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Selecting the Most Adequate Bedding Material for Broiler Production in Brazil

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ABSTRACT

Broiler chicken production is widely dispersed across the globe, and one important issue for growers is the selection of adequate bedding material, as the availability and price of substrates varies among countries and regions within a same country. This study aimed at applying a multiple criteria analysis approach for the selection of the most appropriate bedding material for broiler production. Based on field research data and growers' experience, the most desirable characteristics of a litter material were chosen as the main criteria. The selected materials were wood shavings, rice husks, chopped Napier grass *(Pennisetum pupureum)*, 50% sugar cane bagasse *(Saccharum L.)* plus 50% wood shavings, 50% sugar cane bagasse *(Saccharum L.)* plus 50% rice husks, and pure sugar cane bagasse *(Saccharum L.)*. The analytical hierarchy process (AHP) was applied for selecting the most suitable bedding material. Validation was performed using data from previous studies carried out in central-western Brazil on the effects of different types of bedding material on broiler carcass quality. Considering the selected criteria, several bedding materials were tested and ranked, and the results showed that wood-shavings litter was the best option (weight = 0.28), followed by rice husks (weight = 0.24). All other tested alternatives presented lower scores and were, therefore, not considered for use. The AHP approach was found to be an efficient tool to select the most appropriate litter material under specific scenarios.

INTRODUCTION

Bedding material acquisition and litter management are important issues for broiler producers. The sustainability of broiler production requires bedding material to be environmentally friendly, and the replacement of litter needs to be efficient and cost-effective in order to be implemented by growers in a profitable way (Mayne *et al.*, 2007; Bilgili *et al.*, 2009). This requires the availability of alternative bedding sources, as well as good understanding of how to reduce NH_3 emissions in reused litter. Managing litter moisture is challenging in reused litter, especially during the last weeks of the growout. The important factors that influence moisture in the rearing environment include short downtimes between flocks, partial-house brooding, evaporative cooling systems, and poor drinking water management (Bilgili *et al.*, 2009). Health issues and the incidence of breast burns and blisters, leg abnormalities, and footpad lesions are reported in the literature as partially due to poor litter conditions (Benabdewelil & Ayach, 1996).

Amongst the available multi-attribute approaches, the analytic hierarchy process (AHP) is the best because it is capable of combining different types of criteria in a multi-level decision structure in order to obtain a single score for each alternative and to rank the proposed alternatives overall. Several studies have been published on different AHP scenarios and arrays, and the conclusions support the suitability of this analysis for the selection of specific criteria (Benabdewelil & Ayach, 1996; Karami, 2006; Omkarprasad & Sushil, 2006; Halmar *et al.*, 2009; Almeida Paz *et al.*, 2010).

This study aimed at applying the AHP approach for the selection of the most appropriate bedding material considering all restrictions and benefits to the producer.

MATERIALS AND METHODS

Applying AHP model involves the following steps: (a) structuring the selection problem, (b) identifying the technological options, (c) identifying the applicable criteria, (d) developing the weighting schemes, and (e) ranking the management or technological options. These steps are detailed below.

Structuring the selection of the appropriate broiler bedding material and identifying the options

Identifying and structuring the objective of selecting the proper broiler bedding material required careful literature investigation to provide the basis for quantitative modeling. The fundamental challenge was to identify the attributes that producers genuinely consider important because the objective hierarchies should be constructed according to this classification (Rosado Jr. *et al.*, 2011). In this specific study, the main goal was to select the appropriate broiler bedding material for a specific scenario. The attributes were selected based on the criteria broiler growers generally use when purchasing bedding material and on previous research results (Bowers *et al.*, 2003; Bilgili *et al.*, 2009; Macklin & Krehling, 2010).

Choosing a conventional or alternative bedding material involves selecting from a set of available options, each of which may fulfill some or all of the desired criteria. Although there theoretically are several types of adequate bedding alternatives, many options are often considered to be untenable due to technical restrictions (Macklin *et al.*, 2005; Mayne *et al.*, 2007; Bilgili *et al.*, 2009; Garcia *et al.*, 2010).

Identifying the applied selection criteria

The selected criteria were chosen based on findings published in the current literature (Bowers *et al.*, 2003; Mayne *et al.*, 2007; Bilgili *et al.*, 2009; Freitas *et al.*, 2009) and on growers' experience and knowledge. The scheme of the system was designed using the following three distinct levels: level 1 represented the goal, level 2 represented the most important characteristic of a bedding material, and level 3 represented the related characteristics that fulfill level 2 (Figure 1).

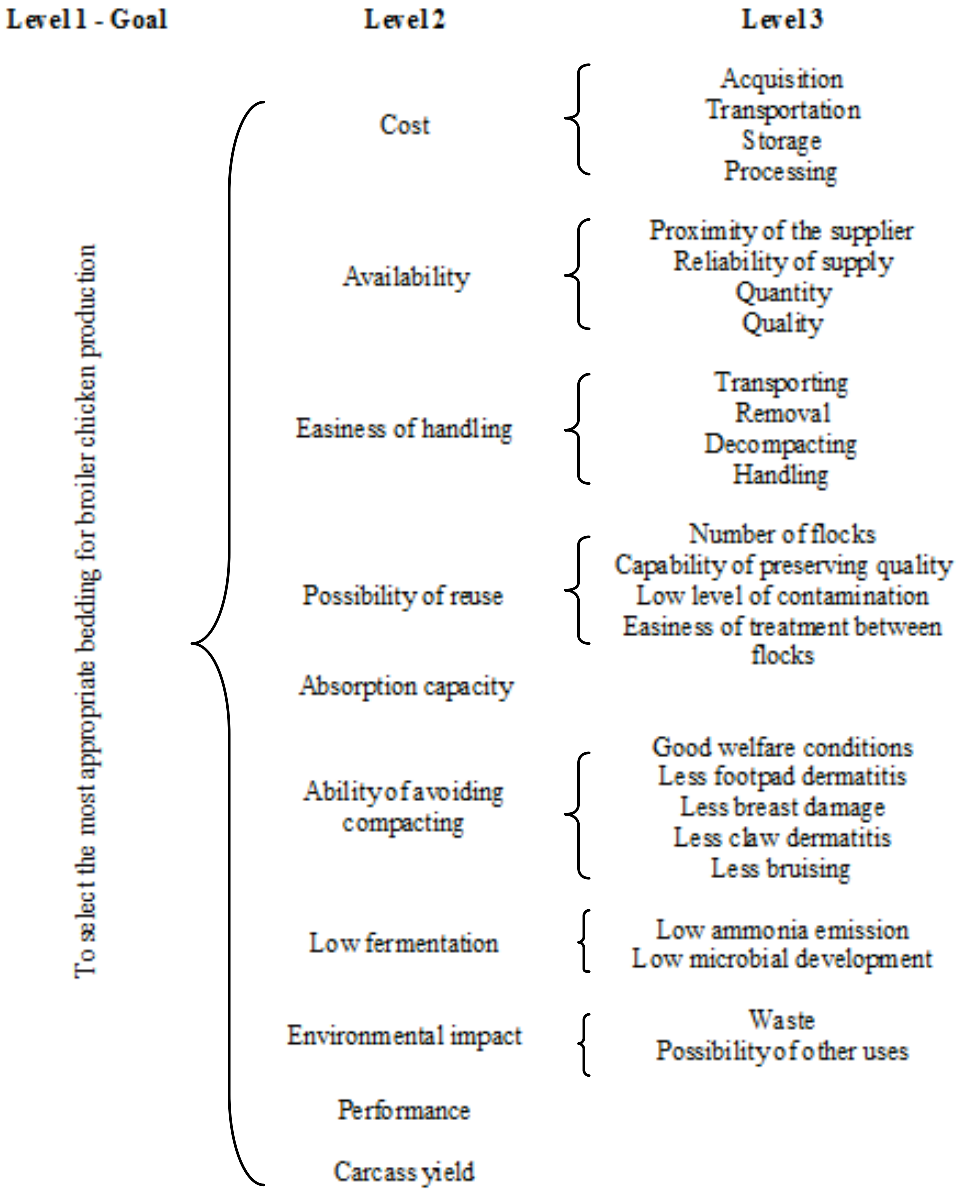

Figure 1 - Schematic description of the criteria used for selecting the most appropriate bedding material for broiler chicken production.

Developing the weighting schemes and ranking the options

The purpose of the AHP is to provide a vector of weights expressing the relative importance of the alternatives for each criterion. The adopted scale of importance was defined according to the method described by Saaty (1977), using a 1–9 score scale for pairwise comparison (Table 1).

Table 1. *Adopted scale of importance*

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong or demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values
Reciprocals of above	If factor i has one of the above numbers assigned to it when compared to factor j, then j has the reciprocal value when compared with i

Adapted from Saaty (1977)

When the AHP approach is applied, a pairwise comparison matrix is established. The rows and columns of this matrix represent the components that belong to the same parent component in the decision hierarchy (Eq. 1). The weight of component i compared to component j relative to the parent component is determined using Saaty's scale (Table 1). The weight is then assigned to the (i, j)th position of the pairwise comparison matrix (Saaty, 1980) in order to support comparisons within a limited range, but with sufficient sensitivity. The reciprocal of the assigned number is assigned to the (j, i)th position. Once the pairwise comparison matrix is established, the weights of the components are calculated by solving for the eigenvector of the pairwise comparison matrix:

$$A = \begin{array}{c} \\ \text{Criterion 1} \\ \text{Criterion 2} \\ \text{Criterion 3} \\ \dots \\ \text{Criterion n} \end{array} \begin{array}{c} \begin{array}{cccccc} \text{Criterion 1} & \text{Criterion 2} & \text{Criterion 3} & \dots & \text{Criterion n} \end{array} \\ \left(\begin{array}{cccccc} 1 & w_{12} & w_{13} & \dots & w_{1n} \\ w_{21} & 1 & w_{23} & \dots & w_{2n} \\ w_{31} & w_{32} & 1 & \dots & w_{3n} \\ \dots & \dots & \dots & 1 & \dots \\ w_{n1} & w_{n2} & w_{n3} & \dots & 1 \end{array} \right) \end{array} \quad \textbf{Eq. 1}$$

where w is the weight of importance and the criterion is more important than . Pairwise comparisons are then made between each pair of factors at a given level of the hierarchy relative to their contribution to the factor at the immediately preceding level. These pairwise comparisons yield a reciprocal (n, n) matrix , where a_{ii} = 1 (diagonal elements) and $a_{ji} = 1/a_{ij}$. Suppose that only the first column of matrix is provided to state the relative importance of factors 2, 3, . . . , with respect to factor 1. If the judgments were completely consistent, then the remaining columns in the matrix would be completely determined by the transitivity of the relative importance of the factors. However, there would be no consistency except for that created by setting $a_{ji} = 1/a_{ij}$. Therefore, the comparison needs to be repeated for each column of the matrix; specifically, independent judgments must be made for each pair. is consistent if and only if λ_{max} = . However, the inequality of λ_{max} > always exists; therefore, the average of the remaining eigenvalues (λ) can be used as a consistency index (CI; Eq. 2), which is the difference between λ_{max} and divided by the normalizing factor (n-1).

$$CI = (\lambda max - n)/(n - 1) \qquad \textbf{Eq. 2}$$

where CI = consistency index; λ_{max} = highest eigenvalue; and n = number of matrix elements.

The CI of the studied problem is compared with the average random index (RI) obtained from associated random matrices of order n to measure the error due to inconsistency (Saaty, 1977; Saaty, 1980). A consistency ratio (CR = CI/RI) with a value ≤ 0.1 should be maintained for the matrix to be consistent; otherwise, the pairwise comparisons should be revised. The homogeneity of factors within each group, a small number of factors in the group, and a better understanding of the decision problem would improve the consistency index.

Field validation

The validation was performed using data obtained from a field study (Caldara *et al.*, 2009; Freitas *et al.*, 2009; Bilgili *et al.*, 2009; Almeida Paz *et al.*, 2010) comparing six different bedding materials available in most regions of Brazil, as well as mixtures of these materials such as wood shavings, rice husks, chopped Napier grass *(Pennisetum pupureum)*, 50%

sugarcane bagasse *(Saccharum L.)* plus 50% wood shavings, 50% sugarcane bagasse *(Saccharum L.)* plus 50% rice husks, and pure sugarcane bagasse *(Saccharum L.)*. The wood shavings consisted of nearly 80% of *Eucaliptus saligna* and 20% of other mixed woods. Chopped grass was 1 to 1.5 cm long, and sugarcane bagasse was 0.1 to 3 cm long. All tested bedding materials were applied at a depth of 10 cm. A total of 3,240 broiler chickens (Manual, 2010) were distributed in 60 pens measuring 4.5 m^2 each, each equipped with a bell drinker and a tube feeder. Flock density was 12 birds m^{-2}, which is typical in Brazil. House side walls were covered with curtains and inside temperature was controlled using fans and foggers. Chicks were brooded using 250 W infrared lamps, one per pen. The lighting regime was 24 h of light during the entire rearing period using 40 W lamps, which provided an average of 22 lx. All birds received feed and water *ad libitum* during the entire experimental period. The feeding program included the following three phases: a starter diet (day 1-21), a grower diet (day 22-35), and a finisher diet (day 36-42).

The following material features were studied: litter microbiological aspects, temperature, litter moisture content and caking index, ammonia emission, house temperature, bird surface and body temperatures, and bird performance (Freitas *et al.*, 2009; Almeida Paz *et al.*, 2010). Data were recorded during the growout period and carcass yield was evaluated at slaughter on day 42.

Computational analysis for calculating the criteria weights and CR was performed using online software MIR (2011).

RESULTS AND DISCUSSION

Local weight represents the specific importance of determined criteria as determined by the previous level of judgment when the presented alternatives are compared pairwise. The pairwise comparison started at the lowest level, which was the level 3, in order to build up the local and global weights in level 2. The global weight represents the importance of a criterion within the level 2, which may influence the goal (level 1). CR values were adjusted to be acceptable ($CR \leq 0.1$), and this procedure was automatically carried out using the multi-criteria software program.

The weight results of the criteria for selecting broiler chicken bedding material show the highest value for "possibility of reuse" (weight = 0.16), followed by "ease of handling" (weight = 0.15) and "cost" (weight = 0.13), as shown in Table 2. Considering those criteria and the tested types of bedding material, it can be seen that wood shavings is the alternative that offers the highest "possibility of reuse" and "ease of handling" (weight = 0.06), followed by rice husks (weight = 0.05 and 0.04, respectively). The criteria "cost" had the highest value (weight = 0.03) for chopped Napier grass *(Pennisetum pupureum)* and the sugarcane bagasse *(Saccharum L.)*, while other material alternatives remained in third place (weight = 0.02).

Criteria were prioritized based on their relative importance to every other choice in their hierarchy and with respect to a dominant choice; therefore, criteria are compared relative to the goal, and the alternatives relative to each criterion. The results of the pairwise comparisons were recorded in a positive consistency matrix. The most favorable is criterion option compared to the alternatives, the higher the value of its weight. Therefore, the high value of "cost" credited to the material means that it is the less expensive bedding alternative. Attention needs to be called upon the fact that not all broiler producers have Napier grass planted on their farm but, when available, it may be the most cost-effective solution (weight = 0.03); this is also applicable when considering sugarcane bagasse as bedding material (weight = 0.03). None of the three highest-scoring criteria ("possibility of reuse", "ease of handling", and "cost") alone or combined was sufficient to determine the best choice of bedding material. Such calculation may require the use of a complex multiple criteria model, with extra levels included.

Although producers' primary goal is to maximize performance and carcass yield, these two criteria accounted for little in the overall decision weight, which is consistent with the results presented by Bilgili *et al.* (2009). These authors evaluated commercial and alternative bedding materials and found that they had little influence on broiler live performance in three successive trials. The incidence and severity of footpad dermatitis significantly varied among bedding materials, and were related to high litter moisture and caking scores. From the standpoint of preventing footpad dermatitis, the capacity of a bedding material to absorb and quickly release moisture may be its most important characteristic (Loch *et al.*, 2011). It has been reported that wet litter conditions increase volatilization of ammonia from the litter (Nagaraj *et al.*, 2007) and that ammonia emissions from wood shavings were 19% greater than from wheat straw around drinkers. In addition, worse caking was observed when wheat straw was used (Tasistro *et al.*, 2007).

Table 2 - Local weight, global weight and final score of bedding materials, considering the given weights of selection criteria .

	Alternatives of bedding material						
	Wood shavings	Rice husks	Chopped Napier grass (Pennisetum pupureum)	50% sugarcane bagasse plus 50% wood shavings	50% sugarcane bagasse plus 50% rice husks	Only sugarcane bagasse (Saccharum L.)	Global weight [1]
Level 2 Criteria	Local weight						
Cost	0.02	0.02	0.03	0.02	0.02	0.03	0.13
Availability	0.02	0.04	0.01	0.02	0.02	0.01	0.12
Ease of handling	0.06	0.04	0.02	0.01	0.01	0.01	0.15
Possibility of reuse	0.06	0.05	0.02	0.01	0.01	0.01	0.16
Absorption capacity	0.03	0.02	0.01	0.01	0.01	0.00	0.08
Capacity to prevent caking	0.02	0.02	0.01	0.01	0.01	0.00	0.06
Low fermentation	0.02	0.02	0.01	0.01	0.01	0.00	0.06
Environmental impact	0.02	0.01	0.00	0.01	0.01	0.00	0.05
Performance	0.03	0.02	0.02	0.02	0.02	0.02	0.12
Carcass yield	0.02	0.02	0.01	0.01	0.02	0.01	0.08
Final ranking[1]	0.28 (1)	0.24 (2)	0.13 (3)	0.13 (3)	0.12 (4)	0.10 (5)	1.00

[1]The sum of the final weight scores of each alternative is equal to 1 (Saaty, 1980)
The number betweeb parentheses is the ranking of the alternatives of the each tested bedding material

A significant percentage of the crop area in Brazil is used to produce sugarcane, rice and pastures for beef cattle (Table 3). Napier grass is used for cattle grazing and accounts for the smallest harvested area among the crops used in the present study as litter material. Considering that Napier grass is not a residual product of agricultural activities, that its availability is low in the studied region, and that it has high nutritional value for beef cattle production (NRC, 1996; Fontes *et al.*, 2005), this substrate may not be the most cost-effective material to use as broiler chicken litter. The availability of sugarcane and rice varies across different regions of Brazil. In the southern region, a large percentage the planted area (nearly 45%) is used for sugarcane, resulting in high production of bagasse. In the northern region, large areas of rice are planted, generating large quantities of this product. However, sugarcane is a seasonal crop and its accessibility and availability vary throughout the year.

Sugarcane bagasse has a high nutritional value for beef cattle (Bulle *et al.*, 2002; Leme *et al.*, 2003) and presents high energy value (Cortez & Gómez, 1998; Sosa-Arnao *et al.*, 2004). In addition, it is used for generating energy by the sugar plants and to produce ethanol, limiting its use as poultry bedding. Rice husks are available in large quantities in some regions of Brazil, where is it used as broiler litter, but the performance of flocks raised on this material is worse compared with wood shavings. Shields *et al.* (2004) tested four types of bedding materials and found that broilers did not present some natural behaviors, such as dust bathing, when raised on rice husks. According to those authors, dust bath is an important social behavior that helps reducing aggressive behaviors and improves general leg health conditions, leading to better mobility and better flock welfare. In addition, the cost of rice husks is higher than wood shavings in some broiler production regions (Table 3) where rice

Table 3 - Percentage of harvested area of various bedding materials in Brazil (sugarcane, rice and forage grass) according to region and broiler chicken production in each region.

Region	Harvested area (%)			Broiler chicken production (million head)
	Forage grass	*Sugarcane*	Rice	
North	0.00	1.05	20.06	18.96
Northeast	3.06	9.00	5.93	97.06
Southeast	0.42	45.6	0.80	281.83
South	0.14	2.26	6.35	493.67
Central West	0.07	5.51	1.94	102.78
Brazil (Total)	0.91	11.36	4.91	994.30

Source: IBGE (2010)

is not intensively grown. Wood shavings are mainly a byproduct of the wood furniture industry and are available almost everywhere in Brazil. Wood shavings do not have a high energy value and are usually considered as waste, and therefore, in most regions, are considered a low cost broiler bedding material. Broiler performance and welfare were found to be improved when the birds are reared on wood shavings (Neme *et al.*, 2000).

The final ranking of alternatives (Table 2) shows that the most appropriate broiler litter material under the studied scenario was wood shavings, followed by rice husks. Most studies comparing poultry bedding materials have reported that, when birds are reared on alternative bedding materials, their performance is equal to or worse than that of birds reared on wood shavings (Benabdewelil & Ayach, 1996; Grimes *et al.*, 2002). However, according to Tasistro *et al.* (2007), broiler mortality was not affected when nonconventional bedding materials were used, although weight gain was significantly lower when birds were reared on wheat straw relative to wood shavings.

CONCLUSIONS

The results of the present study show that the AHP model can be used as a valuable decision analysis tool for the selection of broiler bedding material under a specific scenario. Wood shavings seemed to be the best choice of bedding material for broiler producers in Central-Western Brazil.

An alternative, economical and efficient source of bedding material presenting favorable, environmentally-friendly characteristics that allows recycling or reducing waste may be needed to meet future demands of broiler producers.

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