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EVALUATION OF BEHAVIOR IN PIGLETS USING DIGITAL IMAGE PROCESSING

FLAVIO ALVES DAMASCENO[1], CLÁUDIO MAGELA SOARES[2], CARLOS EDUARDO ALVES OLIVEIRA[3], LEIDIMAR FREIRE BRANDÃO DAMASCENO[4] e PATRICIA FERREIRA PONCIANO FERRAZ[5]

[1] *Departamento de Engenharia, Universidade Federal de Lavras – Av. Dr. Sylvio Menicucci, 1001, Kennedy, 37200-000, Lavras, Minas Gerais, Brasil. E-mail: flavio.damasceno@ufla.br*
[2] *Campus Anápolis de Ciências Exatas e Tecnológicas Henrique Santillo, Universidade Estadual de Goiás – BR 153, nº 3105, 75132-000, Anápolis, Goiás, Brasil. E-mail: claudiomagela@gmail.com*
[3] *Departamento de Engenharia, Universidade Federal de Lavras – Av. Dr. Sylvio Menicucci, 1001, Kennedy, 37200-000, Lavras, Minas Gerais, Brasil. E-mail: carloseaoliveira@hotmail.com*
[4] *Departamento de Engenharia Civil, Universidade Federal de Ouro Preto – Rua Prof. Paulo Magalhães Gomes, 122, Bauxita, 35400-000, Ouro Preto, Minas Gerais, Brasil. E-mail: leidimarbrandao@gmail.com*
[5] *Departamento de Engenharia, Universidade Federal de Lavras – Av. Dr. Sylvio Menicucci, 1001, Kennedy, 37200-000, Lavras, Minas Gerais, Brasil. E-mail: patricia.ponciano@ufla.br*

ABSTRACT: World production of pork has increased in recent years, and currently Brazil is the fourth largest producer. One of the major challenges in animal production systems is providing adequate thermal comfort. In the pork industry, the lactation area presents a peculiar environmental requirement: the lactating sows need to be cooled while the piglets need to be heated, requiring two distinct microenvironments. Thus the objective of this study was to evaluate the behavior of piglets using digital image analysis techniques, detecting the presence and calculating the time of the animals inside the shelter equipped with different types of heating system. The study was conducted during the summer of 2015, in a swine maternity, where four different heating systems were used: a) shelter equipped with 250 W infrared light (SALI); b) shelter equipped with heated concrete floor heating by means of solar water heater constructed with alternative materials (SASA); c) shelter equipped with heated concrete floor heating by conventional solar water heater (SASC) and d) retractor shelter equipped with thermal concrete floor heating by means of electric resistance (SAEL). During the study, the environmental variables were monitored inside the shelter. A sequence of images of the piglets was used to evaluate the behavior of the animals. The algorithm developed was able to detect the presence of the piglets, and thus reduce the time for manual analysis of video monitoring.

Keywords: Thermal comfort, swine, segmentation

AVALIAÇÃO DE COMPORTAMENTO DE LEITÕES UTILIZANDO PROCESSAMENTO DIGITAL DE IMAGENS

RESUMO: A produção mundial de carne suína vem crescendo nos últimos anos, sendo que atualmente o Brasil é o quarto maior produtor. Um dos grandes desafios na produção é o conforto térmico dos animais. Na suinocultura, a maternidade é onde encontra-se o maior problema, pois a porca necessita ser resfriada e o leitão aquecido, necessitando de dois microambientes diferentes. Objetivou-se com o presente trabalho, avaliar o comportamento de leitões por meio da análise de imagem, detectando a presença e calculando o tempo de permanência dos animais dentro do abrigo escamoteador equipado com diferentes tipos de sistema de aquecimento. Todo o estudo foi conduzido durante o período de verão de 2015, numa maternidade de suínos, onde instalou-se quatro diferentes sistemas de aquecimento: a) abrigo escamoteador equipado com lâmpada infravermelho de 250 W (SALI); b) abrigo escamoteador equipado com piso térmico de concreto aquecido por meio de tubos de água quente construído com materiais alternativos (SASA); c) abrigo escamoteador equipado com piso térmico de concreto aquecido por meio de tubos de água quente convencional (SASC) e d) abrigo escamoteador equipado com piso térmico de concreto aquecido por meio de resistência elétrica (SAEL). Durante o estudo, foram monitoradas as variáveis ambientais no interno ao abrigo escamoteador. Para avaliar o comportamento dos animais foram utilizadas a técnicas de

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processamento de uma sequência de imagens dos leitões. O método de avaliação por imagens digitais mostrou-se viável na avaliação do comportamento dos leitões, diminuindo o tempo de análise manual da monitoração por vídeo.

Palavras-chaves: conforto animal, suíno, segmentação de imagem

1 INTRODUCTION

Pig farming is an activity that requires a lot of dedication from the breeder to achieve good productivity levels and, consequently, satisfactory economic results. External environmental factors and the microclimate inside the premises have direct and indirect effects on pig production, leading to reduced productivity, with consequent economic exploitation losses (PANDORFI et al., 2008). The productive and reproductive performance of pigs depends on the management system employed, which involves the system of nutrition, health and facilities chosen for breeding. These facilities, which require a larger initial fixed investment, are built on the basis of cost and management of facilities, the comfort of the animal being neglected (TOLON; NÄÄS, 2005).

In the case of the farrowing house, this problem is evidenced by the coexistence in it of two categories with very different environmental requirements. On the one hand is the sow which must be cooled, and, on the other hand are the piglets, which must be heated. The range of thermal comfort environment for the piglets during the first days of life is between 32 and 34 °C and that for the sow is in the range of 16 to 21 °C (PERDOMO et al., 1987).

The solution of this problem, present in all pig farms, is a priority when seeking to improve the performance of both categories. Thus, within the principles of thermal comfort and animal welfare, the producer is faced with a major problem, where, in a small physical space, it is required to provide two different microenvironments where otherwise the performance of both the sows and piglets would be compromised (PANDORFI; SILVA, 2005).

For the thermal comfort of piglets, a creep feeder is maintained, sealed and heated by electric lamps or resistance heating, seeking to maintain the Black Globe Humidity Index (BGHI) in its interior between 82 and 84, while in the rest of the farrowing house BGHI should not exceed 72 (NECOECHEA, 1986).

An extensive field to be researched and discussed is the animal's behavior as an indicator of well-being in a production system. Evaluation and interactive control of the thermal comfort of pigs by image analysis overcomes the problems inherent in the conventional method because the animal itself is used as a biosensor in response to environmental consequences through behavioral analysis (XIN; SHAO, 2001).

Thus, for the collection of information on the behavioral aspects the most widespread and widely used technique has been the use of video cameras to permanently film and record the behavior of animals. This technique allows the monitoring of animals in a relatively simple manner and with less interference of the presence of man in the behavior of animals.

According to Araújo et al. (2011), image analysis can be an efficient technology as a tool to study animal behavior. In addition to this, Alves, Silva and Piedade (2007) noted that this technique of observation and animal behavior analysis is a non-invasive method for monitoring the conditions. It allows studying how animals interact with others and the breeding environment, providing information on their social and environmental preferences.

In Brazil, the technique of video image analysis has been used successfully to study animal behavior in the areas of cattle (MATARAZZO et al., 2006), swine (SOUSA et al., 2014; ARAÚJO et al., 2011; PANDORFI; SILVA, 2005; PANDORFI et al., 2008) and poultry (CORDEIRO et al., 2011; SOUZA et al., 2013).

Based on the above, the aim of the present study was to evaluate the behavior of piglets through image analysis, detecting the presence and calculating the time of residence within the creep feeder equipped with different types of heating system.

2 METODOLOGY

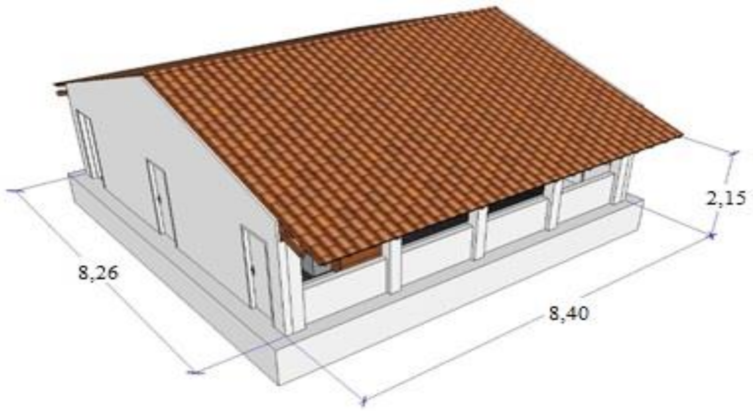
2.1 Farrowing house characterization

The entire study was conducted during the 2015 summer period, in a farrowing house of the experimental center in pig farming at the Federal University of Lavras, in Lavras – MG, Brazil, located at 21° 14' south latitude, 40° 00' of longitude west of Greenwich, at an altitude of 918.84 m with an average temperature of 19.4ºC, average annual rainfall of 1529.7 mm and 76.2% relative humidity.

The farrowing house used in this experiment had the following design characteristics: dimensions of 8.26 m wide and 8.40 m long, ceiling height of 2.15 m, gable roof, structured in wood and covered with ceramic tiles. Five pens were installed within it 1.80 m long by 1.35 m wide, connected to the wooden creep feeders 1.00 m long by 0.68 m wide (Figure 1).

A fan/nebulizer was installed inside the farrowing house. Within it the five similar pens were installed, 1.80 m long by 1.35 m wide, connected to the wooden creep feeders 1.00 m long by 0.68 m wide.

Figure 1. Schematic drawing of farrowing house evaluated in this study with the main dimensions (in meters).



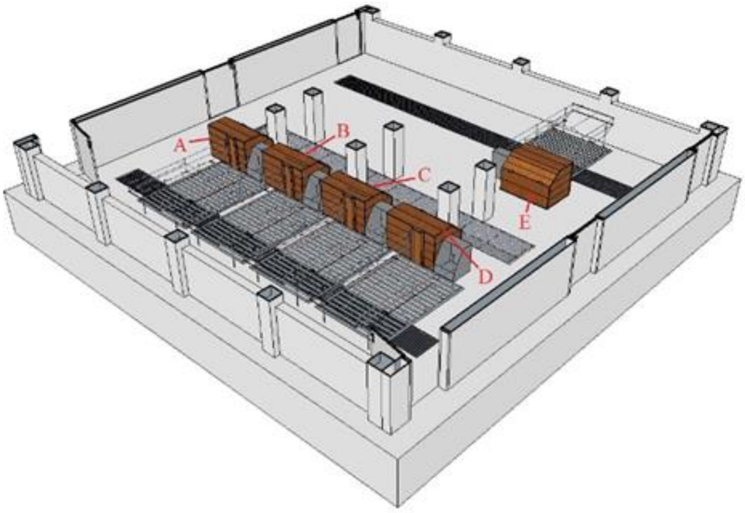
2.2 Construction and installation of heating systems

In the pig farrowing house evaluated in this study, four different heating systems were installed: a) creep feeder equipped with infrared lamp of 250 W, fixed in the ceiling of the shed at a height of 0.50 m from the floor (ILH); b) creep feeder equipped with thermal concrete floor heated by hot water pipes constructed of alternative materials (ASWH); c) creep feeder equipped with concrete thermal floor heated by conventional hot water pipe (CSWH) and d) creep feeder equipped with concrete thermal floor heated by means of electrical resistance (ERH). Distributions of heating systems can be seen in the diagram in Figure 2.

The conventional solar water heating system (CSWH) had a glass plated solar collector, made of aluminum, with internal fins painted in matte black to absorb sunlight and transfer it to the internal piping. The components of the thermal reservoir had internal cylinder and pipes manufactured with stainless steel and rigid expanded polyurethane.

The prototype solar water heaters manufactured with alternative materials (ASWH) were built with PVC pipes and connections (1/2" diameter), PET bottles and milk cartons (Tetra Pak®). The milk cartons were painted matte black to absorb heat, and keep it retained within the cylinders in which it is transferred to water through the PVC pipe which were also painted matte black. In the construction of the alternative solar heater prototype 60 2-liter bottles of transparent polyethylene terephthalate (PET) were used. The milk cartons were opened on the upper and lower part, in which all the boxes were cut using a cutting jig proposed by CELESC (2010).

Figure 2. Schematic drawing of the distribution of different heating systems within the farrowing house. Caption: A - ILH, B - ASWH, C - CSWH, D - ERH and E - Control.



In an alternative construction of the hot water reservoir, a 50-liter fiberglass water box was used, coated with polystyrene plates (30 mm), Silver Tape and self-adhesive asphalt and aluminum blanket (2.5 mm) to protect the polystyrene plates from the weather. In the reservoir four holes were made of 20 mm each, with two holes for circulation of water between the thermal reservoir and the solar collector and the other two holes for water circulation from the heat reservoir to the floor.

In the ERH system heater cables were distributed within a masonry floor, and the temperature was controlled by means of an analog thermostat (100 W).

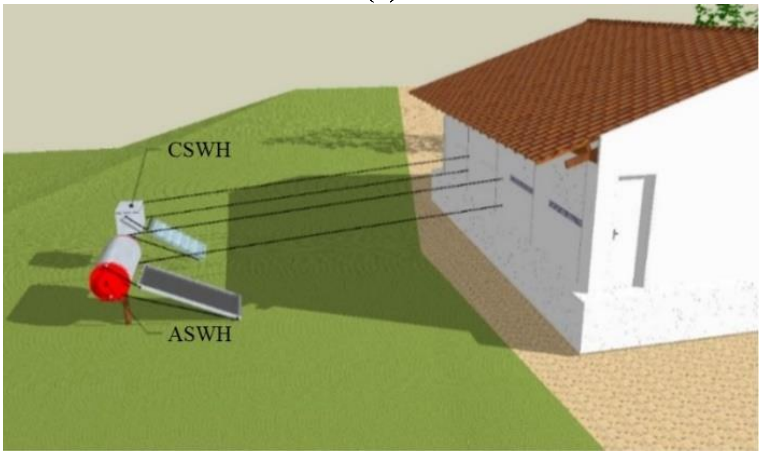
Three masonry floors have been built of dimensions 74 cm long, 46 cm wide and 7 cm thick to test the two water heating systems. To reduce heat dissipation at the base of the floors, we used 30 mm polystyrene plates. In the two floors a 20 mm galvanized steel pipe was placed, forming a coil, aiming at uniform distribution of heat from the water inside the floor. Heater cables were installed in the third floor controlled by means of an analog thermostat.

The two solar collectors and water tanks were distanced from the farrowing house by about 10 m to avoid shading (Figure 3). A low flow water pump (mod. ZC-T40, of 12V and 1.05A) was used in each system to force the circulation of water within each system. On each floor a controlled digital controller (thermostat) was used, designed for solar heating applications, which operated to control water flow through the temperature differential between the floor entrance and the thermal reservoir.

The pigs used in this study were from sows of the same order of delivery and were equalized in order to eliminate interference factors, maternal ability, number of piglets/litter, etc. Each pen presented between 8 to 12 piglets which, after birth, were to be relocated by criteria of weight and number of animals so that all the shelters studied remained with a number fixed between 8 and 12 piglets.

Figure 3. (a) Functional diagram of the thermal floor and (b) detail of the concrete floor inside the creep feeder.

(a)



(b)

2.3 Measurement and instrumentation

During all stages of this study, the environmental variables were monitored in the interior of the creep feeder, in the environment internal to and external to the farrowing house, through sensor/recorder systems with automated registration of the following variables that make up the thermal environment: dry bulb air temperature (t_{db}), Relative humidity (RH) and air velocity (V_{air}).

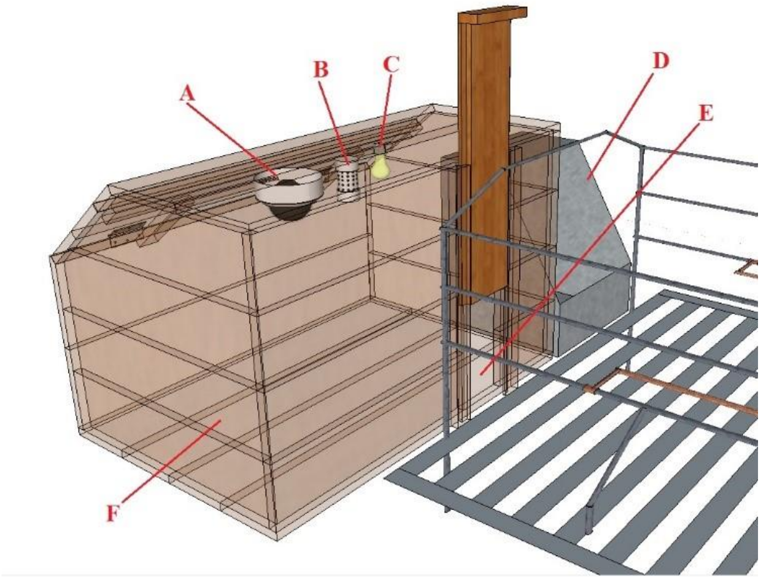
The registration of these environmental variables was performed every 10 minutes for 24 hours daily for the first 21 days of life of the piglets.

Sensors/registers of t_{db} and RH (Hobo® Mod. U12-012 and accuracy of ± 2.5%) were housed inside a perforated container guard, to prevent damage to equipment caused by piglets or excess moisture, and, therefore, the readings were compared to another external sensor protection, to verify any interference of the protection in the reading of the equipment (Figure 4). The air velocity (V_{air}) is manually measured by means of a hot-wire anemometer (Testo® Mod. 416, resolution of 0.1 $m.s^{-1}$).

In the creep feeder, sensors/registers are fixed in the cover of the creep feeder at a distance of 0.5 m from the floor approximately. In the farrowing house, the environmental variables were recorded within the facility, in the center of the pens that will be studied at a height of 1.3 m from the floor, approximately. Outside the premises, sensors/recorders were installed inside of a weather shelter, 1.5 m height from the surface, which represent the microclimate of the site.

To evaluate the behavior of animals (frequency and time of stay in the creep feeder) techniques were used for processing a sequence of images of the piglets confined within each creep feeder. The images were collected using a CCTV kit (Intelbras®, 8-channel HD of 1.0 terabyte) and four micro cameras with infrared (Intelbras® 1000 lines of resolution, 3.6 mm CCD lens, 1/3” CCD sensor and 512 x 492 pixels resolution), which allowed images to be obtained in creep feeders even when there was no light source (Figure 5). However, the installation of a LED lamp (15 W) next to the miniature camera was necessary because it was observed that the animals were not coming inside the creep feeder, perhaps due to fear of entering a dark environment.

Figure 4. Assembly diagram of systems for monitoring images and environmental conditions inside the creep feeder. Caption: A - miniature camera; B – perforated protective container with sensors/ registers; C - LED lamp; D - feeder; E - creep feeder entrance; F - creep feeder.



Analyses were recorded at 30 minutes intervals for six different times of day (4:00, 8:00, 12:00, 16:00, 20:00 and 24:00h) and stored in the HD CCTV kit for further analysis.

For a better understanding of the behavior of piglets that were analyzed in the images from the interior of creep feeders, the average percentage was calculated of the number of piglets performing each activity analyzed in the 24 hour period.

For image pre-processing threshold techniques (binarization) were used which convert images from grayscale to binary images from the Image Processing Toolbox and MATLAB® 2006. Thus, images are all binarized and subtracted in pairs for motion detection between images.

For each image, the Pearson correlation coefficient between the succeeding image and that immediately preceding it is calculated, to get the degree of similarity between them, and the values of correlation coefficient will cover the range of –1 to 1.

For the calculation of behavioral variables, $R = 1 - r$ is used to calculate how much the images are different, indicating movement from one image to another (ROSNER et al., 2006; BORGES et al., 2010). If $r = 1$, the correlation is perfect, the images are the same, so there was no activity, because $R = 1 - 1 = 0$. Thus, it follows that R is the activity level that varies from 0 to 1.

In the preprocessing stage, the background image and the frame in question were modified from RGB to grayscale. The background image was determined to be the video frame in which there was no presence of piglets in the creep feeder, as shown in Figure 5a. Segmentation and thresholding techniques (binarization) were used for the processing of the images, which convert images from grayscale to binary images. Thus, the following images were subtracted from the background image and binarized. The result of using this technique can be seen in Figure 5b.

Binarization is converting a grayscale image to an image with only two colors. In the binary image all the input pixels with higher luminance value are replaced with 1 (white), and all other pixels are replaced with value 0 (black). In the binary image the pig is represented by pixels with unit value.

Figure 5. Real image (a) and (b) of binarized background.

(a)

(b)

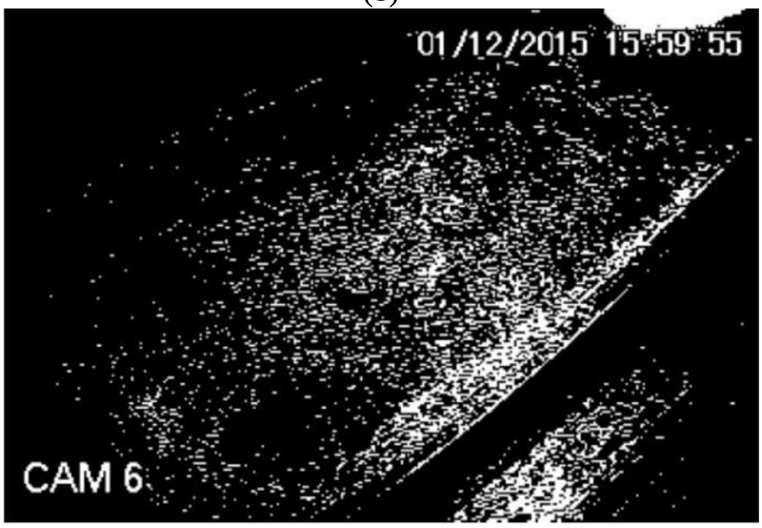
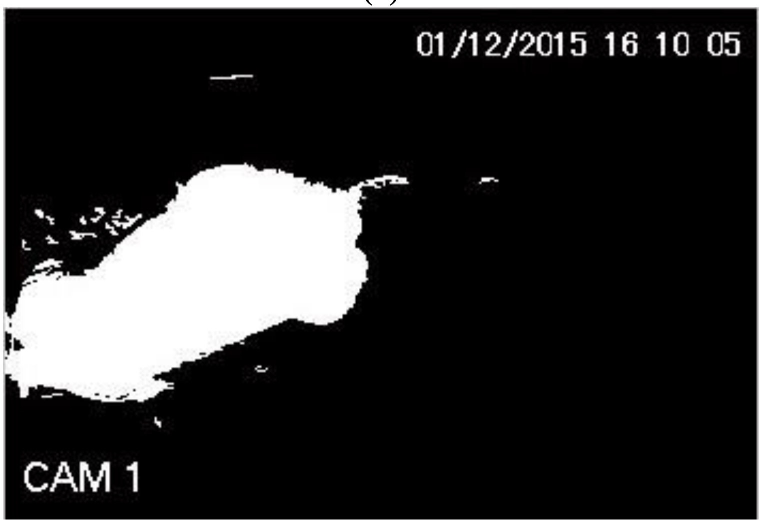


Figure 6. Real image (a) and (b) segmented and binarized with the animal's presence within the creep feeder.

(a)

(b)



For each frame of the video, the quantity of non-zero numbers was compared between the background image and the current image. If the quantities of non-zero numbers of the matrix are equal, there was considered to be no movement of pigs within the shelter. If the amount of non-zero numbers of the analyzed frame is greater than the background image, there will be animals in the creep feeder.

Having piglets inside the shelter, we used the mathematical formula below to determine the animal residence time within the creep feeder.

$$\text{Time} = \frac{\text{FCL}}{\text{QPS}} \quad (1)$$

Where: Time - residence time of piglets; FCL - amount of frames with pigs: and QPS - frames per second.

The videos captured in the swine farrowing house where images related to piglets were obtained as described above were used to validate the program.

3 RESULTS AND DISCUSSION

The digital image processing possible to analyze an image every two seconds, meaning within 1 hour of continuous video, it was possible to analyze up to 1800 images, facilitating the study of animals and behavior analysis. Furthermore, it was observed that the digital image processing can be used to trigger the heating system, namely, when the camera detects the presence of an animal in the creep feeder, it can trigger the heating system, saving energy during periods in which animals are not present inside the creep.

For elimination of objects in the videos like flies and waste, aperture filters and small point recognition filters were necessary. This methodology has been used by Shao, Xin and Harmon (1998) and Silva et al. (2004). According to the author, the aperture operators can be viewed with a morphological filter, which usually smooths the outline of objects, deletes undefined objects and eliminates small objects. Similar procedures have to be taken in order to eliminate these same unnecessary objects from images, to thereby improve the quality of the contrast between animal and background.

To obtain more accurate results in field conditions, intensifying the contrast of the animal to the floor for a better identification, a capture camera must be used with at least 400 lines of resolution and the brightness adjusted in the creep feeder, and floors with colors different from the animal coloration must be used. When improving lighting, care must be taken not to overheat the internal environment of the creep feeder.

According to the analysis of the behavior of piglets through digital image processing, it appears that the animal access and the time spent in creep feeders equipped with different heating systems were influenced by environmental conditions in the farrowing house and in the creep feeders that were above the requirement of the animals most of the time. The creep feeders equipped with a hot water heating system (ASHW and CSWH) were the most popular and where the piglets remained for a longer time due to the system to promote adequate temperature to the comfort of the animal, ie between 30 and 32 °C as can be seen from Table 1.

Table 1. Environmental conditions and percentage (%) of time which the animals remained inside and outside the creep feeder.

Weeks	Envir. conditions		Treatments							
	t_{db}	RH	ILH		ASWH		CSWH		ERH	
	(°C)	(%)	Int.	Ext.	Int.	Ext.	Int.	Ext.	Int.	Ext.
1	27.3 ± 3.8	76.4 ± 8.5	14.61	85.39	66.53	33.47	63.97	36.03	4.51	95.49
2	26.0 ± 1.9	73.9 ± 6.3	51.29	48.71	36.42	63.58	27.37	72.63	7.80	92.20
3	25.3 ± 1.9	77.0 ± 7.1	49.35	50.65	39.47	60.53	31.91	68.09	8.60	91.40
Mean	26.2 ± 2.5	75.7 ± 7.3	38.42	61.58	47.47	52.53	41.08	58.92	6.97	93.03

*Int. – internal, Ext. – external.

Due to the collection period being fairly close to the summer, the high values of T_{bs} and RH both in the farrowing house and inside creep feeders, the length of stay and frequency of access to creep feeders were reduced.

According to Table 1, it is noted that during the three weeks evaluated, the mean values of the time animals remain within the creep feeders was best in the treatment with heated water (CSHW and ASHW), followed by the incandescent lamp system (ILH) and electrical resistance (ERH). These results confirm the control efficiency of floor surface temperature and the behavioral response of animals with respect to access frequency and the piglet residence time in the creep feeder.

Considering the intervals analyzed (4:00 to 8:00, 12:00 to 16:00 and 20:00 to 24:00), the creep feeder equipped with the ASHW heating system presented a higher frequency of access and length of stay of pigs in the creep feeder, which may justify concluding that it gives better comfort conditions to the animals.

According to Pandorfi and Silva (2005), the increased efficiency in heat exchange between the floor and the pig is because it is a conductive flow when the animal lies down on the floor and gains heat, until the process of balance is achieved in floor heating in the range between 30 and 32 °C.

During the most critical period for piglets (4:00 to 8:00h), it was found for the creep feeder equipped with incandescent lamp (ILH) that 57.6% of the time analyzed by digital image processing, the presence of at least one animal was observed inside the creep feeder (Figure 3a).

There was increased demand by the piglets for the same period (4:00 to 8:00h), in the ASWH treatment (Figure 7b), for in 73% of the time the presence of at least one piglet within the creep feeder was verified by the digital image processing.

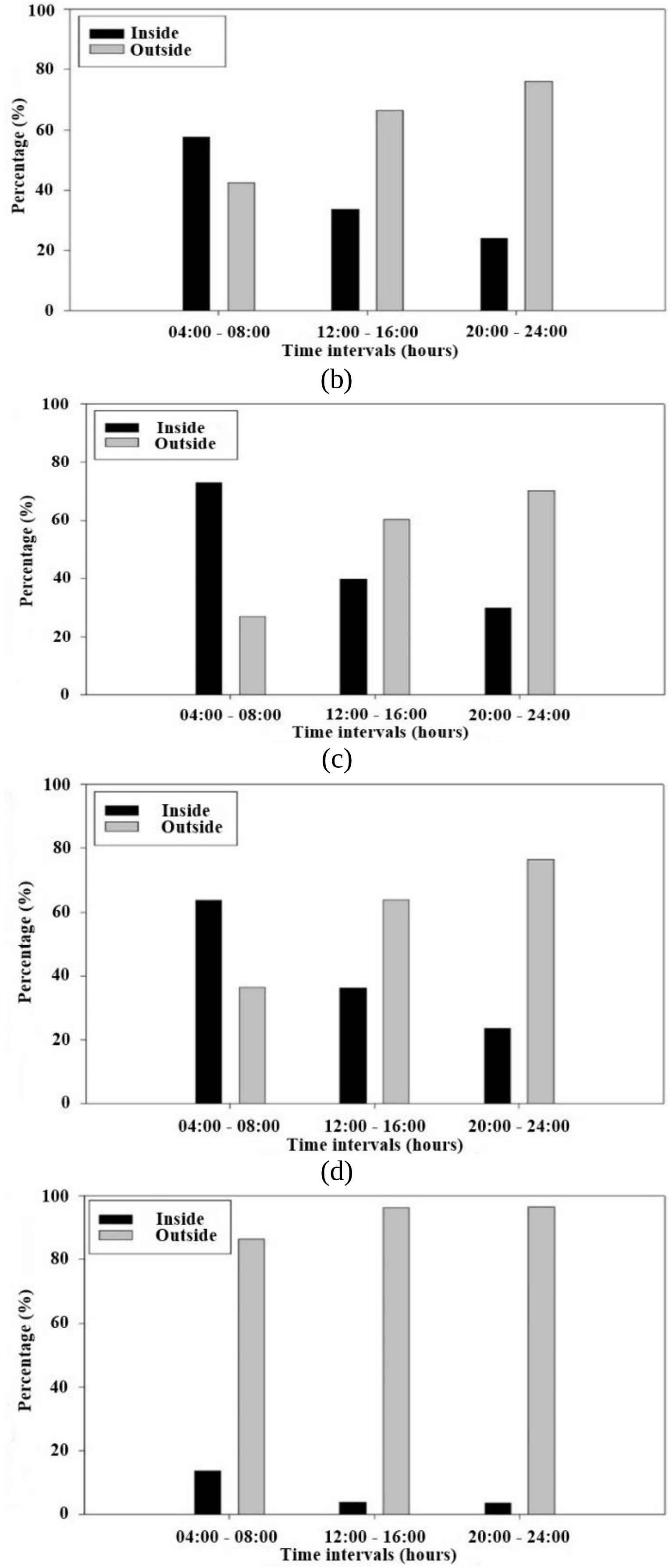
With respect to the data relating to the CSWH treatment (Figure 7c), it was observed that about 63.6% of the time between 4:00 to 8:00, the presence of at least one animal was found inside the creep feeder.

The creep feeder equipped with heater cables on the floor (ERH) had a low residence time when compared to other treatments, ie 13.6% of the time between the range of 4:00 to 8:00 (Figure 7d). This fact is evidenced by the high temperature inside the creep feeder relative to the comfort temperature of piglets.

Pandorfi and Silva (2005) when evaluating the piglets residence time in creep feeders with different heating systems, noted that the creep feeders heated with electric resistance and infrared lamp showed lower demand from the animals.

Figure 7. Percentage of piglet residence time in the creep feeders equipped with heating systems: (a) ILH (b) ASWH, (c) and CSWH (d) ERH at different time intervals.

(a)



4 CONCLUSIONS

From the tests carried out with the use of techniques for digital image processing, it was possible to determine the presence of at least one pig in the creep feeder, allowing the researcher to observe the behavior of animals, in less time than manual evaluation;

Considering the effect of heating on the behavior of piglets, the floor heated with water was the most efficient in heat exchange sensed by conduction, promoting better condition of comfort for the animals, judging from the high frequency of access to creep feeders and longer stay of animals inside creep feeders during the study period; and

In future studies, the use of video and digital image processing techniques for the detection, count and residence time of each animal in the creep feeder is proposed.

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