



## Evaluation of Recycled Tiles and OSB Ceiling Materials in Closed Broiler House Prototypes

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### ■ Keywords

Broiler house environment, recycled tiles, thermal comfort.

### ABSTRACT

This study aimed at evaluating the thermal performance of a modular ceiling system for poultry houses. The reduced- and distorted-scale prototypes used ceiling modules made of reforested wood and were covered with recycled long-life package tiles. The following parameters were measured for 21 days: tile internal surface temperature (ST), globe temperature and humidity index (WBGT), and radiant heat load (RHL). Measurements were made at times of highest heat load (11:00 am, 13:00 pm, and 03:00 pm). Collected data were analyzed by "R" statistics software. Means were compared by multiple comparison test (Tukey) and linear regression was performed, both at 5% significance level. The results showed that the prototype with the ceiling was more efficient to reduce internal tile surface temperature; however, this was not sufficient to provide a comfortable environment for broilers during the growout. Therefore, other techniques to provide proper cooling are required in addition to the ceiling

### INTRODUCTION

Poultry production is one of fastest developing agricultural activities in Brazil in the last few decades. This progress, as demonstrated by the number of marketed broilers and eggs, shows the excellent potential of the local poultry industry to supply a healthy and low-cost protein source to consumers (Macari, 2001). The importance of this industry is also demonstrated by chicken meat export figures, which, according to ABEF (Brazilian Association of Chicken Exporters), was 3.3 million tonnes in 2007, representing a 21% increase relative to 2006 (ABEF, 2008).

Despite the significant growth of the Brazilian poultry industry, broiler production still faces many challenges with the increasing productivity rates. In tropical countries, such as Brazil, the most challenging environmental factors are high temperature and high humidity inside the poultry houses, which may result in heat stress, limiting poultry productivity (Macari, 2001). Therefore, in order to improve intensive poultry production in those countries, companies and experts in poultry-house environment need to plan the houses with maximum thermal isolation in order to reduce the direct negative effects on climate on birds.

In animal housing, one of the main factors that affect incident radiation thermal load is the roof, especially due to their material (Silva & Sevegnani, 2001). The only layer that separates birds from the external environment is the roof, as in open-sided poultry houses, the side curtains do not provide efficient insulation. This demonstrates the importance of choosing the adequate roof material (Tinôco, 2001).

Fiorelli *et al.* (2009) studied the influence of recycled tiles made of recycled long-life packaging material on the thermal comfort of broiler

houses as compared to traditional roofing material (clay tiles, fiber-cement, or white-painted clay tiles). Environmental indexes (WBGT, RHL e THI) were evaluated in two different heights - at 0.7m and 1.5m from the floor, and during different times of the day, the materials presented similar behaviors, showing that recycled tiles may be a roofing material alternative for animal housing.

Conceição *et al.* (2008) evaluated different roofing materials (white-washed asbestos tiles, clay tiles, and tiles made of high-oven scrap and vegetable fibers) in prototypes in reduced and distorted scale. According to those authors, the best environmental indexes results were obtained in the prototype covered with white-washed asbestos tiles. As to the two other roofing materials (clay and vegetable fiber tiles), similar thermal performance was obtained, therefore demonstrating that a tiles made of vegetable fiber may be a good alternative as roofing material for rural buildings.

Several different materials are used in association in rural buildings when the shadow provided by roofs are not capable of providing an adequate micro-climate inside broiler houses. Among these materials, Costa (1982) points out the use of a ceiling, which may reduce environmental temperature in up to 62% when a house with no ceiling is compared to a non-ventilated duratex ceiling.

Therefore, this study aimed at studying the thermal performance of a modular roofing system for broiler houses using reforestation wood material, OSB panel, and tiles made of long-life recycled packages in closed prototypes in a reduced and distorted scale.

## MATERIALS AND METHODS

The study was carried out at the Experimental Campus of UNESP Dracena, located at 21o 29' S latitude, 51o 52' W longitude, and 421m latitude. Annual rainfall is 1235.9mm, and the climate of the region is of type  $C_{wa}$ , with dry winters, according to the classification of Koppen.

A completely randomized experimental design in a 3x3 factorial arrangement for thermal comfort indexes (WBGT e RHL) e 2x3 for superficial temperature (ST) were applied. Factors corresponded to different thermal conditions (HWC - house with ceiling; HWOC - house without ceiling; and O - outside) and different collection times (11:00 am, 01:00 pm, and 03:00 pm). Thermal comfort indexes were evaluated as a function of three thermal conditions and three temperature times), with a total of nine treatments. Superficial

temperature was evaluated as a function of two thermal conditions and three collection times, totaling six treatments.

The models were built in a reduced and distorted scale (1:2 vertically and 1:10 horizontally). One model was built with recycled tiles and OSB as roofing material, previously evaluated by Fiorelli *et al.* (2009), and was called House with Ceiling (HWC), whereas the other model used only recycled tiles and no ceiling, being called House without Ceiling. Models were 2.0m long, 1.4m wide, 1.5m high, and 0.4m high from the floor to the roof. The houses were built longitudinally from east-west, as this region is usually hot and dry (Figure 01). All sides (north, south, east, and west) of both prototypes were closed with blue plastic curtain.



Figure 1. Experimental prototypes in reduced and distorted scale.

The prototypes' roofs were built with a single água, although this is not the most common design for broiler



houses. The roofing material used in both models was recycled tile made of long-life packages, previously evaluated by Fiorelli *et al.* (2009). The HWC model had a ceiling made of OSB (Oriented Strand Board - 10mm),

which consists of a reforested wood panel made of three pressed layers of wood strands aligned in scales using a synthetic resin (Figure 2).



OSB board (10mm)



Module 1



Placement of Module 1



Joining Module 1 and Module 2

**Figure 2.** Building the OSB modular ceiling.

In order to evaluate the thermal performance of each prototype (HWC and HWOC) and of the external environment (EXT), a dry bulb and wet bulb thermometer, a black globe thermometer, and a digital anemometer were used. The instruments were placed at 0.3m distant from the floor, which corresponds to the mass center of broilers inside the house (Santos *et al.*, 2002). Internal temperature (ST) of the roofs was determined using an infrared thermometer

(modelSCAN TEMP 400, -33°C/550°C temperature range) in three different points to provide an uniform sample.

In order to characterize the experimental environment, a weather station (DAVIS, Vantage PRO2) was used. Although summer is considered as the most critical season for broiler production, in the present study, data were collected for 21 days during the spring of 2008, at times when the radiant heat



heat on the prototypes is highest: at 11:00 am, 01:00 pm, and 03:00 pm.. Based on the collected environmental data, WBGT and RHL values were calculated, according to the recommendations of the equation proposed by Buffington *et al.* (1977) and Esmay (1969), respectively.

Thermal comfort indexes (WBGT and RHL) and the variable ST were analyzed in equation 1 and the regression by equation 2.

#### Equation 1

$$Y_{ijk} = \mu + a_i + h_j + (ah)_{ij} + e_{ijk}$$

$Y_{ijk}$  = kth observation of the variable RHL, WBGT, or ST at the jth hour and ith thermal condition

$\mu$  = general mean

$a_i$  = ith level of thermal condition,  $i = \text{HWC, HWOC, or EXT}$

$h_j$  = jth level of time,  $j = 11, 01, \text{ or } 03$

$(ah)_{ij}$  = effect of the interaction between the ith thermal condition level and the jth time level

$e_{ijk}$  = residual effect

#### Equation 2

$$Y_{ij} = a + bh_i + e_j$$

$Y_{ij}$  = jth observation of the variable RHL, WBGT, or ST at the ith time level

$a$  = constant of regression

$b$  = coefficient of regression

$e_j$  = residual effect

After data normality was tested, a parametric test for the comparison of the means (Tukey's) was chosen to analyze the qualitative data, and quantitative data were analyzed by regression analysis, both at  $p < 0.05$ . The obtained results were evaluated and interpreted by the "R" system for statistical analyses.

## RESULTS AND DISCUSSION

There was no effect of the interaction between thermal condition and time for the studied variables. Table 1 summarizes Tukey's test results for the variables ST, WBGT, and RHL obtained during the 21 days of data collection during the spring. ST mean values obtained in the prototypes were significantly

different ( $p < 0.05$ ): mean ST of the OSB ceiling+recycled tile (HWC) model was significantly lower than that of the model only with recycled tiles (HWOC). This may be explained by the fact that the ceiling of the HWC has lower heat flow due to the air cushion that was formed between the tiles and the ceiling (OSB board). The model with recycled tiles+OSB ceiling reduced ST in 15% as compared to the model only with tiles. Similar results were obtained by Tinôco (2001), who observed that the ceiling, as it is a second physical barrier, allows the formation of a mobile air layer between the ceiling and the roof, thereby contributing to the reduction of heat transference from the roof to the inside of the building.

WBGT in the external environment (EXT) was significantly higher than in the internal environment of the prototypes (HWC and HWOC) at the birds' mass center because the black globe was directly exposed to radiation, i.e., a higher amount of electromagnetic waves reached the black globe, which probably increased its temperature as compared to the black globes placed inside the experimental prototypes (HWC and HWOC). However, no WBGT differences were detected between the prototype with OSB ceiling+recycled tiles (HWC) to the prototype without a ceiling (HWOC) (Table 1). Despite the lack of significant differences ( $p < 0.05$ ) in WBGT between the internal environments of the experimental prototypes (HWC and HWOC), the model with ceiling (HWC) presented higher mean WBGT value. It is hypothesized that the shade made by the OSB ceiling+recycled tile prototype (HWC) on the north side of the HWOC may have allowed lower indirect solar radiation on the internal environment of that model.

It was observed that the shading provided by the roofs (HWC e HWOC) reduced WBGT values in 6% as compared to the external environment. The internal environment of the OSB ceiling+recycled tile prototype (HWC) and of the recycled tile prototype (HWOC) presented similar behavior, and the mean experimental value of the HWC was higher. These results are opposed to the findings of Moraes *et al.* (1999), who observed lower WBGT when roofing was associated with a polyethylene ceiling.

According to Furtado *et al.* (2003), WBGT values between 65 and 77 do not influence broiler performance, and can be considered to be in the comfort range. In the present study, WBGT values in all studies environments were higher than the upper temperature of broilers' comfort zone, and therefore, may not provide a good environment for these birds.



RHL values were significantly different ( $p < 0.05$ ) between the external environment (EXT) and the internal environment of the prototypes (HWC and HWOC) at the birds' mass height. This was probably due to the fact that the black globe was directly exposed to solar radiation in the external environment. There as no significant differences ( $p < 0.05$ ) in RHL between the studied prototypes (HWC and HWOC), with the model with OSB ceiling+recycled tiles presenting higher mean experimental value (Table 1). Again, this may be explained by the shading of its north side by the HWC prototype.

The shading generated by the OSB ceiling+recycled tile prototype (HWC) and by the recycled tile roof (HWOC) reduced radiant heat load in approximately 36%, possibly because the plastic curtain provided a physical barrier to the surrounding solar radiation. The internal environment of the prototypes (HWC e HWOC) presented similar behavior, showing that the physical barrier (plastic curtain) hindered the heat loss in the prototype with the ceiling.

**Table 1.** Mean experimental values of internal surface temperature (ST), globe temperature and humidity index (WBGT), and radiant heat load (RHL) at different times.

Internal surface temperature (ST)				
HWC	32.37	34.76	36.5	34.54A
HWOC	37.31	40.66	41.58	39.85B
Globe temperature and humidity index (WBGT)				
HWC	83.04	84.00	86.44	84.49A
HWOC	82.74	84.10	85.95	84.26A
EXT	87.58	90.07	91.35	89.67B
radiant heat load (RHL) - W/m <sup>2</sup>				
HWC	513.01	520.73	539.07	524.27A
HWOC	510.85	521.45	535.67	522.66A
EXT	637.77	734.16	761.04	710.99B

Means followed by different capital letters in the same column are different by the test of Tukey ( $p < 0.05$ ).

The graphs shown in Figure 3 (A, B, and C), showing the profile of the studied variables, were based on the regression equations presented in Table 2.

**Table 2.** Fitted equations of internal surface temperature (ST), globe temperature and humidity index (WBGT), and radiant heat load (RHL) as a function of time.

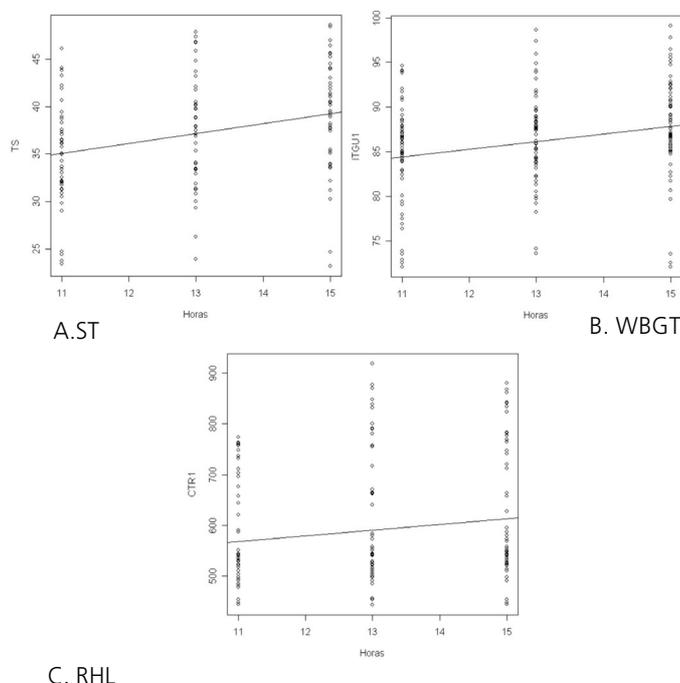
Curve equation	R <sup>2</sup>
STY = 23.5491* + 1.0496*H	0.96
WBGTY = 74.8963* + 0.8646*H	0.99
RHLY = 444.590* + 11.214*H	0.99

\* significant at  $p < 0.05$ .

Figure 3A shows that mean experimental ST values increased as a function of time, and reached its

maximum value at 03:00 pm. These results are different from those obtained by Cravo *et al.* (2008), who observed mean ST values in tiles at 12:00 pm, 01:00 pm, and 02:00 pm of 38.17°C, 37.42°C, 36.61°C in an open house, and 35.05°C, 34.98°C, 34.31°C in a closed house, respectively.

In Figure 3B, it is noted that the mean WBGT increased with time up to a peak at 03:00 pm. This behavior demonstrates that the blue plastic curtain is not sufficiently effective to block the heat waves coming from the external environment. This diurnal behavior of the WBGT values were also observed by Rosa (1984), Fonseca (1998), Zanolla *et al.* (1999), Matos (2001), and Furtado *et al.* (2003), using different roofing materials than those applied in the present study.



**Figure 3.** Estimated internal surface temperature (A. ST), globe temperature and humidity index (B. WBGT), and radiant heat load (C. RHL).

In Figure 3C, mean RHL experimental values present similar behavior relative to WBGT and ST, i.e., they all peaked at 03:00 pm. Jacomé *et al.* (2007) studied the thermal comfort index in developing replacement layer pullets housed under different roofing materials (clay and fibrocement) and obtained higher RHL values at 12:00 pm and 02:00 pm. Abreu *et al.* (2007) evaluate a polyethylene ceiling in broilers houses with fibrocement



roof, and obtained higher RHL values at 12:00 pm and 03:00 pm, which is consistent with the results of the present study.

Despite being carried out in the spring, which is less critical for broiler production as compared to the summer, the values obtained for the thermal comfort indexes indicate that the roofing system used did not provide proper thermal environment for broiler production.

## CONCLUSIONS

The results obtained in the present study allowed us to conclude that the use of a modular ceiling system in prototypes closed with curtains:

1. Was efficient as it significantly reduce internal roof surface temperature, but did not provide enough thermal comfort for broiler production.
2. Was not significantly efficient to provide adequate WBGT and RHL for broilers.

It is suggested that further research studies on this subject are carried out in real-scale broiler houses with commonly used roof materials and in association with other insulating materials.

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