed by Albright (1990):

$$H = 1.006Dbt + W(2501 + 1.805Ts)$$

Where:

H = entalphy (kJ/kg dry air);
Dbt = dry bulb temperature (°C);
W = kg of moisture per kg of dry air.

2.3 Zootechnical Evaluation

The animals responses monitored along the trial were: daily weight gain (DWG) and mortality.
a) The DWG was calculated according to the following equation:

$$DWG = \frac{TWG}{ND}$$

Where:

DWG = daily weight gain (kg/dia);
TWG = total weight gain during the research period (kg);
ND = days of trial.

b) The numbers of piglets death were registered daily during the period of the experiment.

2.4 Pigs Behavior Evaluation

The behavior of the piglets was evaluated using the image analysis, electronic identification and geoestatistical techniques.

The video imaging system consisted of video cameras (2.45mm) mounted above each creep and connected to a PC with an Image Capture Board that recorded the behavioral images at 2 minutes. The creeps that didn't have light sources had infrared lads installed to take the images. The images were registered daily, but the only the three days with the lowest value of entalphy ("called critical days"), had the behavior images analyzed, according to the methodology used by Moura, (1997).

Beyond the video imaging system, the electronic identification system was used to analyze the piglet's behavior. The Electronic Identification System (EIS) consisted in a transponder (Trovan, 11,5 x 2,12mm) that was injected inside the ear base of each studied piglet and antennas (Trovan, Model LID 650, 128 kHz) installed in each creep to record the transponder's signals. According to the manufacturer the reading distance of the antenna was 40 – 50cm.

The best body site to inject the transponders in piglets was found in a previous study, Pandorfi (2002). Figure 3 shows the transponder being injected inside the ear base of the pigs.

Figure 3. Injection of the transponder in the piglet ear base.

A detail of the transponder could be seen in Figure 4. Figure 5 shows the electronic identification system and the video imaging system installed inside a creep.
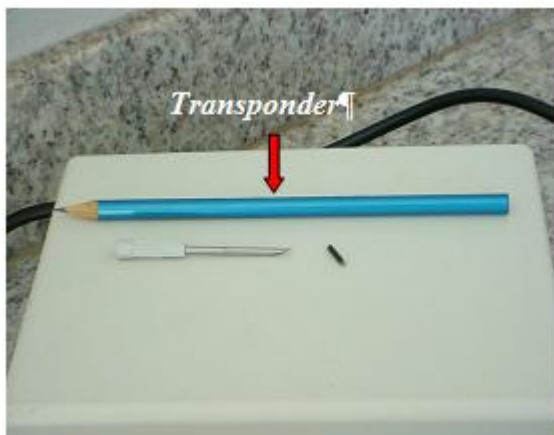

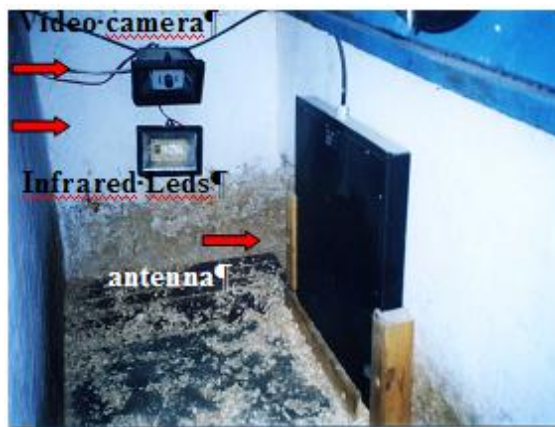| Figure 4. Photograph of the transponder used in the EIS. | Figure 5. Video camera, infrared leds and the antenna installed inside a creep. |

Using the video image and the electronic identification, was possible to verify, the time the piglets spend in each heating system and their frequency of use.

A geoestatistical analysis was done to analyze the piglet's behavior in relation to the distribution of the floor temperature in each studied creep. The software Surfer was used to make this analysis.

2.5 Economical Analysis

The economical analysis was done monitoring the amount of energy used by each treatment (kWh) during all period of study (19 days). The cost-benefit analysis was calculated according to the kWh cost, the weight gain of the animals, associated with the swine meet costs.

3. RESULTS AND DISCUSSION

3.1 Climatic Data

Analyzing the ambient temperature monitored inside the creeps at the moment of the daily minimum temperature, Figure 6 shows the influence of the different heating systems on the temperature of the creeps, during all studied period. This figure was divided in three parts, corresponding to the first, second and third weeks of trial. It can be observed that only the standard heat lamp and the electrical resistance reached on the first and second week the desired comfort level temperature for the animals, 28 to 32° C. (Silva, 1999). The floor-heating panel only reached the desired temperature level on the third week of trial.

The infrared lamp exceeded the desired temperature levels in all weeks, reaching temperature values of 38° C.
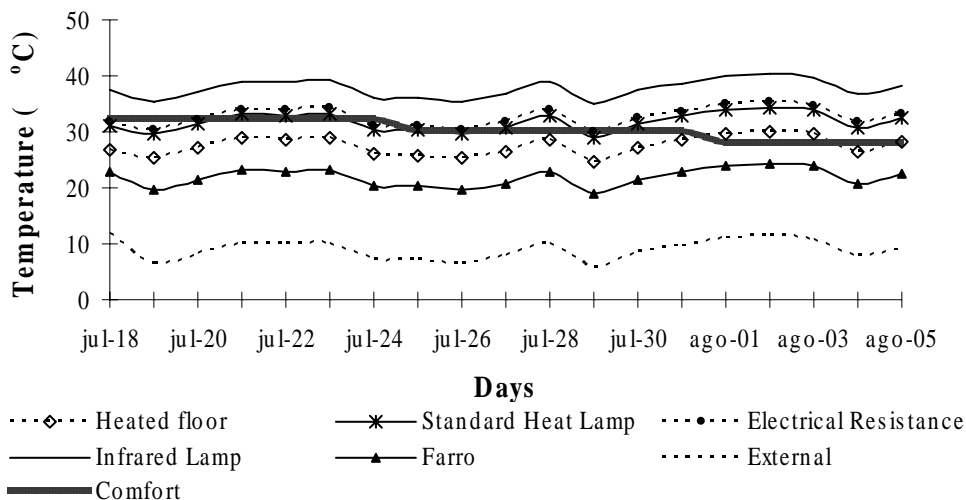

Figure 6. Effect of Minimum daily temperature average in different treatments, external (outdoor), comfort (animal thermal comfort), farro (farrowing house-indoor).

Analyzing only the days with the lowest enthalpy value, the "critical days" it was verified that both standard heat lamp and the electrical resistance, presented the better environment for weaning piglets. (Figure 7). The infrared lamp and the floor-heating panel presented temperatures above and under the recommendations for this piglets stage, 32 a 28° C, respectively (Perdomo et al., 1987).
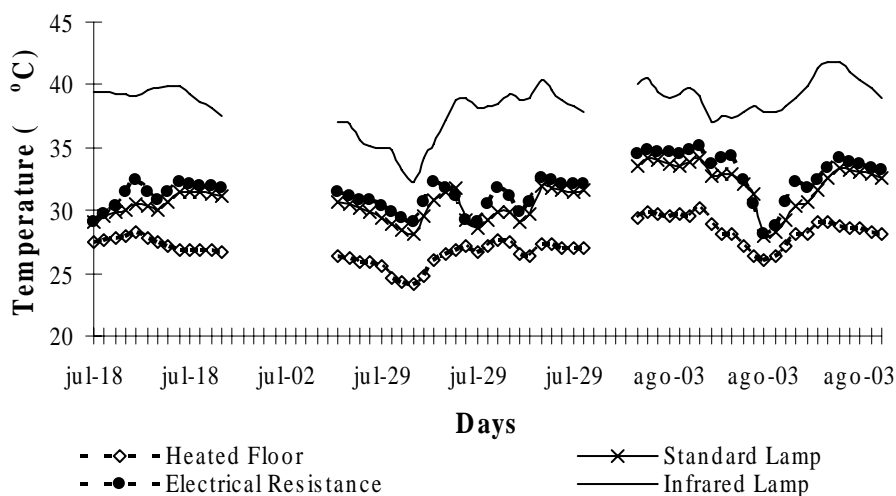

Figure 7. Temperature variation in lowest enthalpy days for the different treatments.

The averages of BGHI, obtained at the days with the lowest entalphy values for the three weeks of study are showed in Figure 8. It can be seen that the creeps with standard heat lamps and electric resistance, presented the BGHI values closest to the ideal level, 82 to 84 (Necoechea, 1986). Once again, the infrared lamp and the floor-heating panel presented values of BGHI above and under the ideal levels, respectively.
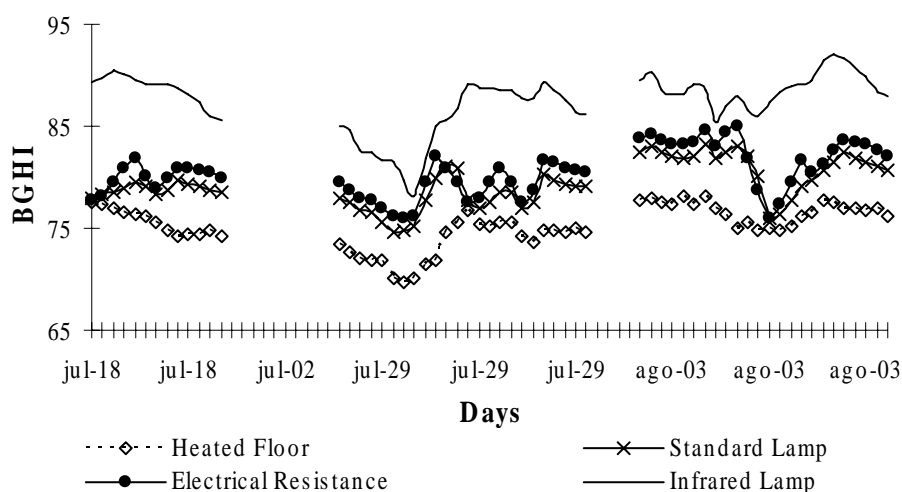

Figure 8. BGHI variation in lowest enthalpy days for the different treatments.

Analyzing the THL calculated values, for the critical days, it was verified that the floor heating panels, presented the THL closest to the recommended value, $450 W/m^2$ (Baêta e Souza, 1997). The average THL of the other heating systems exceeded the ideal value, as it can be seen in Figure 9.
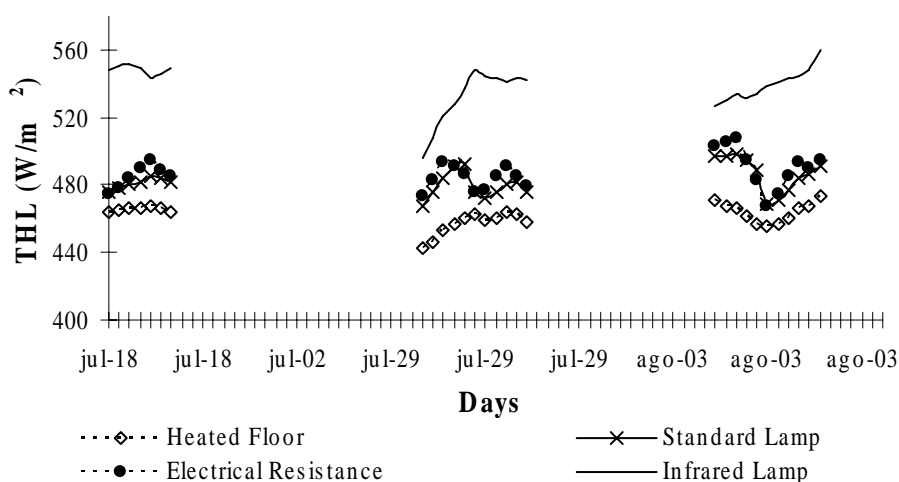

Figure 9. THL variation in lowest enthalpy days for the different treatments.

Neither of all studied heating sources, reached the ideal value of enthalpy for the piglets first week (90,2 kJ/kg of dry air). The infrared lamp had the highest value of enthalpy, as it happens with temperature and BGHI data. For the second week, the most efficient treatment was the electrical resistance that presented the enthalpy values closest to the recommendable value 81,6 kJ/Kg of dry air. For the last week, the standard lamps and electrical resistance were the treatments that reached the ideal conditions of piglet's comfort (73,8 kJ/Kg of dry air). The enthalpy average values founded in the floor-heating panel creep, were smaller than the predicted ideal values in all weeks of study as can be seen in Figure 10.
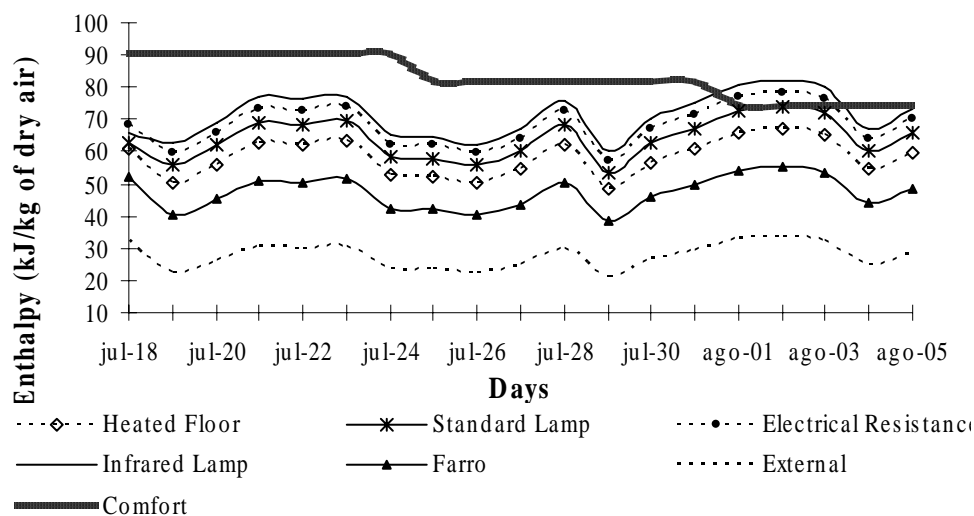

Figure 10. Enthalpy averages variation in all studied period.

Considering the amount of heat contained in each kg of dry air, none of the treatments was efficient for the piglets heating, mainly on the first and second weeks of life. On the third week, all the heating systems, reached the comfort conditions for the animals, unless the floor heating panel.

3.2 Piglets Behavior

To analyze the frequency of creep usage, the days with the lowest enthalpy were used. Among the critical days, day 08/03/2002 that has the lowest enthalpy was chosen to analyze the individual and hourly frequency of creep usage. This day correspond to the third week of piglets life.

According to Figure 11 (a), (b), (c), and (d) it can be seen that the frequency of creep usage was directly related with temperature variations. As can be seen, when the farrowing temperature reaches its minimum, the piglet's usage to creeps is maximum.
Despite the lowest values of temperature, enthalpy, and BGHI that the creep with floor heating panel presented, it had the greatest usage of pigs during all day, as is shown in Figure 10. Following the floor-heating panel, the analysis of pig usage, showed the electrical resistance, the infrared lamps and at least the standard lamps.
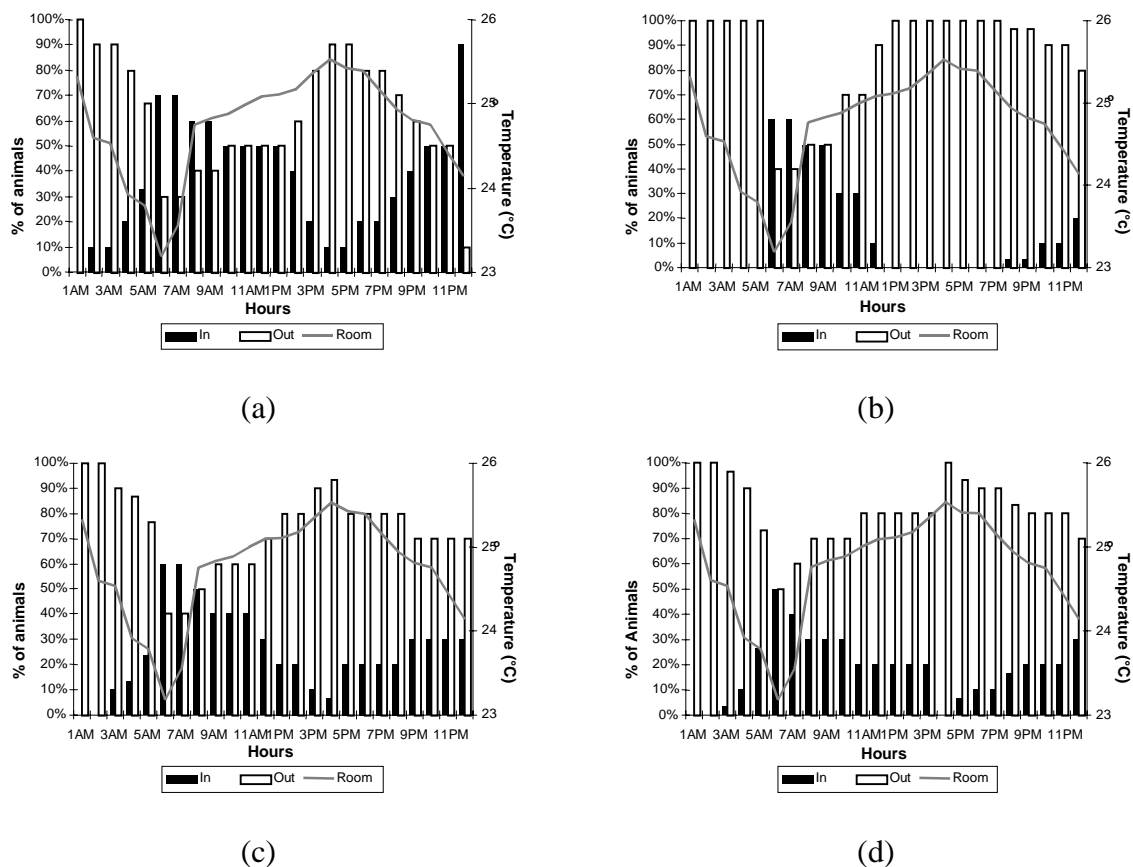
(a)

(b)

(c)

(d)

Figure 11. Frequency of pig usage in creeps in relation with room temperatures, for the critical day, 08/03/2002. Being: a - heated-floor, b - standard lamps, c - electrical resistance and d – infrared lamps.

Based on the percentage of animals inside creeps for the critical day, in function of the farrowing house temperature, regression equations were derived for each treatment. The equations are presented in Table 1.

Analyzing the equations it can be seen that the infrared lamp and the heating-floor panel, were the ones that best represent the ideal conditions for the piglets at this week of study.

Table 1. Regression equations fitted for the % of animals inside creeps, in function of the farrowing house temperature in the critical day.

Treatments	Equations	R^2
Heatin-Floor	y = -0,1342 x + 3,5299	0,9554*
Standard Lamp	y = - 0,1411 x + 3,5405	0,9124*
Electrical Resistance	y = - 0,1043 x + 2,6624	0,9055*
Infrared Lamp	y = - 0,1178 x + 3,0462	0,969*

* Significantly at 1% of probability

H. Pandorfi and I. da Silva. "Evaluation of the Behavior of Piglets in Different Heating Systems using Analysis of Image and Electronic Identification". Agricultural Engineering International: the CIGR Ejournal. Vol. VII. Manuscript BC 03 021. August, 2005.

Analyzing the time that the piglets spend inside the creeps, using both the electronic identification and the imaging analysis techniques, it was observed that the use of the systems was significantly influenced by the environmental conditions of the farrowing house for the three weeks of piglet's life. The creep with the floor-heating panel had the highest piglets permanence time inside it. As can be seen in Table 2, the time of piglet's permanence was also high inside the creeps with electrical resistance and infrared lamp. The standard lamp, had the lowest time of piglet's permanence especially on the third week, when the temperature requirements of the piglets were lower than the first weeks.

Table 2. Percentage of piglet's permanence inside the creeps for the different tested heatins systems.

Days	Tm (°C)	H (kJ/kg)	Percentage (%) of permanence of total time							
			Heated-Floor		Standard Lamp		Electrical Resistance		Infrared lamp	
			In	Out	In	Out	In	Out	In	Out
07/18	24,5	53,1	83	17	74	26	48	52	78	22
07/29	24,1	52,5	83	17	52	48	65	35	87	13
08/03	25,8	55,3	100	0	43	57	96	4	87	13
Average Values			89	11	56	44	70	30	84	16

Where Tm = average temperature and H = average enthalpy;

Considering that the heating systems remained on, during all the experimental period, the heating-floor panel system presented the best environmental conditions for the animals showing the greatest frequency of piglet's usage and the highest time of piglet's permanence. In heated floors the heat energy is passed almost directly (by conduction) from the heating element to the piglets, transfering energy much more effectively than by radiation flow. The surface temperature reached by the heated floor was 30 to 32° C. These results are different than the found by Zhang & Xin, 2000, where the heat mat surface temperature was close to 37° C, promoting a low heat mat usage when compared to standard lamp.

Using the video camera images and the data of floor surface temperature it was possible to associate the position of the pigs and the pattern of creep floor temperature distribution. This analysis was done for the most critical day 08/03/2003. The software "surf" was used to draw the isothermal lines, of the creep floor temperature.

The Figures 12 to 15 (a), the images captured by the video cameras, inside all the creeps, at 8 AM and 4PM, when the minimum and maximum temperature occurs inside the farrowing house, respectively 24,7° C and 25,5° C. Figures 12 to 15 (b) shows the postural behavior of the piglets in function of the floor surface temperature, where can be seen the isothermal lines.
According to Figure 12 (a), it is observed that for the lowest temperature hour, all the piglets remain positioned on the region of the highest temperature level, between 29,7 e 30,7° C. In the same way it is noted that at the hour of the maximum room temperature 71% of the piglets

remain located between the floor area with 29,6 to 30,6° C, and 29% on the areas with floor temperature around 28° C.

Using the geoestatistical analysis it was possible to study the thermal efficiency of the different heating systems in relation to the pattern of temperature distribution among the creep floor.
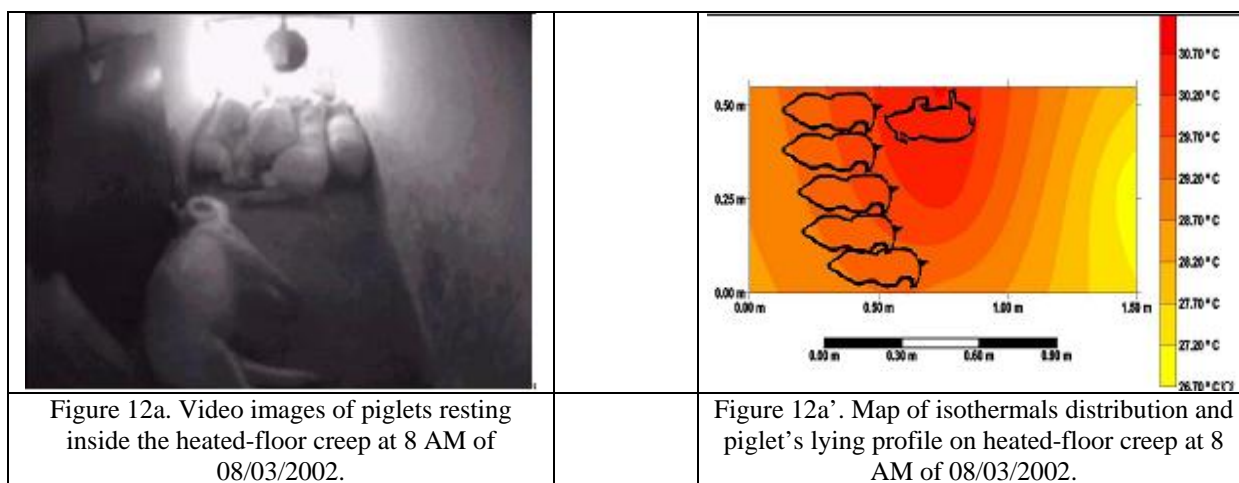Comparing the creeps with standard lamps and the electrical resistance, it is observed that the floor temperature decreased with the distance from the heating source (Figures 13a, 13b, 13a', 13b', 14a, 14b, 14a', 14b').
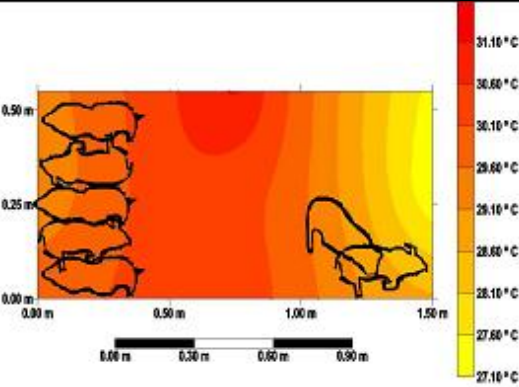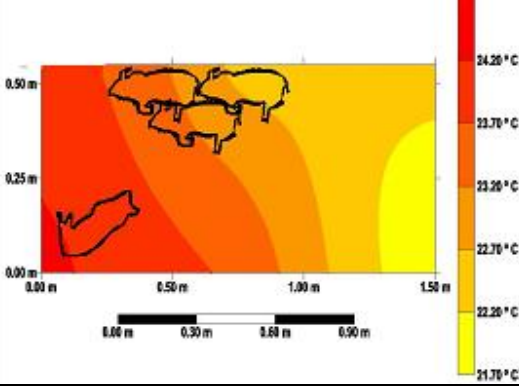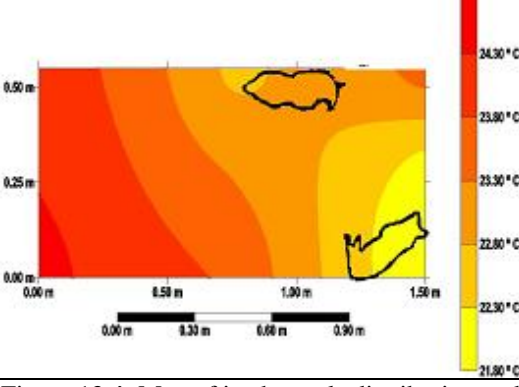
This behavior is also noted in the creep with the infrared lamp, however it is observed that the floor temperatures of this creep were lower than the required ones. It is fact that the convective process is modified in function of the movement of the air inside the creep, what may influence in the distribution of the isotherms.
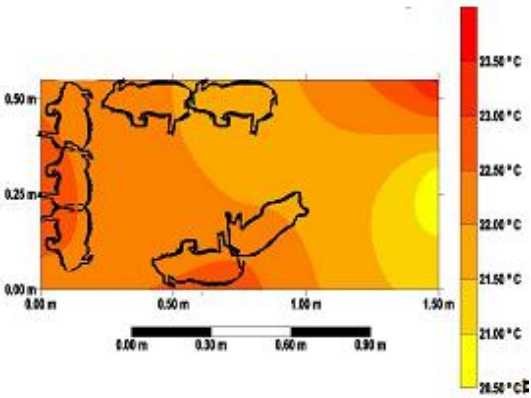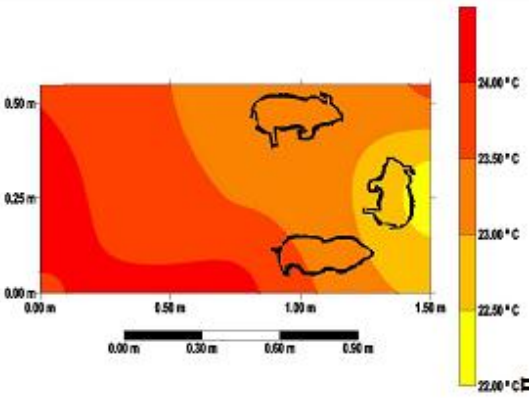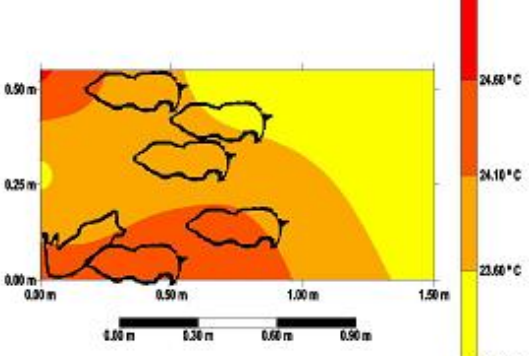
It was observed that the distribution of the temperature on the heated floor surface was more uniform, than the others heat sources, what agree with the piglet's behavior results.
This effect can be explained by the conductive efficiency of the thermal floor and by the thermal requirement of the animals. It must be considered, that the analysis was carried through the 3rd week of animals life.

Observing the profile of piglet's distribution inside the creeps, it is verified in general that, for all the evaluated treatments, that the animals had the tendency to remain next the heat source, at the lowest temperature hour. In the other hand, at the maximum temperature hour, the profile of piglet's distribution was inverted and they remain far from the heat source.

Figure 12a. Video images of piglets resting inside the heated-floor creep at 8 AM of 08/03/2002.

Figure 12a'. Map of isothermals distribution and piglet's lying profile on heated-floor creep at 8 AM of 08/03/2002.

Figure 12b. Video images of piglets resting inside the heated-floor creep at 4 PM of 08/03/2002.	Figure 12b'. Map of isothermals distribution and piglet's lying profile on heated-floor creep at 4 PM of 08/03/2002.
Figure 13a. Video images of piglets resting inside the standard lamp creep at 8 AM of 08/03/2002.	Figure 13a'. Map of isothermals distribution and piglet's lying profile on standard lamp creep at 8 AM of 08/03/2002.
Figura 13b. Video images of piglets resting inside the standard lamp creep at 4 PM of 08/03/2002.	Figure 13a'. Map of isothermals distribution and piglet's lying profile on standard lamp creep at 4 PM of 08/03/2002.

Figure 14a. Video images of piglets resting inside the electrical resistance creep at 8 AM of 08/03/2002.		Figure 14a'. Map of isothermals distribution and piglet's lying profile on electrical resistance creep at 8 AM of 08/03/2002.
Figure 14b. Video images of piglets resting inside the electrical resistance creep at 4 PM of 08/03/2002.		Figure 14b'. Map of isothermals distribution and piglet's lying profile on electrical resistance creep at 4 PM of 08/03/2002.
Figure 15a. Video images of piglets resting inside the infrared lamp creep at 8 AM of 08/03/2002.		Figure 15a'. Map of isothermals distribution and piglet's lying profile on infrared lamp creep at 8 AM of 08/03/2002.

Figure 15b. Video images of piglets resting inside the infrared lamp creep at 4 PM of 08/03/2002.		Figure 15b'. Map of isothermals distribution and piglet's lying profile on infrared lamp creep at 4 PM of 08/03/2002.
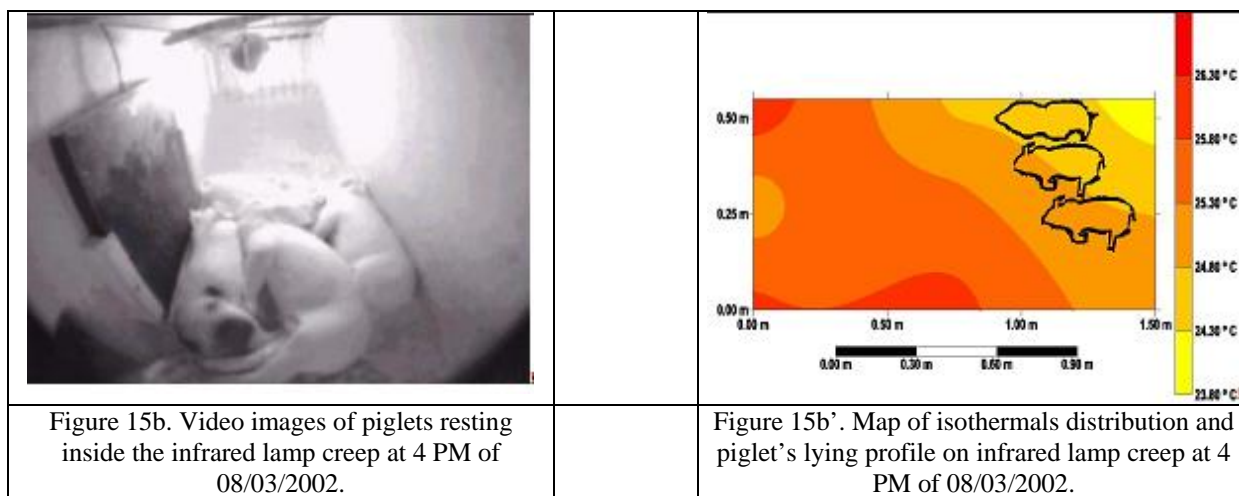
3.3 Piglet's Performance

The average of piglet's daily weight gain (DWG) for each treatment is showed in Figure 16. All the evaluated treatments had exceeded the desired DWG of 0.240kg, according to Moraes, 1993. The pigs have born with a weight average of 1.8 kg and have weaned with 6.4 kg in average, with 19 days of life.
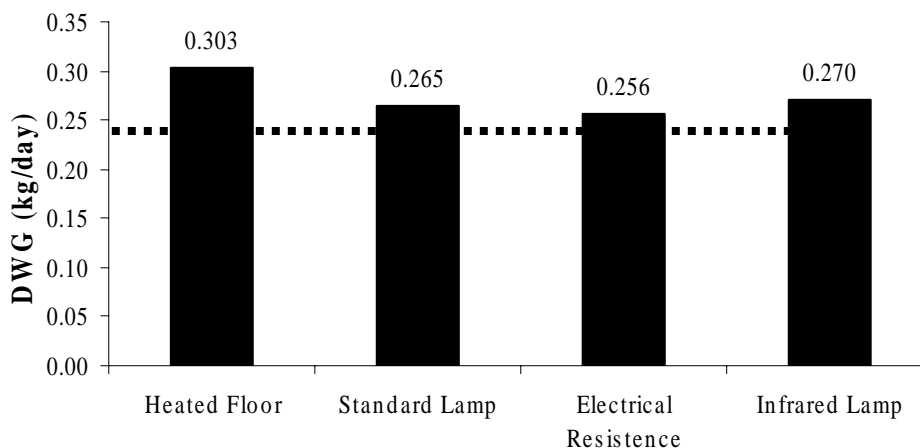

Figure 16. Piglet's daily weight gain (DWG) in kg/day for the different treatments.

The creep with the heated-floor presented the greater value of piglet's daily weight gain, 0.303 kg/day, followed by the infrared lamp, the standard lamp, and at least the electrical resistance. It can be observed a relationship within the animal behavior, the thermal environment and the piglet's performance. It can be observed the influence of the animal's welfare in their performance, affecting the DWG of the animals. It wasn't observed any piglet's death among the treatments.

3.4 Energy Usage

The heat sources remained in operation 24 hours/day. The electricity energy usage of the different treatments, can be seen in Figure 17. The heated-floor clearly show higher energy usage throughout the study, different that founded by McDonald et al, 2000. It's energy usage was 48, 49 e 34%, higher than the usage by the standard lamp, electrical resistance and infrared lamp, respectively. Sensors as thermostats and creep controls surely will decrease these energy usage, in almost 35% (Bird, 2001), reducing the costs of heated pad usage.

Table 3, shows the costs, in relation to the electrical energy usage for the studied heat sources. Considering a cost of U$ 0,03/kWh, for the agricultural zone (CPFL –11/05/2002), the total weight gain of the piglets for the different treatments, and the price of the live weight of the pigs around U$ 2,16/kg (values for November 2002) according Porkworld, 2002.
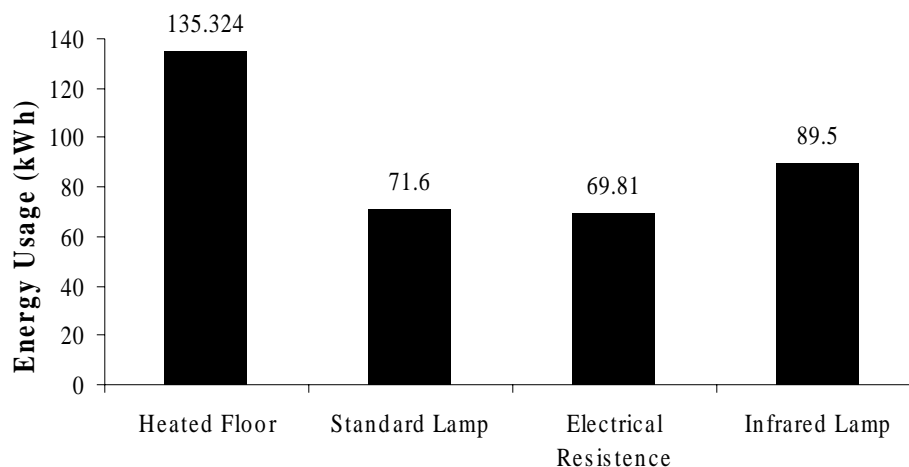

Figure 17. Electrical energy usage for different heat sources.

Table 3. Total cost (U$), of the electrical energy usage (kWh), for the different evaluated heating systems and their total income (U$).

	Treatments			
	HF	SL	ER	IL
Energy (kWh)	135.3	71.6	69.8	89.5
Energy Cost (U$)	5.05	2.67	2.60	3.35
TWG (kg)	5.76	5.03	4.86	5.13
LWP (U$)	12.45	10.87	10.51	11.08
Income (R$)	7.40	8.2	7.9	7.72

HF – heated floor; SL – standard lamp; ER – electrical resistance;
IL – infrared lamp; TWG – total weight gain; LWP – live weight price.

The creep with the standard lamp showed the best income (U$8.2) around 9.72% greater than the heated-floor, 3.6% upper than the electrical resistance and 5.76% than the infrared lamp. These results showed that the treatment with the standard lamp had the lowest heating cost.

4. CONCLUSION

Despite the heated-floor presented the lowest values of climatic data such as temperature and thermal comfort indexes inside the creeps, it showed the best performance of the piglets. The heated floor had the greatest frequency and time of usage, showing the efficiency of the energy transference by conduction.
It also may be concluded that an electrical control for the energy sources is need to save energy, and turn the heated – floor more economical, in terms of energy usage and its payback.

5. ACKNOWLEDGEMENTS

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