Assessing the most suitable floor system for growing-finishing piggery under tropical conditions using the analytic hierarchy process

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Abstract

Studies were carried out worldwide for evaluating different types of floor systems for growing-finishing pigs, specifically for assessing their effectiveness on pig performance, health and behaviour, leaving the opportunity for using multi-criteria analysis in decision-making towards the selection of flooring type. This study aimed to select the most suitable floor system for growing-finishing pigs under tropical conditions, considering performance traits and farmers management aspects. The analytic hierarchy process was applied for seeking the best solution considering both the farmers’ goals and the pigs’ welfare. Aspects considered in the analysis were: economic feasibility, rearing thermal and aerial condition, animal behaviour, performance, and health status. The input used in the calculation was based on the results of a field trial using three treatments: whole concrete floor, coffee and rice husks bedding, and wood shavings deep-bedding. Rearing conditions and pigs’ physiological parameters, performance, behaviour, and health status were analysed. When the floor system was considered, the most significant criteria were economic feasibility (0.31) and overall pig performance (0.31) leading to a final deep-bedding selection ranking of coffee and rice husks (1°), concrete floor (2°), and wood shavings (3°). Conversely, when the animal welfare was considered, the most decisive criterion was health status (0.32), followed by physiological parameters (0.25), and behaviour (0.23) leading to a final bedding selection ranking of coffee and rice husks (1°), wood shavings (2°), and concrete floor (3°). Results indicate that the deep-bedding of coffee and rice husks provided the best choice for both the farmer and the growing-finishing pigs.

Introduction

Pig production is a significant economic activity in tropical countries. Traditional rearing conditions and manure handling in confinement using concrete floor might lead to a negative environmental impact (Wang et al., 2011). The swine production sector often searches for alternative systems that lead to less environmental impact, and reduce maintenance costs. The use of deep-bedding in pig production has been increasing as it facilitates and reduces the cost of waste management, it improves the physical comfort of the floor, and it functions as a crucial motivation and outlet for exploration behaviours (Tuyltens, 2005). Several bedding materials and their depth used in piggeries have been studied, such as rice husk, wood shavings, barley and wheat straw (Corrêa et al., 2000; Morrison et al., 2003). Each deep-bedding option enhances a particular benefit the material may provide (Morrison et al., 2003; Cordeiro et al., 2007), not necessarily leading to the farmers’ right choice. The selection of the deep-bedding material is clearly a decision-making multi-criteria task as it involves different aspects related to the animal benefit, farmer’s financial advantage, and availability and price of the material. Amongst the possible mathematical solutions, the use of the analytic hierarchy process (AHP) enables the possibility of arranging the selected criteria in a level structure, and by weighting the alternatives it is possible to classify them according to established parameters criteria helping supporting decision-making. The AHP is a multi-criteria decision-making methodology that aims at providing simple solutions to complex choice problems. The AHP has been applied in different scenarios were there are viable alternatives, and the diversity of solutions can be arranged in a matrix (Bolloju, 2001; Ananda and Herath, 2003; Rosado Júnior et al., 2011; Zang et al., 2012).

The aim of this research was to select the most suitable floor system to rear pigs during growing-finishing stage under tropical conditions, considering the restrictions of producers, and seeking the best solution to meet pigs’ welfare, using the AHP.
daily weight gain (DWG). Skin [neck (NST), palette (PST) and gammon (GST)] and rectal temperature (RT) and respiratory frequency (RF) were recorded weekly in alternating days (with respect to the behavioural evaluation), in four pigs randomly chosen in each treatment. To characterise the thermal environment, the black globe and dry bulb temperatures and the relative humidity were recorded twice daily, in the morning (8:00 a.m.) and the afternoon (2:00 p.m.) at 0.4 m from the floor, during the entire experimental period, using a black globe thermometer and an analog thermo-hygrometer, respectively. The black globe temperature and humidity index (BGTHI) was calculated using the equation proposed by Buffington et al. (1981). Statistical analysis was applied to the environmental data, performance and physiological variables (RT, RF and skin surface temperature (ST) adopting the Scott-Knott test at 5% significance level. Since similar behavioural pattern was observed in all variables along the seven weeks of trial, the calculated means were used as input for the multi-criteria analysis. Results from the field test (Table 1) were used to support weight given during the comparison between the selected criteria within the level.

**Complementary indicators related to ideal rearing conditions**

As the AHP may also use qualitative analysis, complementary knowledge was added to the field trial results (Table 2). The knowledge base retrieved data on rearing condition (bedding temperature, ammonia concentration, BGTHI), behaviour (positives and negatives interactions, and natural behaviour), and health status (incidence of lymphadenitis, respiratory problems and stomach lesion). Research results related to performance (DWG, DFC, and FC), and physiological traits (RF, RT and ST) were also used to weight the criteria. Financial feasibility was done based on the following items initial cost of deep-bedding material, availability of the material, and cost with the manure management (Kunz et al., 2005).

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**Table 1. Mean values and standard deviations obtained in the field trial and used as input variables in the analytic hierarchy process analysis.**

| Input variables in AHP analysis | Whole concrete floor | Floor alternatives | Coffee and rice husks deep-litter |
|---------------------------------|----------------------|--------------------|----------------------------------|
| Performance                     |                      |                    |                                  |
| DWG, kg/day                     | 0.702±0.04           | 0.671±0.04         | 0.674±0.04                       |
| DFC, kg/day                     | 1.696±0.23           | 1.655±0.22         | 1.662±0.22                       |
| FC, kg/kg                       | 2.41±0.42            | 2.46±0.43          | 2.46±0.40                        |
| Physiological parameter         |                      |                    |                                  |
| RF, mov/min                     | 69.7±4.42            | 68.2±5.79          | 69.2±5.10                        |
| RT, ºC                          | 39.0±0.31            | 39.3±0.42          | 39.5±0.44                        |
| NST, ºC                         | 33.8±0.25            | 33.4±0.30          | 33.4±0.40                        |
| PST, ºC                         | 33.1±0.30            | 33.0±0.40          | 32.9±0.40                        |
| GST, ºC                         | 33.4±0.25            | 33.3±0.30          | 32.8±0.40                        |
| Behavioural repertoire, % of the total observation times | | | |
| D                               | 2                    | 2                  | 2                                |
| E                               | 17                   | 15                 | 15                               |
| I                               | 54                   | 58                 | 59                               |
| Io                              | 20                   | 14                 | 15                               |
| Ex                              | 7                    | 11                 | 9                                |
| BGTHI                           | 70.44                | 74.36              | 77.72                            |

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**Table 2. Description of the literature used to help designate weights related to qualitative data in the multi-criteria analysis.**

| Source                          | Comments                  | Behaviour | Performance | Health status | Rearing condition | Physiological traits |
|---------------------------------|---------------------------|-----------|-------------|---------------|-------------------|----------------------|
| Wang et al. (2011)              |                           | X         | X           |               |                   |                      |
| Avérous et al. (2010)           | Meta analysis             | X         | X           |               |                   |                      |
| Hötzel et al. (2009)            | Wood shaving and rice husk| X         | X           | X             |                   |                      |
| Paulo et al. (2009)             |                           | X         | X           |               |                   |                      |
| Dalla Costa et al. (2008)       | Wood shaving, wheat straw and rice husk | X | X | | | |
| Day et al. (2008)               | Straw                     | X         | X           |               |                   |                      |
| Caldara et al. (2012)           |                           | X         |             |               |                   |                      |
| Cordeiro et al. (2007)          | Wood shaving and rice husk| X         | X           |               |                   |                      |
| Karlen et al. (2007)            | Sows                      | X         | X           |               |                   |                      |
| Morrison et al. (2007)          |                           | X         | X           |               |                   |                      |
| Morrison et al. (2003)          |                           | X         |             |               |                   |                      |
| Gentry et al. (2002)            | Only experiment 3         | X         | X           |               |                   |                      |
| Corrêa et al. (2000)            |                           | X         | X           |               |                   |                      |
| Oliveira (2000)                 |                           | X         |             |               |                   |                      |
Structuring the multi-criteria analysis

The AHP analysis involves five stages (Saaty and Vargas, 1998) and it is used to establish consistent sets of estimates of relative weights and criteria from experimental data and experts’ evaluation (Saaty, 1980). The five stages at stake are presented in the following.

First, to structure the problem the criteria were selected by the experts and producers. They were related to economic feasibility of the business (initial cost, management cost of manure, availability of material), animals’ performance, behaviour and physiological traits (performance results, rectal and skin temperature, and behavioural repertoire), rearing condition (floor system surface temperature, and ammonia concentration), and animals’ health status. Different weights were given in the analysis from the farmer's point of view and the animal welfare.

Second, the possible technological alternatives in this particular case were the three floor systems (whole concrete floor, deep-bedding of wood shavings, and deep bedding of coffee and rice husk).

Third, the selected criteria were weighted based on the field trials results and literature data (Tables 1 and 2), and the system was defined (Figure 1).

Fourth, a set of pairwise comparison matrices \( A \) (equation below) were built. Each element in an upper level is used to compare the elements in the level immediately below with respect to it (Saaty and Vargas, 1998; Saaty, 2008). The judgment of relative weights \( w_i \) of all pairs of the \( n \) elements and these judgments are included in as a number \( (a_{ij}) \) in a square matrix \( A \) (i.e. the comparison matrix):

\[
A=(a_{ij}), \quad (i,j=1,2,\ldots,n)
\]

where \( a_{ij} = w_i/w_j \) and \( a_{ji} = 1/a_{ij} \).

The parameters for pair-wise comparison followed a 1-9 scale, where: 1 (not a priority); 2 (no-to-moderate priority); 3 (moderate priority); 4 (moderate-to-high priority); 5 (high priority); 6 (high-to-very-high priority); 7 (very high priority); 8 (very high-to-utmost priority); 9 (utmost priority). It was assigned to the \((i,j)^{th}\) position of the pairwise comparison matrix chosen to support comparisons within a limited range with sufficient sensitivity. Automatically, the reciprocal of the assigned number was given to the \((j,i)^{th}\) position. The highest eigenvalue \( \lambda_{\text{max}} \) was used to determine the consistency index (CI; following equation):

\[
CI=\frac{\lambda_{\text{max}}-n}{(n-1)}
\]

where CI is the consistency index, \( \lambda_{\text{max}} \) is the highest eigenvalue, and \( n \) is the dimension of the matrix. If all judgments are fully consistent, then \( a_{ij}=a_{jia} \) for all \( i,j,k=1, \text{etc.} \)

Fifth, to apply the weights of element \( i \) compared to element \( j \), and assigned to the \((i,j)^{th}\) position of the pairwise comparison matrix chosen to support comparisons within a limited range with sufficient sensitivity. The relative importance of each element was ranked using quantitative data from the field trial’s results and current literature qualitative data (Tables 1 and 2). Three farmers and two swine specialists were asked to give their expert opinion on the analysis as suggested by Rosado Junior et al. (2011).

In this research, two scenarios were applied adopting two different criteria of preference for selecting the most suitable floor system under tropical conditions. The pig performance was the main focus from the farmer’s perspective, in the first analysis. In the analysis

Figure 1. Hierarchy diagram for selecting the most suitable floor system material for growing-finishing piggery under tropical conditions.
with the focus on animal welfare, it was given priority to the animal. The weights attributed to each criterion changed with respect to the selected scenario. This procedure was done because although animal welfare is highly demanded to be implemented in farms, producers are still reluctant to adopt the overall concept, complaining about the increase in production cost.

Computational analysis was done using the web based software MakeitRational (2010), and the comparison calculation was only achieved when the CI≤0.1.

Results and discussion

The scheme of the hierarchy criteria to achieve the goal of selecting the most suitable floor system alternative for growing-finishing piggery is shown in Figure 1. Regarding the pigs farmer scenario which considered pig performance as a priority, the results showed that the most significant criteria were economic feasibility (0.31) and performance (0.31), as can be seen in Table 3. A3 was the best alternative for the economic feasibility (0.387), and A1 provided the best solution for the item performance (0.425). The third most important criterion was the pigs’ health status (0.24), and the best option was reached when selecting the alternative A3 (0.463). In the overall ranking, the best alternative of deep-litter flooring system by the farmers’ criteria was A3, followed by A1 and A2 (Figure 2). The results on the scenario which considered the animal welfare as priority (Table 4) indicated that the most significant criterion was the health status (0.32), followed by the physiological parameters (0.25), and behaviour (0.23). The best alternative on the physiological parameter was A1 (0.581), followed by A3 (0.257) and A2 (0.162); however, both alternatives A2 and A3 (0.437) showed the best results in the criteria behaviour. A3 was the best alternative for the health status (0.422). A1 is the best alternative for the rearing condition (0.418). In the overall ranking, when the pig welfare concept is taken into account, the best floor system is the alternative A3, followed by A2 and A1.

In both scenarios, the best alternative was the use of deep-bedding of coffee and rice husk material. When selecting the material, the availability of each substrate needs to be taken into account by the farmer; thus, the use of unconventional material, which is a residue from another agriculture activity, may present better economic overview than new substrate. The benefits of deep-bedding in animal production systems are widely presumed to improve the welfare status and behaviour of the animals (Tuytens, 2005; Day et al., 2008). The confinement rearing environment is amongst the critical points for achieving satisfactory welfare, and it involves the exposure to heat stress, and social adaptability. The adoption of straw and others substrates as deep-bedding is reported to perform also as recreational material, improving the general welfare status of pigs as the time budget involved in negative social behaviours increased with group size in the absence of bedding (Day et al., 2008; Averós et al., 2010). Although there may be better alternatives for the functions of deep-litter separately, it remains unlikely that these alternatives can properly replace the whole integration of rearing hygiene and environment, as well as labour and economics (Morrison et al., 2003; Hötzel et al., 2009; Averós et al., 2010). Pigs in deep-bedding flooring systems played and interacted more with each other and presented less skin lesions and less mucous problems than those reared on full concrete floor (Day et al., 2008). For pigs at all ages, there is weak evidence that whole concrete floor rather than straw is a risk factor for increased overall morbidity and mortality (Tuytens, 2005; Dalla Costa et al., 2008; Gilhespy et al., 2009). However, the relationship between deep-litter and hygiene remains complex, vague and disease specific, as the use of deep-litter over the concrete floor for pigs may cause airflow across contaminated surfaces and between pens (Gilhespy et al., 2009). Studies in hot weather found that swine reared in deep-bedding systems had similar performance to those reared on full concrete floor, although those in deep-litter presented higher skin surface temperature than those reared in full concrete floor (Corrêa et al., 2000; Hötzel et al., 2009). There are several alternatives of deep-litter systems for pig production, and the choice of the most appropriate one is not an easy task. Suggestions have been made (Corrêa et al., 2000) that the performance of pigs on deep-litter systems was lower than those on concrete flooring due to the
### Table 3. Weights found using the pigs farmer scenario.

| Criteria                          | Sub-criteria                          | A1          | A2          | A3          |
|-----------------------------------|---------------------------------------|-------------|-------------|-------------|
| Economic feasibility [0.31; 0.31] | Availability and initial cost [0.50; 0.15] | 0.345 (2)   | 0.269 (3)   | 0.387 (1)   |
|                                   | Cost of manure management [0.50; 0.15]  | 0.547 (1)   | 0.109 (3)   | 0.345 (2)   |
| Performance [0.31; 0.31]          | WG [0.23; 0.07]                        | 0.386 (1)   | 0.326 (2)   | 0.288 (3)   |
|                                   | PC [0.67; 0.21]                        | 0.493 (1)   | 0.311 (2)   | 0.196 (3)   |
|                                   | DFC [0.19; 0.03]                       | 0.333 (1)   | 0.333 (1)   | 0.333 (1)   |
| Behaviour [0.07; 0.07]            | Positive interaction [0.45; 0.03]      | 0.125 (2)   | 0.437 (1)   | 0.437 (1)   |
|                                   | Negative interaction [0.05; 0.0001]    | 0.125 (3)   | 0.429 (2)   | 0.444 (1)   |
|                                   | Natural behaviour [0.45; 0.03]         | 0.143 (3)   | 0.444 (1)   | 0.429 (2)   |
|                                   | RF [0.56; 0.02]                        | 0.547 (1)   | 0.109 (3)   | 0.345 (2)   |
|                                   | ST [0.12; 0.0001]                      | 0.493 (1)   | 0.196 (3)   | 0.311 (2)   |
|                                   | RT [0.32; 0.01]                        | 0.509 (1)   | 0.157 (3)   | 0.249 (2)   |
| Rearing condition [0.05; 0.05]    | BGTHI [0.44; 0.02]                     | 0.418 (1)   | 0.301 (2)   | 0.282 (3)   |
|                                   | Bedding temperature [0.17; 0.01]       | 0.493 (1)   | 0.196 (3)   | 0.311 (2)   |
|                                   | Ammonia concentration [0.39; 0.02]     | 0.303 (1)   | 0.235 (2)   | 0.461 (3)   |
| Health status [0.24; 0.24]        | Incidence of lymphadenitis [0.43; 0.10] | 0.474 (1)   | 0.03 (3)    | 0.474 (1)   |
|                                   | Incidence of respiratory problem [0.37; 0.09] | 0.196 (3)   | 0.311 (2)   | 0.493 (1)   |
|                                   | Incidence of stomach lesion [0.08; 0.02] | 0.122 (3)   | 0.558 (1)   | 0.320 (2)   |

A1, whole concrete floor; A2, wood shavings deep-litter; A3, coffee and rice husks deep-litter; WG, weight gain; FC, feed conversion; DFC, daily feed consumption; RF, respiratory frequency; ST, skin temperature; RT, rectal temperature; BGTHI, black globe temperature and humidity index. Numbers in square brackets are the local and global weight, respectively; numbers in simple brackets represent the rank of importance.

### Table 4. Weights found using the animal welfare scenario.

| Criteria                          | Sub-criteria                          | A1          | A2          | A3          |
|-----------------------------------|---------------------------------------|-------------|-------------|-------------|
| Economic feasibility [0.02; 0.02]  | Availability and initial cost [0.5; 0.01] | 0.345 (2)   | 0.269 (3)   | 0.387 (1)   |
|                                   | Cost of manure management [0.5; 0.01]  | 0.547 (1)   | 0.109 (3)   | 0.345 (2)   |
| Performance [0.05; 0.05]          | WG [0.43; 0.02]                        | 0.425 (1)   | 0.320 (2)   | 0.253 (3)   |
|                                   | PC [0.43; 0.02]                        | 0.493 (1)   | 0.311 (2)   | 0.196 (3)   |
|                                   | DFC [0.14; 0.01]                       | 0.333 (1)   | 0.333 (1)   | 0.333 (1)   |
| Behaviour [0.23; 0.23]            | Positive interaction [0.45; 0.11]      | 0.125 (2)   | 0.437 (1)   | 0.437 (1)   |
|                                   | Negative interaction [0.05; 0.01]      | 0.125 (3)   | 0.429 (2)   | 0.444 (1)   |
|                                   | Natural behaviour [0.45; 0.11]         | 0.143 (3)   | 0.444 (1)   | 0.429 (2)   |
|                                   | RF [0.56; 0.14]                        | 0.509 (1)   | 0.157 (3)   | 0.249 (2)   |
|                                   | ST [0.12; 0.03]                        | 0.493 (1)   | 0.196 (3)   | 0.311 (2)   |
|                                   | RT [0.32; 0.08]                        | 0.509 (1)   | 0.157 (3)   | 0.249 (2)   |
| Rearing condition [0.13; 0.13]    | BGTHI [0.44; 0.06]                     | 0.418 (1)   | 0.301 (2)   | 0.282 (3)   |
|                                   | Bedding temperature [0.18; 0.02]       | 0.594 (1)   | 0.157 (3)   | 0.249 (2)   |
|                                   | Ammonia concentration [0.39; 0.05]     | 0.303 (1)   | 0.235 (2)   | 0.461 (3)   |
| Health status [0.32; 0.32]        | Incidence of lymphadenitis [0.14; 0.05] | 0.474 (1)   | 0.03 (3)    | 0.474 (1)   |
|                                   | Incidence of respiratory problem [0.29; 0.09] | 0.196 (3)   | 0.311 (2)   | 0.493 (1)   |
|                                   | Incidence of stomach lesion [0.29; 0.09] | 0.122 (3)   | 0.558 (1)   | 0.320 (2)   |

A1, whole concrete floor; A2, wood shavings deep-litter; A3, coffee and rice husks deep-litter; WG, weight gain; FC, feed conversion; DFC, daily feed consumption; RF, respiratory frequency; ST, skin temperature; RT, rectal temperature; BGTHI, black globe temperature and humidity index. Numbers in square brackets are the local and global weight, respectively; numbers in simple brackets represent the rank of importance.
excess of moisture kept under the substrate. Amongst the studied alternatives, the best one is the substrate with coffee and rice husks, followed by the concrete floor, and the wood shavings in both scenarios (Figures 2 and 3). However, the overall differences in the final weights remained below the expected as previous studies strongly recommend the use of a certain type of flooring system (Tuytten, 2005; Dalla Costa et al., 2008; Gilhespy et al., 2009; Hötzel et al., 2009). Deep-litter flooring system may affect the ambient temperature as it decreases the heat loss to the floor; thus, in tropical areas the reduction of heat exchange may increase the need of high ventilation rate in order to remove both heat and moisture generated within the rearing system (Oliveira, 2000). As in hot environments waste fermentation may be a problem, and deep-bedding tends to absorb the liquid component of the waste, reducing the rate of the decomposition process, and the resulting ammonia and hydrogen sulphide concentrations (Paulo et al., 2009). Smaller concentrations of ammonia in the deep-litter system when compared to the concrete floor were observed by Oliveira (2000); and between deep-bedding substrates, those using rice husks provided lower concentrations of this gas. In this matter, lower concentration of noxious gases may be a preference for the scenario of animal welfare.

**Conclusions**

The use of the AHP allowed the indication of the most suitable choice of growing-finishing piggy floor system. The study indicates that the deep-bedding of coffee and rice husks provided the best choice for both the farmer and the growing-finishing pigs under tropical conditions, followed by the concrete floor and the wood shavings.

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