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Thermoregulation and performance of *Melipona scutellaris* Latreille in beehives made of different types of wood

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ABSTRACT: In this research was evaluated the temperature of the nest and hive, production and biometry of *Melipona scutelaris* hives made with pine and macaúba wood, and macaúba trunk. Twenty-four hives were used consisting of eight of macaúba, eight of pine, and eight of macaúba trunk to collect the productive and biometric data of M. scutellaris bees. Four collections were carried out with intervals of 30 days, evaluating each colony considering the following variables: number, size, and volume of honey pots, estimate of honey production, number of combs, average diameter of combs, height of combs, height of cell brood, number of combs, and number of wax coat on pups. The air temperature had a higher value (28.8 °C) at 5:00 p.m. and lower at 8:00 a.m. (20.5 ºC), with a thermal amplitude of 8.3 ºC. The relative air humidity reached the highest value at 9 a.m. (93.7%) and the lowest (49.4%) at 5:00 p.m. The temperature black globe and humidity index (TBGHI) had the highest values (80.2) between 1:00 p.m. and 2:00 p.m. and the lowest (71.2) at 5:00 p.m. The materials used to built the hives (pine, macaúba, and macaúba trunk) had a significant impact on temperature regulation. The beehive made of macaúba trunk promoted the temperature reduction on average of 0.5 oC in comparison to beehives made with pine. The insulating effect of wood reduced temperature variations in the nest in relation to the ambient temperature. The colonies of *M. scutellaris* had the production of honey influenced by the type of wood used to build the hives.

Key words: nest temperature; rational breeding; stingless bee; thermography; “uruçu do Nordeste”

Termorregulação e desempenho de *Melipona scutellaris* Latreille em colmeias com diferentes tipos de madeira

RESUMO: Nesta pesquisa foi avaliada a temperatura do ninho e colmeia, produção e biometria de colmeias de *Melipona scutelaris* feitas com madeira de pinus e macaúba, e tronco de macaúba. Foram utilizadas 24 colmeias, sendo oito de macaúba, oito de pinus e oito de tronco de macaúba para coletar os dados produtivos e biométricos das abelhas *M. scutellaris*. Foram realizadas quatro coletas com intervalos de 30 dias, consistindo na avaliação de cada colônia submetida aos diferentes tratamentos, considerando os seguintes parâmetros: número, tamanho e volume de potes de mel, estimativa de produção de mel, número de favos, diâmetro médio de favos, altura dos favos, altura da ninhada celular, número de favos, número de pelagem de cera nos filhotes. A temperatura do ar apresentou maior valor (28,8 °C) às 17 h e inferior às 8 h (20,5º C), com amplitude térmica de 8,3 ºC. A umidade relativa do ar atingiu o valor mais alto às 9h (93,7%) e o mais baixo (49,4%) às 17 h. O índice de temperatura de globo negro e umidade (ITGU) apresentou o maior valor (80,2) entre as 13 e 14 h e o menor valor às 17 h (71,2). A temperatura do ninho foi significantemente afetada pelo material usado na confecção das colmeias. A colmeia confeccionada de tronco de macaúba proporcionou redução de temperatura na ordem de 0,5 oC comparado às colmeias confeccionadas com pinus. O efeito isolante da madeira reduz as variações de temperatura no ninho em relação à temperatura ambiente. As colônias de *M. scutellaris* tiveram a produção de mel influenciada pelo tipo de material utilizado na confecção das colmeias.

Palavras-chave: temperatura do ninho; criação racional; abelha sem ferrão; termografia; uruçu do Nordeste

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Introduction

The stingless bee *Melipona scutellaris* is found mainly on the coastal strip of the Northeast region of Brazil (Brito et al., 2013). These bees prefer to inhabit humid places, and they nest naturally in tree hollows. Due to their large size and easy domestication, they are attractive to commercial breeders. In addition, this species stands out from other meliponines due to the higher commercial value of produced honey compared to *Apis mellifera* (Dorigo et al., 2019). However, in tropical regions, honeys physical and chemical characteristics are still poorly known since the bee flora is quite diverse, associated with high rates of humidity and temperature (Medeiros & Souza, 2016).

Belonging to the Meliponina subtribe, Meliponine bees vary in size from very small to medium, and are grouped in the Apidae family, as are other social bees (Duarte et al., 2018). Meliponines, also known as stingless bees, have a stunted stinger and are therefore unable to sting (Francoy et al., 2016). They are also known as "indigenous bees" or "native bees" due to the creation of indigenous peoples, carried out for many centuries (Carvalho et al., 2014). This is the reason why many of the scientific names of this group of bees are of indigenous linguistic origin, the Tupi (Athayde et al., 2016).

The most frequent nesting sites for meliponines are pre-existing cavities, such as tree hollows, rock crevices, soil cavities, and interior of termite nests, with exposed or semi-exposed nests (Batista et al., 2003). Some species may occasionally nest in other types of natural or artificial cavities, such as ravines, walls and crevices in walls (Athayde et al., 2016). In studies with bees, it is often difficult to quantify characteristics of economic interest. Therefore, it is necessary to conduct a study that involves the characteristics that directly and indirectly influence the colony (Henry & Rodet, 2017). In addition, most meliponine beekeepers report the increasing need to explore and constantly evaluate the potential and performance of their colonies in order to maximize productivity, minimize costs, and labor (Medeiros & Souza, 2016; Requier et al., 2017; Silva et al., 2020).

The objective of this work was to evaluate the temperature of the nest and hive, production and biometry of *M. scutelaris* hives made with pine and macaúba wood, and macaúba trunk.

Materials and Methods

Experiment site

Data were collected from a meliponary located in Areia, Paraíba, Brazil (latitude -6° 55′ 60″ S and longitude -35° 36′ 60′′ W) and altitude of 333 m a.s.l. The annual average temperatures vary from 18.0 to 26.0 °C, presenting an irregular annual rainfall distribution of 1,415.6 mm.

Bee hive

Twenty-four hives made of macaúba and pine wood, and macaúba trunk with eight of each one to collect the productive and biometric data of *M. scutellaris* bees (Figure 1).

The hives made with wood of macaúba and wood of pine had 20 × 20 × 60 cm in W × H × L, and 2 cm thick wooden wall, making up a volume of 24 L of the complete hive. This type of hive was predominant in the meliponary and by the use of macaúba trunk. The macaúba trunk had dimensions of approximately 20 × 60 cm in diam × L, in which adaptations were made with the placement of hinges on the lid and knockers to facilitate handling.

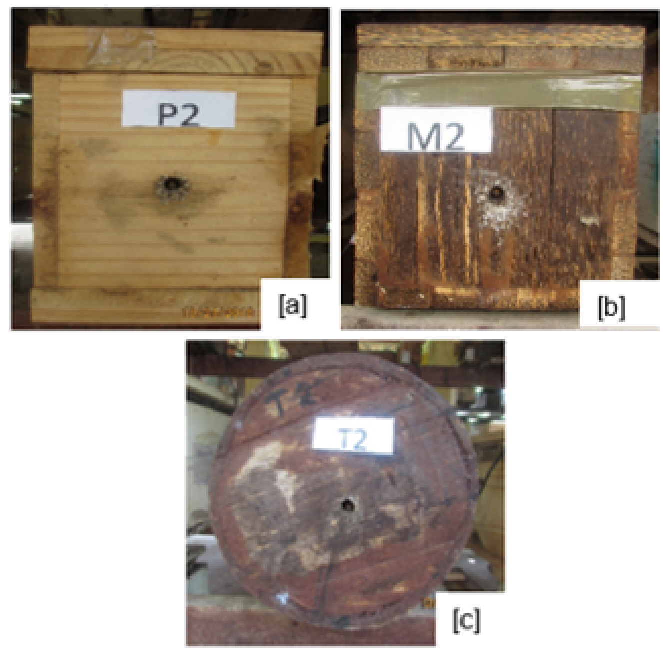

Figure 1. Experimental hives [a] pine wood, [b] macaúba wood, and [c] macaúba trunk.

Determination physical and thermal

Samples of pine and macaúba wood were taken in the size of 1.5 × 0.3 m in L × W following the guidelines of NBR 7190 (ABNT, 1997), for the determination of physical (moisture and density) and thermal (thermal conductivity) properties and thermal resistance), and the analyzes to determine the humidity and density

The moisture content was determined through simplified characterization, using six specimens of each type of wood, with a rectangular cross section, 2 × 3 cm length, along the fibers of 5 cm (NBR 7190 - ABNT, 1997). After determining the initial mass, the wood were placed in an oven with circulation and air renewal (SOLAB™, SL-102/480, Piracicaba, SP, Brazil), with a maximum temperature of 103 ± 2 °C. During drying, the mass of the specimens was checked every 6 hours, until there was a variation between consecutive measurements, less than or equal to 0.5% of the last mass measured.

Once the dry mass (ms) was known, the moisture was determined by the Equation 1.

$$M(\%) = \frac{im - md}{md} \times 100 \quad (1)$$

where: im - initial mass of the wood (g); and, sm - mass of dry wood (g).

The pine and macaúba samples were submerged in water until they reached constant mass with a maximum variation of 0.5%, in relation to the previous measurement. The saturated volume (Vsat) was reached by the fine dimensions of the specimen, through a digital caliper with a precision of 0.1 mm, Stainless Hardened model. For the dry mass (ms) the same procedure used to determine the moisture content was followed.

Thus, the basic density (ρbas) was determined by the Equation 2.

$$\rho bas = \frac{dm}{Vsat} \quad (2)$$

where: dm - dry mass of wood (kg); and, Vsat - volume of saturated wood (m³).

The fluximetric method was adopted in steady state, according to NBR 15220-5 (ABNT, 2005). To determine the thermal conductivity and thermal resistance of the pine and macaúba wood samples, the K30 Conductivity Meter was used.

- Thermal conductivity: quotient of the heat flux by the temperature gradient in the specimens, according to the Equation 3.

$$\lambda = \frac{\frac{q}{A}}{\frac{\Delta T}{e}} \quad (3)$$

where: q - heat flux by conduction through a specimen of thickness "e" and area "A", in steady state, subject to a temperature difference ΔT between the faces, calculated by the Equation 4.

$$q = \frac{\lambda \cdot A}{e} \Delta T \quad (4)$$

- Thermal resistance: value obtained by the Equation 5.

$$R = \frac{e}{\lambda} \quad (5)$$

In this test, planar samples of wood were used, based on the measurement of the heat flux and the temperature difference between the sides of the sample, submitted to the thermal gradient, defined in the equipment. The samples of the wooden boards had the following dimensions: 30 × 30 cm in W × L; the thicknesses being equal to 2 cm for the pine board and for the macaúba board.

Environmental variables

The internal environment of the meliponary was characterized with the aid of two black globes handmade from plastic spheres 15 cm in diameter and DHT 22 sensors connected to a microcontroller and inserted to collect Tgn.

For the monitoring the temperature inside the colonies (nest area), DHT22 sensors were used, directly connected to a free hardware electronic prototyping platform and a single plate designed with an Atmel AVR microcontroller, with input/output support embedded with a standard programming language, with AT Mega 2560 microcontroller, which has 54 digital ports (Figure 2).

The data logger was programmed to collect instantaneous temperature data in the periphery of the nests of the 24 hives during 15 minutes intervals. Subsequently, the average data for each hour were obtained during the 24 hours period throughout the experimental period (148 days).

By using the Microsoft Excel program, the average, maximum and minimum values (hourly, daily, and monthly) of all nest and external environment temperature data were calculated. The daily maximum and minimum values was used to calculate the thermal amplitude of the surface of the nest of the experimental hives was established concerning. Furthermore, the thermal gradient of the surface of the nests of the experimental hives was determined from the difference between the average daily temperatures during the experimental period and the ambient temperature, the latter being obtained through daily records from the meteorological station in Areia, Paraíba, Brazil.

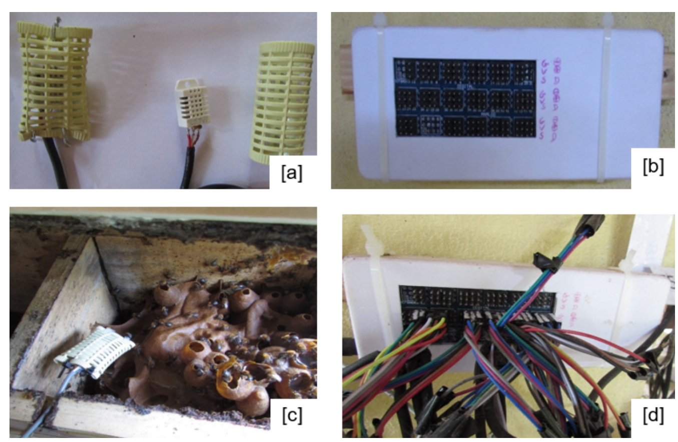

Figure 2. Instrument used to collect temperatures in the nest [a] DHT22 sensors, [b] ATmega 2560 microcontroller, [c] In-cage sensor stops in the nest area, and [d] digital ports with sensors connected.

Camera thermographic

The thermographic camera (FLIR, TG165, Wilsonville, OR, USA) with an accuracy of ± 0.15 °C, temperature range from -25 to 380 °C and infrared spectrum range from 8 to 14 µm was used to take the readings from each closed hive. Average data was obtained from each collection repeated every three hours, at 7:30 a.m., 10:30 a.m., and 1:30 p.m., respectively.

Production parameters

The variables described above were collected 4 times at intervals of 30 days consisting of the evaluation of each colony submitted to the different hives, considering the following variable: number, size, and volume of honey pots (NHP, SHP, and VHP, respectively), estimate of honey production (HP), number of combs (NC), average diameter of combs (ADC), height of combs (HC), height of cell brood (HCB), number of combs (NC), and number of wax coat on pups (NWCP). The beehives were populated and after 45 days of this process, the population estimate (POP) was obtained according to the Equation 6.

$$POP = \left(\frac{NBC + NBC}{2} \right) \quad (6)$$

where: NBC - number of cells brood in the colony.

The methodology applied to carry out the collections were based on the studies of biometric and productive parameters carried out by Silva et al. (2020). Collections were always started at the same time (7:30 a.m.), and measurements were taken with the aid of a 150 mm/MTX digital caliper (Digital 50, DIGIMESS, Mooca, SP, Brazil), with a measurement range of 0.01-150 mm and an error of 0.03 mm. Disposable syringes graduated up to 20 mL were used to determined the honey volume. In this study, the NWCP was computed by the simple counting method. From the readings taken, arithmetic averages were performed for each hive in the experimental period (Figura 3).

Productive characteristics were assessed by the size of the honey pots (height and diameter) and the average volume of the operculated honey pots (n = 05/colony). Then, honey production was estimated for each hive by counting the operculated pots, multiplying the number obtained by the average volume of honey pots found at each collection field.

The population estimate for each colony was obtained by using the Equation 7.

$$NBC = ADB \times NC \times k \quad (7)$$

where: NBC - stands for number of brood cells is the product of: ADB - average diameter of brood combs, NC - number of combs, and k = 27 is the constant of the number of cells per area (number of cells/honeycomb diameter).

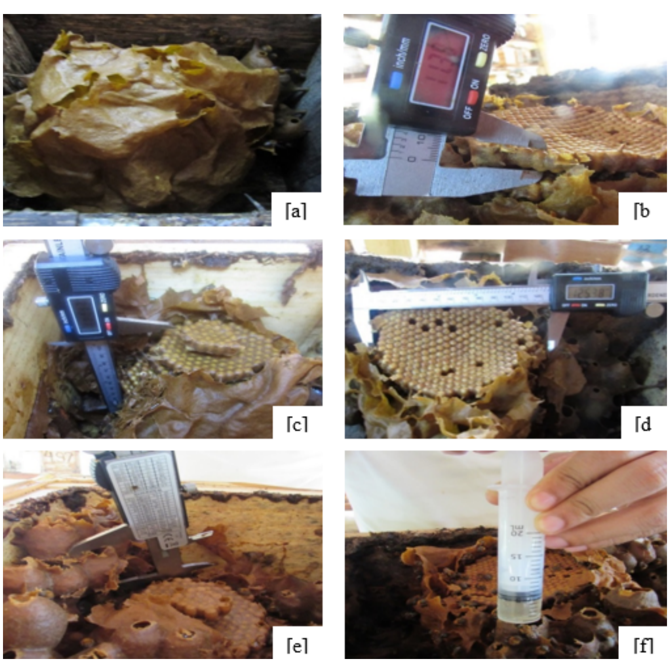

Figure 3. Production measurement process and biometrics: [a] counting of the wax envelope involving the pups, [b] height of brood cell, [c] height of brood combs, [d] diameter of brood combs, [e] height of the honey pot, and [f] volume of the honey pot.

Statistical analysis

A completely randomized design was adopted, consisting of three types of hives (pine, macaúba, and macaúba trunk), with eight replications. The data obtained were evaluated by means of analysis of variance (ANOVA) and the means compared by Tukey's test at 5% significance level using the GLM procedure (General Linear Model) of the SAS® Statistics Software (SAS, 2001).

Results and Discussion

The analysis of the woods showed that there was no variation between the woods tested for moisture content. However, there was a greater variation between the pine and macaúba woods for density and thermal resistance (Table 1).

Although research does not analyze the properties of wood, which will be used in the construction of hives, it is understood that knowing these properties is very important. In addition, the natural durability of the wood must also be taken into account in this choice, especially if it is exposed to the open environment.

According to Jarimi et al. (2020) the type of wood and the appropriate thickness are important variables to be considered in the construction of hives, since it must provide thermal insulation, protection from wind and rain. In regions where reduction or increase the internal temperature of the hive is relevant, the choice of a wood thickness that meets the thermoregulatory needs of the colony and adequate to the local temperature can be used as a strategy.

The Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri, 2017) suggests that the thickness of the wood is a fundamental element to be considered in the construction, as it can avoid excessive temperature

Table 1. Mean results of moisture content, basic density, thermal conductivity and thermal resistance of pinus (*Pinus* sp.) and macaúba (*Acrocomia aculeata*) samples.

Properties	Woods	
	Pinus	Macaúba
Moisture content (%)	12.56	12.14
Base density (g cm^{-3})	0.63	0.93
Thermal conductivity W mk^{-1})	0.13	0.13
Thermal resistance (m^2 k W^{-1})	133.18	120.71

fluctuations inside the hive, offering thermal comfort. The same was observed by Jesus (2017) in Florianópolis, using *Pinus elliotti* wood for *Plebeia droryana* hives, increasing the box thickness from 2.5 to 4.7 cm, thus verifying that the thicker insulation kept smaller humidity variability (2%) and lower temperature oscillation (10%), in relation to the thickness recommended in the literature (2.5 cm).

The value of the ambient temperature (AT) and relative air humidity of the air (RH) were observed to be practically constant during the first nine hours of the day. As of 9:00 a.m., AT and RH increased and decreased, respectively (Figure 4).

The air temperature had a higher value (28.8 °C) at 5:00 p.m. and lower at 8:00 a.m. (20.5 °C), with a thermal amplitude of 8.3 °C. The RH reached the highest value at 9 a.m. (93.7%) and the lowest (49.4%) at 5 p.m. The temperature black globe and humidity index (TBGHI) had the highest values (80.2) between 1 and 2 p.m. and the lowest (71.2) at 5 p.m. Nest temperature had a significant effect ($p < 0.05$) for hive materials (pine, macaúba, and macaúba trunk) (Table 2), with pine having the highest temperature for the nest.

The temperature considered optimal for the nest in stingless bee species is between 28 and 36 °C (Dorigo et al., 2019). In the experimental hives of pine, macaúba and macaúba trunk was observed that the nests maintained average temperatures within the adequate range (Table 2). The temperature variation from the hive to the nest shows that *Melipona scutellaris* maintains its colonies in a relatively high temperature range, even when there are variations in the ambient temperature. However, we must take into account that the thermoregulatory process can be influenced not only by the action of the external environment, but also by other factors such as positioning of the meliponary, height of the hives, exposure of the hives to the sun for a long time, nesting time and more frequent handling for data collection.

Table 2. Temperature (means ± SD) of *Melipona scutellaris* hive nests made with different woods.

Different woods	Nest temperature (ºC)
Pinus	27.3 ± 2.58a
Macaúba	26.8 ± 3.07b
Macaúba trunk	26.8 ± 2.87b
p-value	< 0.0001

a,b - Different letters in the column differ by the Tukey test at the 5% probability level.

Unlike *A. mellifera* bees that manage to control the internal temperature of the nest within a thermal range of 33 and 36 °C by producing metabolic heat, achieving variations in temperature of heat or cold inside the nest, bee does not have this ability to actively regulate the nest environment. They are dependent on nesting site and nest structure, such as the wax covers that surround the rearing area and help retain heat for developing broods (Dively et al., 2017).

The external temperature of the hives had no significant effect ($p > 0.05$) in relation to the type of material used in the construction of the hives (Table 3).

Although the appropriate installation evaluated has constructive characteristics (ceiling height and roof pitch) within dimensions, the outer side of the meliponary has different environmental characteristics, consisting of high and dense vegetation on the right side and low and thin vegetation on the left side.

While the external temperature of the hive presented an average of 29 ºC (Table 3), it was observed that this temperature of the nest was lower than the external

Table 3. Thermography of *Melipona scutellaris* hives made with different woods.

Different woods	Thermography of hives (ºC)
Pinus	29.2 ± 3.36
Macauba	29.9 ± 12.93
Macaúba trunk	29.2 ± 3.33
p-value	0.2371

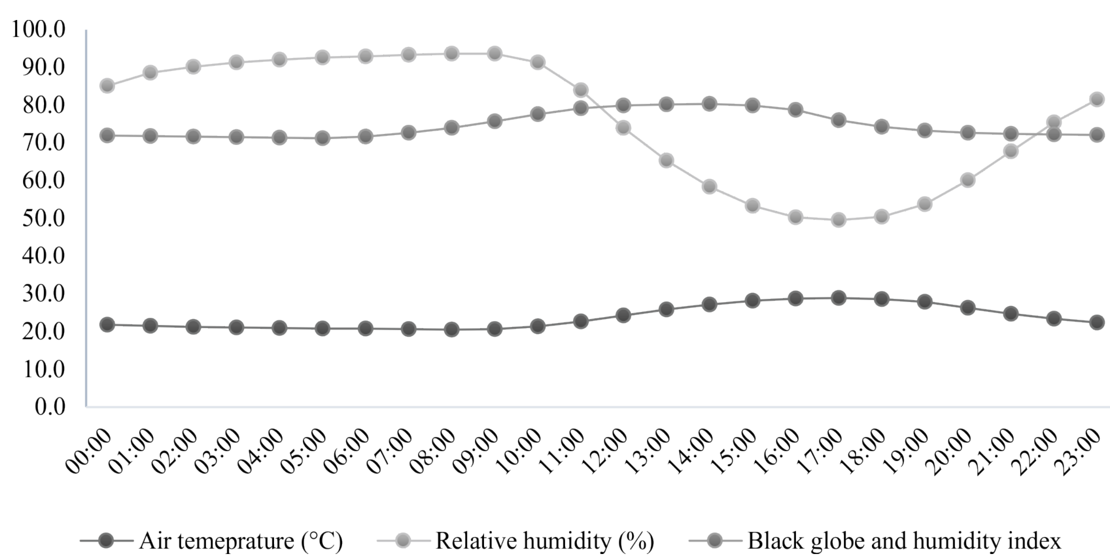

Figure 4. The air temperature, relative air humidity and the black globe and humidity index determinted for the facilities of the meliponary during the experimental period.

temperature of the hive. The hive made of pine showed a difference of 1.91 °C from outside. Temperatures inside the hives made of macaúba wood and macaúba trunk were 2.30 and 2.53 ºC, respectively. Infrared thermography contributes to the knowledge of thermoregulation due to thermal changes in the nest (Figure 5) (Mota-Rojas et al., 2021).

It is also an option in the identification of environmental conditions and their influence on animal behavior, promoting the diagnosis of these environmental conditions at specific temperatures in a less invasive way; this has been widely used in animal production (Reyes-Sotelo et al., 2021).

In the results obtained for honey production characteristics, it was observed that NHP (number of honey pots), SHP (size of honey pots), and VHP (volume of honey pots), did not present significant differences ($p > 0.05$) among the hives of pine, macaúba, and macaúba trunk (Table 4).

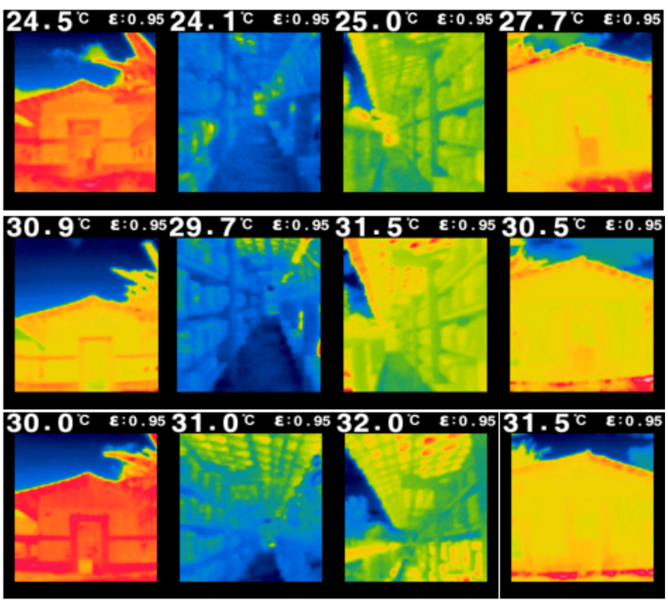

Figure 5. Thermographic images of the facades of the meliponary.

Temperature is the physical condition that most directly affects the metabolism of insects, it will also influence the development of broods. When young bees survive extreme temperature variations in the nest, they may have morphological, physiological or behavioral deficiencies in adulthood. Consequently, it can be assumed that these changes have negative results for the production of honey and other hive by-products. Brito et al. (2013) suggested that the productive and biometric characteristics are affected between different generations of *Melipona* in the same colony.

The estimated population (POP), considering the total number of eggs, larvae and adults are directly related to the characteristics of the hatching disc and is influenced by the availability of nectar and pollen. Torres et al. (2015) reported that the number of individuals is a significant factor. Populous colonies have many forage workers that collect more resources during flowering seasons and allow for the defense and maintenance of adequate temperatures for the development of broods. However, studies on the evasion of *M. scutellaris* workers carried out by Stanimirovic et al. (2019).

The honey production showed a significant difference ($p = 0.023$) in relation to the type of wood used to build the in the hives. The bees nested in the hives made of macaúba trunk had a a greater honey production amount of honey in the macaúba trunk. The analysis of the biometric measurements, however, did not portray significant difference depending regarding the tested woods used to build the hives (Table 5). Kulhanek et al. (2021) found that during repetitive or unnecessary management, there is a gradual decrease in the number of individuals in the colony, with a loss of 83.3% of the bees, leading to a decrease in productivity and even the death of the colony.

Table 4. Mean values of number of honey pots (NHP), size of the honey pots (SHP), volume of honey pots (VHP), and honey production (HP), traits assessed in the colonies of *Melipona scutellaris* nested in hives of different woods.

Different woods	NHP (unit)	SHP (mm)	VHP (mL)	HP (mL)
Pinus	9.4 ± 4.20 a	15.4 ± 3.41 a	6.8 ± 1.54 a	62.4 ± 30.30 c
Macaúba	9.7 ± 5.39 a	17.8 ± 3.49 a	7.5 ± 0.99 a	72.8 ± 44.24 b
Macaúba trunk	9.8 ± 4.90 a	16.6 ±3.61 a	6.9 ± 1.75 a	82.8 ± 5.47 a
p-value	0.381	0.112	0.230	0.023

a, b - Different letters in the columns differ by the Tukey test at the 5% probability level.

Table 5. Mean of biometric characteristics average diameter of comb (ADC), height of combs (HC), height of cell brood (HCB), number of combs (NC), number of pups (NP), and number of wax coat on pups (NWCP), evaluated in colonies of *Melipona scutellaris* nested in hives with different types of woods.

Different woods	ADC (mm)	HC (mm)	HCB (mm)	NC (unit)	NP (unit)	NWCP (unit)
Pinus	85.1 ± 13.21	103.8 ± 28.92	11.3 ± 0.31	10.7 ± 2.80	271.0 ± 103.20	2.8 ± 0.72
Macaúba	77.3 ± 16.82	101.3 ± 29.43	11.4 ± 0.37	9.8 ± 2.28	227.1 ± 85.17	3.0 ± 0.84
Macaúba trunk	77.1 ± 17.73	104.3 ± 39.70	11.6 ± 0.41	11.6 ± 2.40	262.8 ± 100.29	2.9 ± 0.80
p-value	0.2438	0.9159	0.4431	0.0909	0.5188	0.5811

a, b - Different letters in the columns differ by the Tukey test at the 5% probability level.

Conclusions

The choice of nesting site is a significant decision of meliponian bees to maintain the internal temperature inside the nests appropriate to the colony growth.

The wood tested in this study to build the hives affected the temperature variations inside the nest in relation to the ambient temperature. Furthermore, the colonies of *M. scutellaris* had the production of honey influenced by the type of material used to build the hives.

The beehive made of macaúba trunk had a lower temperature value, 0.5 °C, than the beehives made of pine. Studies with *M. scutellaris* in commercial farming need further investigation regarding thermal comfort indexes, the effect of the facilities where the colonies are housed, and not just the types of hives where they are nesting, with a need for more significant expansion in the studies on the effect of temperatures on rational breeding systems of the species.

Compliance with Ethical Standards

Author contributions: Conceptualization: MCS, DAF; Data curation: MCS, YCCP; Formal analysis: NLR; Funding acquisition: DAF; Investigation: MCS, , YCCP; Methodology: MCS, DAF, NLR; Project administration: DAF; Resources: MCS, DAF; Software: NLR; Supervision: DAF; Validation: MCS; Visualization: MCS, DAF, NLR; Writing – original draft: MCS, DAF, NLR; Writing – review & editing: MCS, DAF, NLR.

Conflict of interest: The authors declare that there is no conflict of interests.

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Literature Cited

Associação Brasileira de Normas Técnicas - ABNT. NBR 7190: Projeto de estrutura de madeira. Rio de Janeiro: ABNT, 1997. 107p.

Associação Brasileira de Normas Técnicas – ABNT. NBR15220-5: Desempenho térmico de edificações Parte 5: Medição da resistência térmica e da condutividade térmica pelo método fluximétrico. Rio de Janeiro: ABNT, 2005. 10p.

Athayde, S.; Stepp, J.R.; Ballester, W.C. Engaging indigenous and academic knowledge on bees in the Amazon: implications for environmental management and transdisciplinary research. Journal of Ethnobiology and Ethnomedicine, v. 12, e26, 2016. https://doi.org/10.1186/s13002-016-0093-z.

Batista, M. A; Ramalho, M.; Soares, A. E. E. Nesting sites and abundance of Meliponini (Hymenoptera: Apidae) in heterogeneous habitats of the Atlantic Rain Forest, Bahia, Brazil. Lundiana, v.4, n. 1, p. 19-23, 2003. https://doi.org/10.35699/2675-5327.2003.21830.

Brito, B.B.P.; Faquinello, P.; Paula-Leite, M. C.; Carvalho, C.A.L. Parâmetros biométricos e produtivos de colônias em gerações de *Melipona quadrifasciata anthidioides*. Archivos de Zootecnia, v. 62, n. 238, p. 265-273, 2013. https://doi.org/10.21071/az.v62i238.669.

Carvalho, R.M.A.; Martins, C.F.; Mourão, J.S. Meliponiculture in Quilombola communities of Ipiranga and Gurugi, Paraíba state, Brazil: an ethnoecological approach. Journal of Ethnobiology and Ethnomedicine, v.10, e3, 2014. https://doi.org/10.1186/1746-4269-10-3.

Dively, G.P.; Embrey, M.S.; Kamel, A.; Hawthorne, D.J.;, Pettis, J.S. Correction: Assessment of chronic sublethal effects of imidacloprid on honey bee colony health. PLoS ONE, v.10, n.3, e0118748, 2017. https://doi.org/10.1371/journal.pone.0118748.

Dorigo, A.S.; Rosa-Fontana, A.S.; Soares-Lima, H.M.; Galaschi-Teixeiram J.S.; Nocelli, R.C.F.; Malaspina, O. *In vitro* rearing protocol for the stingless bee species *Melipona scutellaris* for toxicological studies. Plos One, v.14, n.3, e0213109, 2019. https://doi.org/10.1371/journal.pone.0213109.

Duarte, A.W.F.; Vasconcelos, M.R.S.; Oda-Souza, M.; Oliveira, F.F; Lópes, A.M.Q. Honey and bee pollen produced by Meliponini (Apidae) in Alagoas, Brazil: multivariate analysis of physicochemical and antioxidant profiles. Food Science and Technology, v. 38, n.3, p. 493-503, 2018. https://doi.org/10.1590/fst.09317.

Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina – Epagri. Produção e processamento de pólen apícola. Florianópolis: Epagri, 2017. 28p, (Epagri. Boletim Didático, 140) https://ciram.epagri.sc.gov.br/ciram_arquivos/apicultura/acervo/BD140-producao-e-processamento-de-polen-apicola.pdf. 05 Nov. 2022.

Francoy, T. M.; Bonatti, V.; Viraktamath, S.; Rajankar, B. R. Wing morphometrics indicates the existence of two distinct phenotypic clusters within population of *Tetragonula iridipennis* (Apidae: Meliponini) from India. Insectes Sociaux, v.63, n.1, p. 109-105, 2016. https://doi.org/10.1007/s00040-015-0442-2.

Henry, M.; Rodet, G. Controlling the impact of the managed honeybee on wild bees in protected areas. Scientific Reports, v.8, e9308, 2018. https://doi.org/10.1038/s41598-018-27591-y.

Jarimi, H.; Tapia-Brito, E.; Riffat, S. A Review on Thermoregulation Techniques in Honey Bees' (*Apis mellifera*) Beehive Microclimate and Its Similarities to the Heating and Cooling Management in Buildings. Future Cities and Environmental, v.6, n. 1, e7, 2020. https://doi.org/10.5334/fce.81.

Jesus, F. T. Sistema de calefação para ninhos de abelhas sem ferrão com controle e leitura de temperatura interna por sistema remoto. Florianópolis: Universidade Federal de Santa Catarina, 2017. 75p. Master's Dissertation. https://repositorio.ufsc.br/handle/123456789/179779. 05 Nov. 2022.

Kulhanek, K.; Steinhauer, N.; Wilkes, J.; Wilson, J.; Spivak, M.; Sagili, R.R.; Tarpy, D.R.; McDernott, E.; Garavito, A.; Rennich, K.; VanEngelsdorp, D. Survey-derived best management practices for backyard beekeepers improve colony health and reduce mortality. Plos One, v.16, n.1, p. e0245490, 2021. https://doi.org/10.1371/journal.pone.0245490.

Medeiros, D.C.F.; Souza, M.F.F. Contaminação do mel: a importância do controle de qualidade e de boas práticas apícolas. Atas de Ciência da Saúde, v.3, n.4, 2016. https://revistaseletronicas.fmu.br/index.php/ACIS/article/view/1073. 05 Nov. 2022.

Mota-Rojas, D.M.; Titto, C.G.; Orihuela, A.; Martinez-Burnes, J.; Gómez-Prado, J.; Torre-Bernal, F.; Flores-Padilla, K.; Fuente, V.C.; Wang, D. Physiological and Behavioral mechanisms of thermoregulation in mammals. Animals, v.11, n.6, p. 1733, 2021. https://doi.org/10.3390/ani11061733.

Requier, F.; Odoux, J.-F.; Henry, M.; Bretagnolle, V. Te carry-over efects of pollen shortage decrease the survival of honeybee colonies in farmlands. Journal of Applied Ecology, v. 54, p. 1161–1170, 2017. https://doi.org/10.1111/1365-2664.12836.

Reyes-Sotelo, B.; Mota-Rojas, D.; Martinez-Burnes, J.; Olmos-Hernández, A.; Hernández-Ávalos, I.; José, N.; Casas-Alvarado, A.; Gómez, J.; Mora-Medina, P. Thermal homeostasis in the newborn puppy: behavioral and physiological responses. Journal of Animal Behaviour and Biometerology, v.27, e2112, 2021. https://doi.org/10.31893/jabb.21012.

SAS Institute. SAS software. Cary: SAS Institute, 2001.

Silva, M.C.; Lopes Neto, J.P.; Ribeiro, N.L.; Furtado, D.A. Biometry and production of *Melipona scutelaris* bees: a multivariate approach. International Journal of Tropical Insect Science, v. 40, n. 4, p. 113-117. 2020. https://doi.org/10.1007/s42690-020-00140-9.

Stanimirovic, Z.; Ristanic, M.; Glavinic, U.; Aleksic, N. Looking for the causes of and solutions to the issue of honey bee colony losses. Acta Veterinaria-Beograd, v.69, n.1, p.1-31, 2019. https://doi.org/10.2478/acve-2019-0001.

Torres, D.J.; Ricoy, U.M.; Roybal, S. Modeling hooney bee populations. Plos One, v. 10, n.7, e0130966, 2015. https://doi.org/10.1371/journal.pone.0130966.