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ANÁLISE DO CONFORTO TÉRMICO EM MODELOS DE GALPÕES AVÍCOLAS COM DIFERENTES ESTRATÉGIAS DE COBERTURA

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RESUMO: O objetivo deste estudo é analisar o conforto térmico em modelos de galpões avícolas com diferentes estratégias de cobertura na região central do RS na primavera de 2022. O estudo foi conduzido na UFSM, Campus de Cachoeira do Sul. Foram avaliados 3 modelos de galpões em dois períodos de coleta de dados: de 23/09 a 5/10 (período 1) e de 6 a 19/10 (período 2) , alterando a configuração de cobertura: (M1) telha de fibrocimento com pintura em branco (testemunha); (M2) telha de fibrocimento com pintura em branco e forro em lona (M2.1) – período 1; adicionalmente, pintura branco térmico (M2.2) - período 2; (M3) telha de fibrocimento com pintura em branco e forro com tela de sombreamento prata (M3.1) - período 1; alteração para sombreamento com tela prata (M3.2) - período 2. A coleta de temperatura e umidade foi realizada com termohigrometro *datalogger* a cada 2 h. Em dias de temperatura mais amena e nos horários mais frios do dia houve pouca influência da estratégia de cobertura no conforto térmico. Já, em condições temperatura mais elevada, o forro contribuiu para a mitigação do estresse calórico. O M3.1 apresentou-se como a melhor estratégia de cobertura para as condições de estudo.

Palavras-chaves: acondicionamento térmico, avicultura, estratégias construtivas.

ANALYSIS OF THERMAL COMFORT IN MODELS OF POULTRY HOUSES WITH DIFFERENT COVERAGE STRATEGIES

ABSTRACT: The objective of this study is to analyze the thermal comfort in models of poultry houses with different covering strategies in the central region of RS in the spring of 2022. The study was conducted at UFSM, Cachoeira do Sul Campus. Three models of sheds were evaluated in two periods of data collection: from 09/23 to 10/5 (period 1) and from 10/6 to 19/19 (period 2), changing the coverage configuration: (M1) fiber cement tile with white paint (witness); (M2) asbestos-cement tile with white paint and canvas lining (M2.1) – period 1; additionally thermal white paint (M2.2) - period 2; (M3) fiber cement tile painted in white and lining with silver shading screen (M3.1) - period 1; change to shading with silver screen (M3.2) - period 2. The temperature and humidity were collected with a datalogger thermohygrometer every 2 h. On days with milder temperatures and at the coldest times of the day, there was little influence of the coverage strategy on thermal comfort. However, under higher temperature conditions, the lining contributed to the mitigation of heat stress. The M3.1 was presented as the best coverage strategy for the study conditions.

Keywords: thermal conditioning, poultry, constructive strategies.

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1 INTRODUCTION

Brazil has increasingly stood out in chicken production, not only in terms of productivity but also in terms of slaughter volume and economic performance (ABPA, 2022). Chicken meat is the protein most consumed by Brazilians, who consumed an average of 43.41 kg per person $^{-1}$ in the years 2010 to 2020, according to data from the Brazilian Animal Protein Association (ABPA). Rio Grande do Sul has remained the third largest producer and exporter of broiler chickens in Brazil over the years, accounting for 13.65% of chicken slaughter in the country, behind only Paraná (35.54%) and Santa Catarina (14.89%) (ABPA, 2021).

Birds are homeothermic animals that are in continuous thermal exchange with their environment. According to Abreu and Abreu (2011), approximately 80% of the energy ingested is used to maintain homeothermia, and only 20% is used for production. Therefore, for productivity indicators to be maintained, it is important to maintain the environmental temperature within the limit (thermoneutrality zone) at which metabolic costs for thermoregulation are minimal. Under conditions of high relative humidity and temperature, birds face difficulty in exchanging excess heat with the environment, causing an increase in body temperature and, as a consequence, thermal discomfort, which leads to a decrease in production (ABREU; ABREU, 2011).

Therefore, in most chicken-producing regions in Brazil, the climate is challenging. Among the production systems, the conventional system is characterized by natural thermal conditioning, in which the warehouses only have curtains on the sides and openings at the top of the roofs, without environmental control mechanisms. Semiair-conditioned systems are characterized by the use of positive pressure fans that change humidity and air temperature conditions in the internal environment through convective processes, generally using linings to reduce the volume of internal air. Finally, a system with greater environmental control, air conditioning, in this system, in addition to the use of positive pressure fans or negative pressure exhaust fans to control the air flow, is associated with a cooling system that can use nebulization or evaporative cooling plates (BAÊTA; SOUZA, 2012). According to Carvalho *et al.* (2012) and Saraz *et al.* (2012), the distribution of heated air within a facility is influenced by its type, ventilation system, insulation, temperature and relative humidity.

The roof plays an important role in transmitting heat to the interior of the building, as according to Machado *et al.* (2012), most of the overheating originates from the roof. Protection against direct insolation from roofs can be achieved with the use of highly reflective coverings, thermal insulators and materials with high thermal inertia (ABREU; ABREU, 2011). For hot regions, tiles with thermal insulation, ceramic tiles or fiber cement tiles are more effective, especially when painted with white acrylic paint (COELHO, 2019). Souza *et al.* (2018) reported that the use of white paint on fiber cement roofs reduced the average temperature and humidity index (THI) from 77.3 to 74.9 inside reduced models of poultry sheds in the Cachoeira do Sul-RS region.

The use of the lining allows the formation of a layer of air next to the cover, which helps to reduce heat transfer into the poultry house. Thus, the lining acts as a physical barrier to the radiation received and emitted by the roof. According to Castro (2012), when lining the roof (ceramic and fiber cement), there is a general reduction in the global temperature and humidity index (ITGU) values. Camerini *et al. (2012) evaluated the influence of* ethylene vinyl acetate (EVA) waste-based lining in reduced models of agricultural facilities and found that the lining enabled a reduction in thermal index values. According to Abreu *et al.* (2007), the use of a lining under the roof increases the density of chicken farming and improves the performance of birds. Therefore, the present study aimed to analyze thermal comfort in poultry shed models with different covering strategies in the central region of the RS in the spring of 2022.

2 MATERIALS AND METHODS

The research was carried out at the Federal University of Santa Maria, Cachoeira do Sul Campus (30° 02' 21" S and 52° 53' 38" W, altitude 68 m), in the Central Depression region of the State of Rio Grande do Sul. The region's climate is classified as humid subtropical, predominant in the southern region. To characterize the external environment during the data collection period, temperature and relative humidity data were obtained from an automatic meteorological station located next to the location of the survey. experiment.

The poultry shed models (on a reduced scale) were built as described by Souza *et al*. (2018) based on real measurements of sheds used in poultry farming. Commercial warehouses generally have a width of 12 m, length of 120 m, ceiling height of 3.5 m, spacing between scissors of 5 m, eaves of 1.0 m and sidewalls of 0.15 m. With the reduction process to the 1:10 scale, the measurements of the models used are as follows: width of 1.2 meters, length of 1.5 meters – 12 m should have been used; however, 1.5 m was used (equivalent to 3 5 m modules), according to work by Santos *et al.* (2005) and Ferreira Júnior *et al.* (2009) - ceiling height of 0.35 m; 0.10 m eaves; and 1.5 cm walls. The roof slope was 15%.

Data collection was carried out in two periods, from September 23 to October 5, 2022 (period 1) and from October 6 to 19, 2022 (period 2), with changes in the configuration of the models, as shown in Table 1 and Figure 1.

Table 1. Data collection period information and coverage structure configuration.

Model	Period 1	Period 2
Model 1 (M1)	Fiber cement tile painted in white (M1).	Fiber cement tile painted in white (M1).
Model 2 (M2.1; M2.2)	Fiber cement tile with white paint + canvas lining (M2.1).	Fiber cement tile painted in thermal white + canvas lining (M2.2).
Model 3 (M3.1; (M3.2)	Fiber cement tile painted in white + lining with silver shade cloth (M3.1).	Silver shading screen on top of the roof (shading) + fiber cement tile with white paint (M3.2).

Source: Author

Figure 1. General view of the experiment in period 1. Cachoeira do Sul, 2023

Source: Author

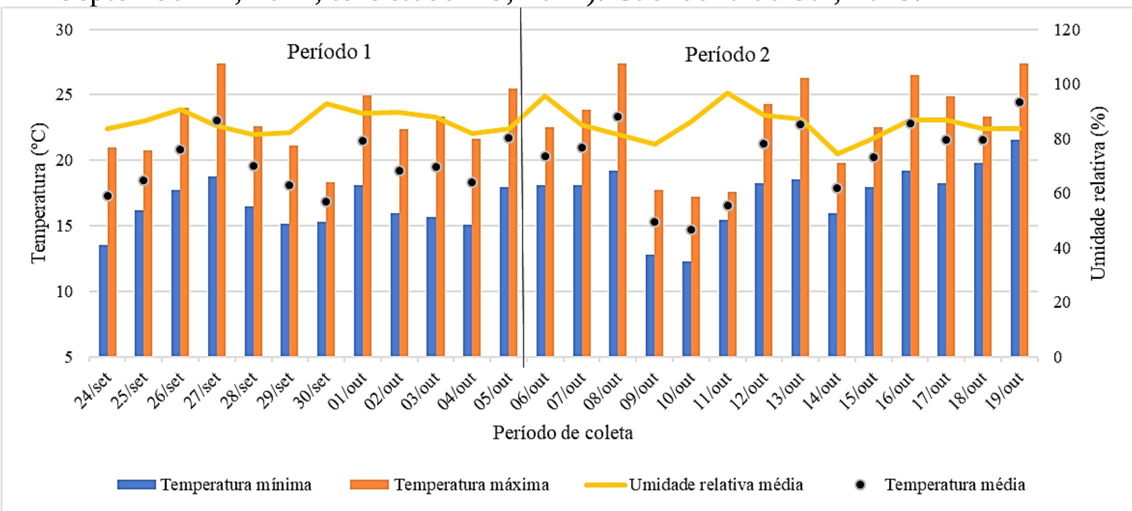
The sidewall is made of masonry, and the rest of the structure is made of wood (Figure 1). The white paint used in all sheds on the roof and on all surfaces was acrylic paint, and the thermal paint used in M2 (second collection period - M2.2) was the commercial brand Termocril. Temperature and relative humidity data were collected inside the models with a thermohygrometer. *datalogger* at 2 h intervals between collection (at 00 h, 2 h, 4 h, 6 h, 8 h, 10 h, 12 h, 14 h, 16 h, 18 h, 20 h and 22 h). With these variables in hand, the ITU was calculated using the equation proposed by Buffingrton and Canton (1983). On September 25th (period 1), images were collected with a thermal camera at the bottom of the ceiling.

For statistical analysis, air temperature and UTI data were grouped into two time intervals: 8 pm to 8 am and 10 am to 6 pm. Afterwards, they were subjected to analysis of variance, using the "F" test, and the means were compared by the "Tukey" test at a 5% probability of error. For this purpose, a randomized block experimental design was considered with three treatments, and the repetitions were the number of collections at each time.

RESULTS AND DISCUSSION

Figure 2 presents the temperature and relative humidity data obtained at the meteorological station next to the experimental site from September 24, 2022, to October 19, 2022.

Figure 2. Temperature and relative humidity data were obtained from the external environment (from September 24, 2022, to October 19, 2022). Cachoeira do Sul, 2023.



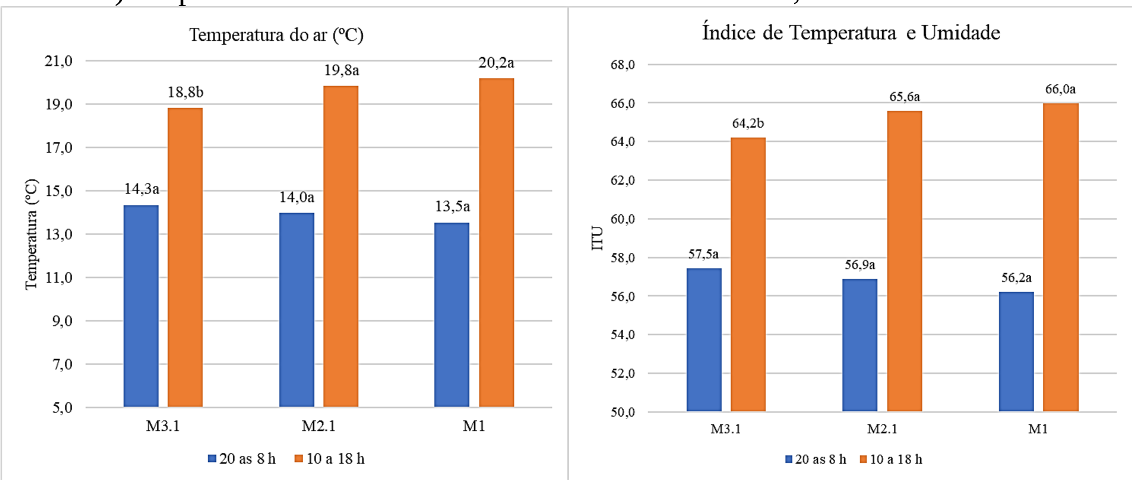
Source: Author

The air temperature varied between 12 °C and 27 °C, and the relative humidity remained high, above 70%. The conditions of high thermal amplitude and maximum temperature values below 30 °C are characteristic of the period (spring) depending on the geographical location. The average temperatures were 19.8 and 20.2 °C for periods 1 and 2, respectively, and the average relative humidity was close to 85% in both periods.

Figure 3 demonstrates that the significant differences between treatments (for the first evaluation period) occur at the time when the air temperature is highest between 10 am and 6 pm (Figure 4), with an average reduction of 1.2 °C and 1.6 ITU when using the lining with silver shade cloth (M3.1) compared to the other two models (M2.1 and M1). The use of the lining (Figure 4) also contributed to the attenuation of the thermal amplitude, which was 11.2 °C (M1), 10.8 °C (M2.1) and 9.8 °C (M3.1).

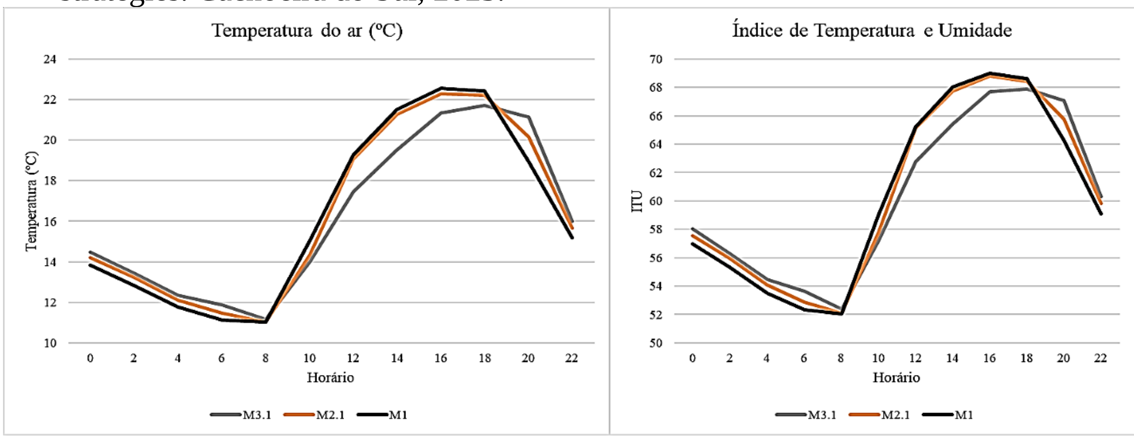
For the second period of analysis, placing silver shade cloth on top of the roof (M 3.2) did not reduce the temperature as it did in the previous period (M 3.1). Therefore, the average temperature for the period inside the aviaries on a reduced scale was between 15 °C and 20 °C for the intervals between 8 pm and 8 am and between 10 am and 6 pm, respectively. In this case, the use of thermal paint + canvas lining (M 2.2) made it possible to reduce UTIs during the hottest times of the day (Figure 5).

Figure 3. Average temperature and ITU values with results of the average test (comparing the same time) for period 1 in two time intervals. Cachoeira do Sul, 2023.



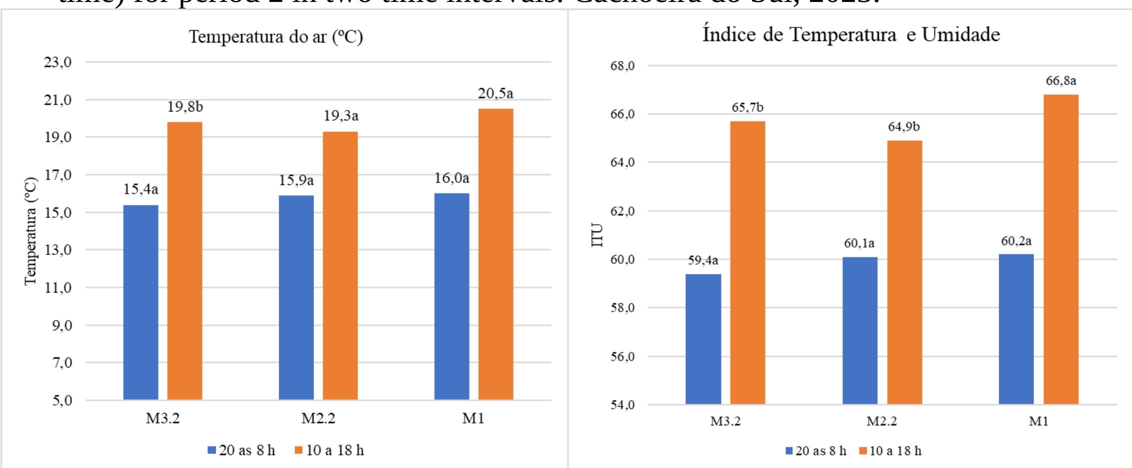
Source: Author

Figure 4. Hourly average temperature and THI values for 1 in poultry models with different covering strategies. Cachoeira do Sul, 2023.



Source: Author

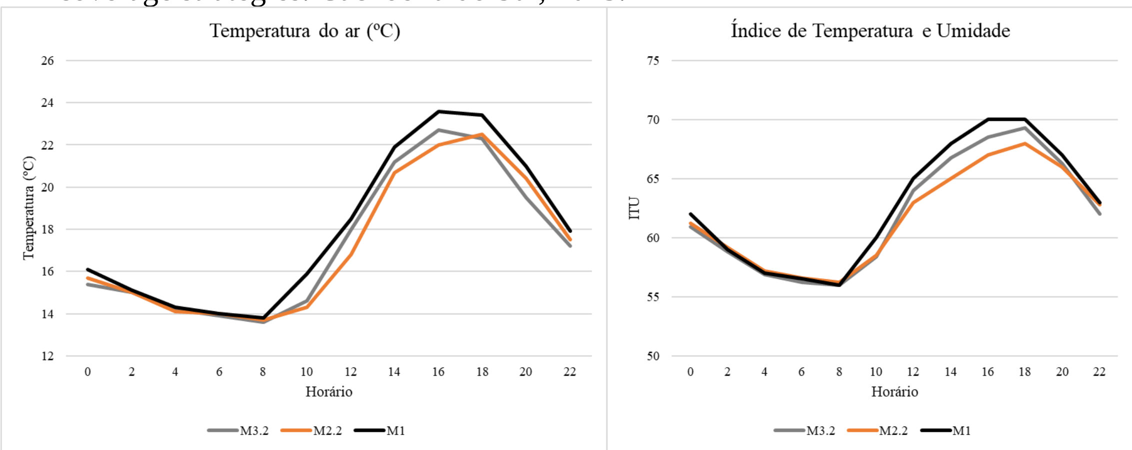
Figure 5. Average temperature and ITU values with results of the average test (comparing the same time) for period 2 in two time intervals. Cachoeira do Sul, 2023.



Source: Author

The average hourly variation in temperature and ITU for the period from 06 to 10/19 in poultry houses with different covering strategies (Figure 6) demonstrated a lower thermal amplitude with the use of thermally painted tiles + canvas lining (M 2.2), which allowed a reduction of up to 2 °C in the temperature value and 2 ITU points at the hottest times of day (4 to 6 pm).

Figure 6. Hourly average temperature and THI values for period 2 in poultry models with different coverage strategies. Cachoeira do Sul, 2023.



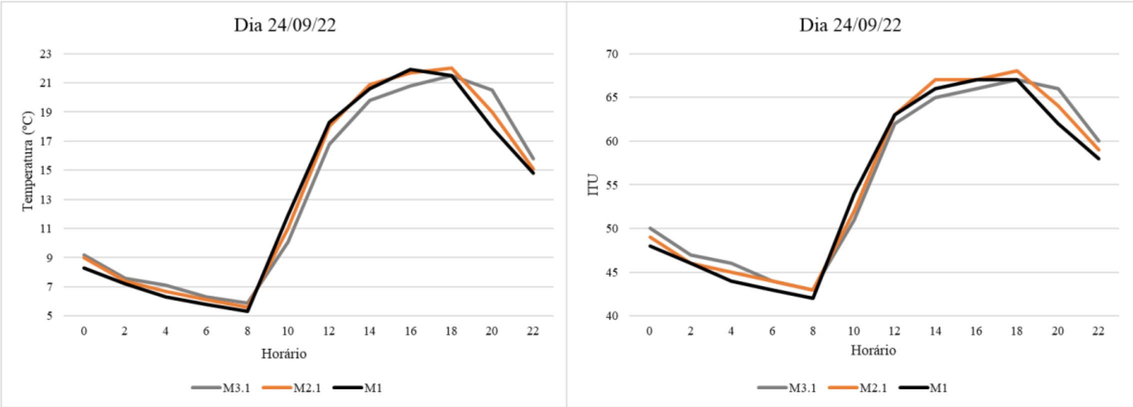
Source: Author

Through data analysis, it can be seen that the use of silver shading fabric as a lining (M 3.1) was a better strategy than the use of silver shading on top of the roof (M 3.2), and painting the roof with thermal paint improved the performance of the canvas lining (M 2.2). Compared to using tiles alone (M 1), using silver shade cloth as a lining (M3.1) reduced the temperature by an average of 1.4 °C and the ITU by 1.8. However, when used on the roof (M3.2), the temperature reduction was 0.7 °C, and the ITU decreased by 1.1. Castro (2012), evaluating the thermal comfort provided by the use of different materials in the roof and different linings using models on a reduced and distorted scale, found that when the lining was used as a shading strategy, it did not improve the thermal conditions of the room. evaluating the environment.

The use of thermal paint + canvas lining (M 2.2) reduced the internal temperature of the warehouses by up to 1.4 °C and that of the ITU by 1.8, while in the first period (M 2.1), the internal temperature decreased by up to 0. 3 °C and 0.2 ITU, compared to using tiles only (M1). Therefore, the adoption of covering strategies using reflective materials and the addition of barriers to heat transfer contribute to reducing the temperature, thermal amplitude and ITU inside poultry models, which could contribute to reducing the cost of practices for artificial thermal conditioning. The increase in internal temperature is noticed, mainly in installations that have exposed tiles, that is, when there is no ceiling (or slab) to separate the space from the rest of the building (CAMERINI *et al.*, 2012; NÄÄS *et al.*, 2007).

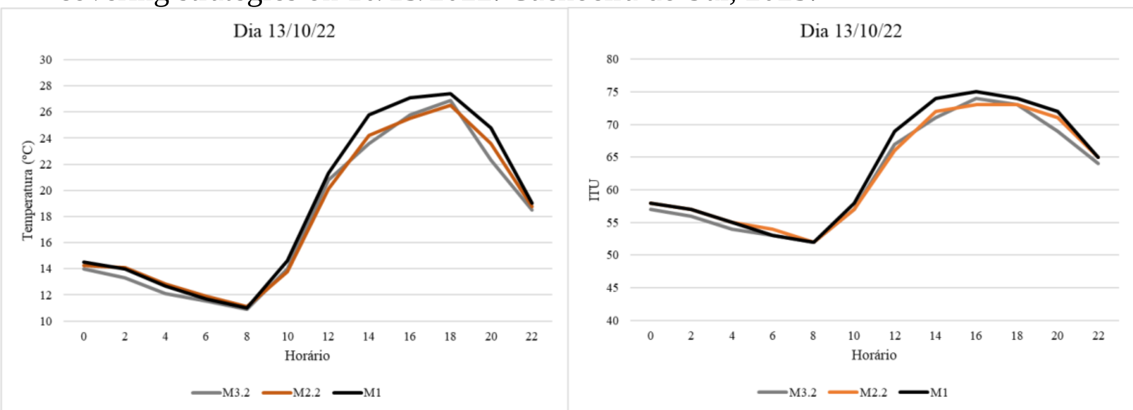
Figures 7 and 8 show the patterns of thermal comfort indicators on two days of the evaluated periods (09/24 – period 1 and 10/13 – period 2). A day with a milder temperature and a day with a higher temperature were used to determine the characteristics of the region with a high thermal amplitude. According to Oliveira and Knies (2019), the climatic conditions in the central region of Rio Grande do Sul are of high daily and annual thermal amplitude and are associated with high relative humidity (>50%).

Figure 7. Patterns of thermal comfort indicators inside small-scale poultry houses with different covering strategies on 09/24/2022. Cachoeira do Sul, 2023.



Source: Author

Figure 8. Patterns of thermal comfort indicators inside small-scale poultry houses with different covering strategies on 10/13/2022. Cachoeira do Sul, 2023.



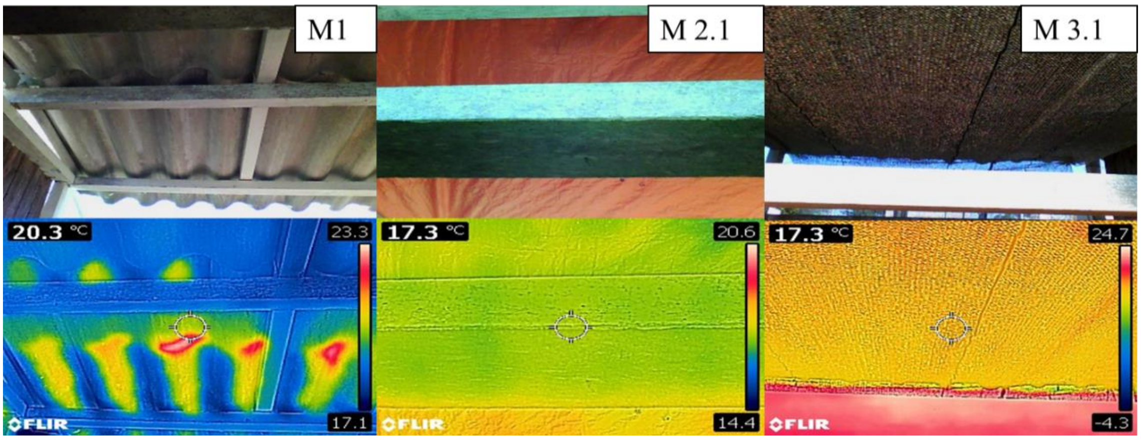
Source: Author

The daily pattern of thermal comfort indicators inside the poultry shed models evaluated demonstrated that on hotter days, such as on the 13th/10th day, there was a greater influence of the covering strategy than on days with milder temperatures, such as on the 24th day./09. This also occurs throughout the day, as at the coldest times of the day, there is little influence of the coverage strategy on the thermal comfort indicators. However, at higher temperatures, the lining contributes to mitigating heat stress, especially between 12 and 4 pm.

By analyzing the influence of the EVA waste lining on the thermal comfort of agricultural facilities, Camerini and Nascimento (2012) found, in models built on a reduced scale (1:10), that the use of the EVA lining provided better thermal conditions inside. This makes the environment more comfortable for animals in full-scale agricultural facilities. According to Abreu *et al.* (2007), the use of a lining in the roof of aviaries is justified because it results in better thermal comfort conditions for the birds.

The thermal images shown in Figure 9 illustrate the importance of the lining in reducing heat transfer to the interior of buildings, with a reduction in temperature values and the amplitude of these values. The heat flow that reaches the internal environment is directly influenced by the type of roofing material, its reflective properties and the thermal insulation it provides. In this context, the linings can be placed above or below the roof to shade the roof or to separate the attic space from the rest of the installation, which is a functional and low-cost alternative for improving thermal comfort inside buildings (CASTRO, 2012).

Figure 9 1. Set of images and thermal images captured on 09/25/2022 (first period) under different coverage strategies. Cachoeira do Sul, 2023 .



Source: Author

4 CONCLUSIONS

Among the roofing strategies evaluated in this study, the use of silver shade cloth as a lining, associated with fiber cement tiles (white painting), contributed most to reducing the temperature and humidity index inside the warehouse model. poultry farm than when used as shading (on top of the roof).

Compared with the use of acrylic paint, the use of thermal paint on fiber cement tiles contributed more to reducing the temperature and humidity indices inside the poultry shed model.

Under relatively high temperature conditions (hotter days and hotter days), the lining contributed to mitigating heat stress. However, on days with milder temperatures and at colder times of day, there was little influence of the covering strategy on the thermal comfort indicators.

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