Original research article

Effect of ImprovedHive CoverDesigns on Internal Microclimateand Colony Establishment of WestAfrican Honeybees (*Apismelliferaadansonii*L.) in Awka, Nigeria

ABSTRACT

Hive cover designs majorly affects the microclimate and colony establishment of African honeybee colonies in Nigeria. It became pertinent therefore to assess theeffect of modified hive cover designs on the internal microclimate and colony establishment of West African honeybee (*Apismelliferaadansonii*L.)Colonies in Awka, Nigeria. Four insulating materials were used to construct the covers of twelve modified frame bar hives and designated: Control (plywood); T1 (warped boards); T2 (PVC) and T3 (foam).Each hive treatment was replicated three times. Data on ambient and hive microclimate and colonization of honeybees'colonieswere monitored and recorded.The results revealed that the control had the highest temperature (31.86 ºC)while T1 (30.40ºC) had the least. The hive temperature was higher in March, 2023 (32.72°C) while August (29.87°C) had the least. The highest relative humidity(73.18%) was recorded in T1 whilethe control had the least (64.38%).The hive temperature and relative humidity was significantly affected byhive cover designsand different months of the study period (P<0.05).The highest colonization was observed in the control (100%) but none occurred in T2 (0.00%). Colonization of the Controlhives occurred in July, October, and November, 2022 while that of T1 and T3occurred in December, 2022. Colonization of African honeybees was significantly affected by hive cover designs (p=0.26) and different months of the study period (p=0.24). It was concluded that beekeepers should adopt the insulation of hiver covers with plywood wood since it had 100% colonization of West African honeybees'.

Keywords: Hive Cover Designs, Internal Microclimate, Colony Establishment, African Honeybees

INTRODUCTION

Thermoregulation is one of the most remarkable characteristics of the honey bee, particularly the *Apismellifera* colony, which can maintain a temperature range of 33-36°C while the ambient temperature falls between -40 and 40°C (Ellis, 2016). Honeybee colonies exposed to high external temperatures may experience a rise in hive temperature, which can have a negative impact on honeybee growth, metabolism, and physiological responses (Fasasi, 2016;Poot-Báez *et al*., 2020; Li *et al*., 2019). On the other hand, temperature and relative humidity have a significant impact on the honeybee colony's homeostasis in the hive(Abou-shaara *et al*., 2017). The level of bee activity in the hives and their surroundings is highly influenced by ambient temperature and relative humidity, which, if consistently observed, might be used to determine the harvest season(Fasasi, 2016; Brito, 2022; Supandi *et al.*, 2020).Previous research revealed that maintaining the optimal temperature range in the hives (33 to 36°C) is crucial to beekeeping because to the vulnerability of juvenile bee development cycles to high temperatures (Gajardo-rojas*et al*., 2022).When the external temperature is too hot or cold, honeybees maintain an interior temperature of roughly 32°C of the hive by fanning their wings to either circulate air and cool the hive or create friction and warm the internal air (Brown, 2018). However, Park *et al*. (2021)found that, despite the shift in ambient temperature, the internaltemperature remained above 31°C. According to Abd-

Elmawgood*et al*. (2015), honeybees can survive in temperatures ranging from -20 to +60 degrees Celsius, however they perform best in temperatures ranging from +21 to +35 degrees Celsius.

Maintaining a constant temperature and relative humidity is critical for bee colony activities, this is why some researchers have redesigned hives in the past. For instance, the modifications of hive entrances was previously reported to significantly affect the temperature and relative humidity variations of hives (Li *et al*., 2019; Ononye and Akunne, 2019). Tuo *et al*. (2020)used pan traps (UV- brilliant yellow, white, and blue) to analyse the impact of different agroecosystems on bee activity in hives and found that bee activity evolves with temperature (34°C and 35°C) up to a threshold and inversely with relative humidity (56% and 65%).Furthermore, bees' responses to changing environmental temperatures have ramifications for pollination in natural and agricultural systems, with rising average temperatures leading to pollinator population decreases(Jaboor *et al*., 2022). Studies by Lepkova *et al*.(2022)revealed that the microclimate in hives composed of various materials was substantially altered, however ceramic hives with high kaolin content had better thermal insulation capabilities than timber hives. Some authors earlier reported that foam polystyrene is one of the most recent alternatives utilised for hive design, and it is proven to be harmless to organisms when used under normal settings, thus it is recommended for future bee breeding because its qualities are superior to those of wood (Bykov and Zaitsev, 2021; Hassan *et al*., 2016; MacIvor and Moore, 2016; Prendergast, 2019; Wang *et al*., 2021). Furthermore, hives made of foam polystyrene have strong thermal insulation capabilities, preventing the hive from being heated or cooled from the outside(Bykov and Zaitsev, 2021). St. Clair *et al*. (2022) recently reported that the development of new insulation materials with higher properties than wood could provide better alternatives for the beekeeping industry, and it was stated that polyurethane hives maintained a significantly higher overall temperature than wooden hives with a significantly more optimal relative humidity (52.05%) compared to wooden hives (62.50%). Furthermore, they discovered that the inside temperature patterns of the wooden hives exhibited significant oscillations as compared to the polyurethane hive.Another study by Meikle *et al*. (2023)conducted to assess the effects of hive entrance orientation on honey bee colony activity and temperature, reported that hive orientation should be considered in the design of field experiments that entail monitoring colony activity.

Developingstrategies for keeping a stable brood hive temperature despite the external environment has allowed western honey bees to colonise much of the globe and are indeed successful organisms (Ellis, 2016). Akinbi *et al*. (2021) studied the performance of wood hive and plywood hive types in three different vegetation types and noted an improvement in the colonisation performance at different months of the study period after installation of hives. They also reported that plywood hives installed in the cocoa farmland and plantation accounted for higher colonisation percentage than natural forest. Studies by Bykov and Zaitsev (2021) revealed that honeybee colonies in wooden hives colonised at a rate of 91.67%, with slower development due to the hive's periodic compression throughout the cold season. Dupleix *et al*. (2020)perceived that the reasons wooden habitat supports bees' well-being include heat insulation, humidity regulation, "naturalness," and fragrance.Adedeji*et al*. (2014) reported that season has a significant impact on hive colonisation in Nigeria's South-South region, and it has also been stated that the best period to build hives is between August and September, because colonisation usually occurs in October. Different times for colonisation of honeybees have been reported ranging from February to April (Adedeji and

Aiyeloja, 2014) and October to February (Adedeji*et al*., 2014). Anumba *et al*. (2020) after the evaluation of the influence of hive colours on the performance of African honeybee colonies in Awka reported that hive colour did not significantly enhance colonisation. Studies by Ononye and Akunne, 2017) on the impact of time and beehive entrance on colony development of African honeybees indicated that the colonisation months in the research area were August to October.

Other independent studies (Goulson*et al*., 2015; Cham, 2017) attributed variation in the rate of colonisation of hive types to a number of environmental and anthropogenic factors while the high colonisation was attributed to differences in vegetation cover. However, delay in hive colonisation of honeybees was attributed to unfavorable microclimatic during rainy season under a natural forest ecosystem (Akinbi*et al*., 2021). Studies on the effects of temperature and relative humidity on colonisation of honey bee hives within FUTA community by Oluwaseyi *et al*. (2022) showed that hive located where the environmental conditions were favorable was observed to colonised quickly when compared to other locations. However, earlier studies by Ononye and Akunne (2019) on the effect of modified hive entrances on colony establishment found that hive entrances had no effect on African honeybee colonisation during the study period. Poor hive and seasonal management were cited as some of the causes responsible for the annual reduction in honey bee colony establishment. The paucity of information on the influence of microclimate and hive cover designs on the performance of West African honeybee colonies in Nigeria necessitated this study which aimed to improve on the existing hive cover designs using various insulating materials such as plywood, warped wood, polyvinyl chloride, PVC ceilings and foam.

MATERIALS AND METHODS

Study Area and Duration

This study was carried out at the Honeybee Research Centre (Figure 1) of the Department of Zoology, NnamdiAzikiwe University, Awka from January, 2022 to March, 2023. Awka lies within geographical coordinates of 6°14′53″ N and 7°05′34″ E. Awka is located in Nigeria's tropical rain forest zone and has two distinct seasons: wet and dry, which occur between April and October and are followed by five months of dryness (November to March). The Harmattan is a dry and dusty breeze that blows through the area from late December to January and is characterised by a grey haze that limits visibility and blocks the sun's beams(National Statistical Book, 2010). The temperature in the study area is generally 27-30^{o}C between June and December but rises to 32-34^{o}C between January and April, with the month of March experiencing the hottest temperature 36-38^{o}C. The relative humidity in the rainy season is 82.37% and 74.25% in the dry season.

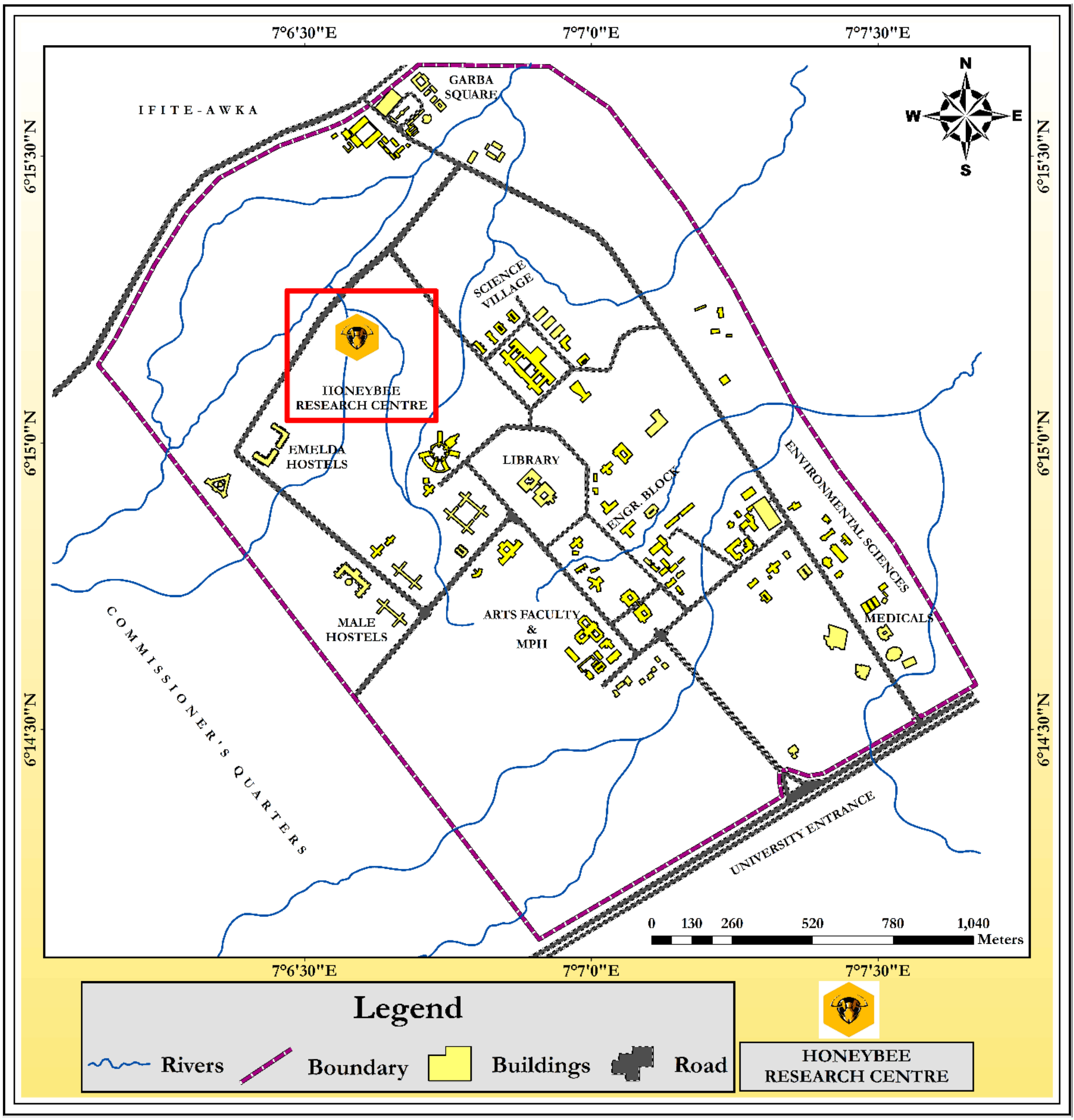

Figure 1: Map of NnamdiAzikiwe University, Awka showing the Honeybee Research Centre
Source: Researcher's Field Work and GIS Mapping, 2023

Experimental Design

The experiment was one factor experiment in a Completely Randomised Design (CRD) with three replication each (Figure 2). The four hive cover designss constructed for this study varied only in the type of insulating materials used for their hive covers and were assigned the following: Control: hive covers insulated with plywood; T1: hive cover insulated with warped boards; T2: hive covers insulated with PVC (Polyvinyl chloride) ceiling and T3: hive covers insulated with foam. The hives were labelled according to the hive cover designs which they are designated and scattered randomly in the experimental area.

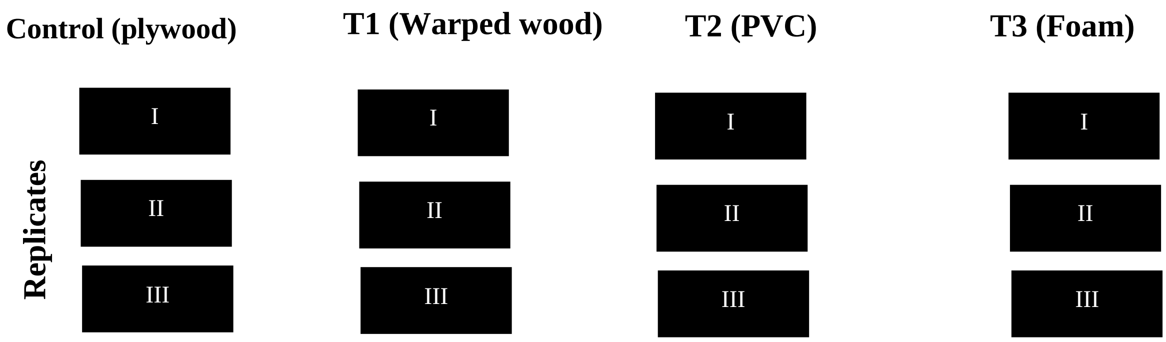

Figure 2: Illustration of the Experimental Set up

Sources of Materials

The hard wood species, *Miliciaexcelsa*(Iroko) used for the hive construction were obtained from the timber market, Umuokpu, Awka, Anambra State, Nigeria. The different insulating materials namely: plywood, warped wood, PVC ceiling and foam used for the various hive cover designs were purchased from Building materials section of Eke Awka market, Awka.

Hive Construction and Installation

A total of twelve (12) modified frame bar hives constructed with *M. excelsa*grouped into four hive cover designs namely: Control, T1, T2 and T3were constructed for this study with each hive treatment replicated three times and labeled as: Control$_{I-III}$, T1$_{I-III}$, T2$_{I-III}$ and T3$_{I-III.}$ The timber boards used for the hive construction were piled with spacers in well aerated timber shed to dry for a period of four months (Mbobua, 2013). Each hive consisted of the bottom board (length = 53.34cm, width = 35.56cm), main cover board (length = 55.88cm, width = 38.1cm), brood chamber (length = 52.07cm, width = 36.83cm, depth = 24.9cm).All the hive cover designss were made of wood covered with corrugated iron sheets. Each hive comprised 10 frame bars of 2cm width with two hive entrances of 1cm in diameter (Ononye, 2018) with a bee space of 3mm between the frame bars.

Each hive was cleaned and baited with beeswax. Between 6:00 and 8:00 a.m., the hives were baited with forty grammes (40 g) of beeswax, which was melted and applied with a brush over the hive entrances, frame bars, and main cover boards. The hives were allowed to dry after which they were installed (Ononye and Akunne, 2019). In the month of January 2022, each of the baited hives was kept on metallic supports (46 cm high) within the apiary. The hives were randomly arranged at a distance of 10 metres apart, with the hive entrances oriented to the east. (Babarinde *et al*., 2012; Ononye and Akunne, 2019). During this experiment, the hives environment were kept clean before and after colonisation (Adedeji *et al*., 2014).

Data Collection

Determination of the influence of different hive cover designs on the microclimate of hives during the study period

Temperature and relative humidity of the four hive hive cover design s labelled Control$_{i-III}$, T1$_{I-III}$, T2$_{I-III}$ and T3$_{I-III}$ were measured and recorded once a week and average taken per month for a period of 15 months from January, 2022 to March, 2023 with the aid of a hand-held digital thermo hygrometer {Model EUROLAB 411TH)(Ononye and Akunne, 2019). The thermo-hygrometer was placed outside and inside of each hive for 2 minutes, in order to record the ambient and hive temperature and relative humidity respectively. This was carried out between 7:00 am to 10:00am on each day before and after colonisation of hives (Akunne *et al*., 2015). The temperature and relative humidity variations of the hive cover design s were determined using the formula adopted by Mogbo (2014):

Temperature variation = Maximum temperature- Minimum temperature
Relative humidity variation = Maximum relative humidity – Minimum relative humidity

Ascertaining the rate of colonisation of African honeybees as influenced by hive cover designs at various periods

The modified frame bar hives labelled $Control_{i\text{-}III}$, $T1_{I\text{-}III}$, $T2_{I\text{-}III}$ and $T3_{I\text{-}III}$with different cover designs were monitored two times per week for one hour between 8:00 am to 9:00 am while the number of hives colonised in each hive cover design and the date of colonisation were recorded. The percentage rate of colonisation per hive cover design was computed using the formula adopted by Babarinde*et al*. (2012) and Ononye and Akunne, (2019).

$$\text{Colonisation rate per hive cover design} = \frac{\text{Number of colonised hives per hive cover design}}{\text{Number of hives installed}} \text{X } 100$$

Data Analysis
Data collected from hive temperatures, relative humidity, colonisation, were subjected to Analysis of Variance (ANOVA) while sample means were separated using Tukey-HSD Test at 5% significant level (P<0.05) using SPSS computer package (version 25) (IBM Corp., 2011). However, Microsoft Excel, 2019 were used to plot the graphs.

RESULTS

Table 1 revealed that the Control had the highest temperature (31.86 ºC) followed by T3 (31.76ºC) while T1 (30.40ºC) had the least. There was significant difference in the hive temperatures recorded among the four hive cover designs (P=0.00). Figure 3 revealed that the hive temperature was higher in the month of March, 2023 (32.72°C) followed by the month of February, 2023 (32.56°C) while August (29.87°C) had the least. There was a significant difference in the hive temperature among the various months (P=0.00). The interaction between hive cover designsand different months of the study period had significant effect on the hive temperature (P=0.01).

Table 1: Average minimum and maximum hive temperature, temperature variation, ambient temperature and mean hive temperatures

Hive cover design	Min. average temp. (ºC)(a)	Max. Average temp. (ºC) (b)	Range (b-a) (ºC)	Min. average ambient temp. (ºC)(a)	Max. Average ambient temp. (ºC) (b)	Mean ambient temperature	Mean hive temperature (ºC) ± SD
Control	23.81	38.44	14.63	22.13	36.76	29.87	$31.86^{b}\pm3.495$
T1	27.21	32.16	4.95	22.13	36.76	29.87	$30.40^{a}\pm1.351$
T2	28.25	34.37	6.12	22.13	36.76	29.87	$31.23^{b}\pm1.490$
T3	29.21	34.09	4.88	22.13	36.76	29.87	$31.76^{b}\pm1.156$

KEY:

Control (Plywood)

T1 (Warped wood)

T2 (PVC)

T3 (Foam)

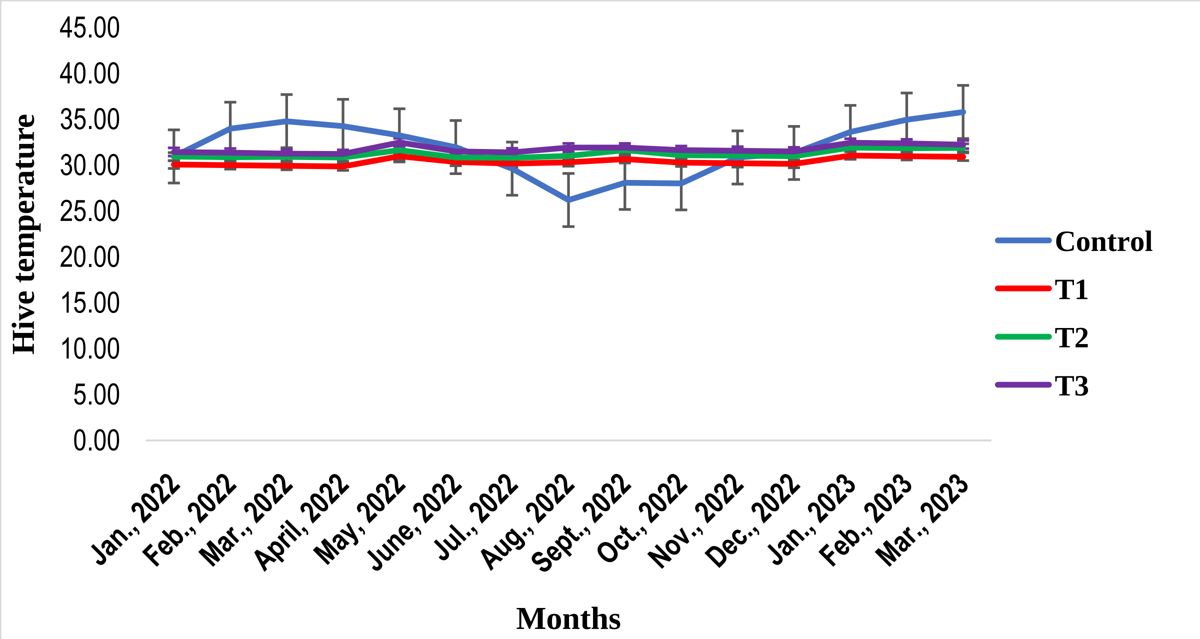

Figure 3: Mean hive temperature of hive cover design at different months of the study period

Hive Relative Humidity

Table 2 revealed that T1 had the highest relative (73.18%) humidity followed by T2 (70.91%) while the control had the least (64.38%). There was a significant difference in the hive relative humidity among the four hive cover designs (p=0.04). Figure 4 revealed that the hive relative humidity was highest in the month of March, 2023 (32.72°C) followed by February, 2023 (32.56°C) while August, 2022 (29.87°C) had the least.There was a significant difference in the hive relative humidity among the various months (P=0.00). The interaction between hive cover designsand different months of the study period had significant effect on the hive relative humidity (P=0.01).

Table 2: Average minimum and maximum hive humidity, humidity variation, mean ambient humidity and mean humidity of the four hive cover designs

Treatment	Min. average humidity (%) (a)	Max. Average humidity (%) (b)	Range (b-a) (%)	Min. average ambient humidity (%)	Max. Average ambient humidity (%)	Mean ambient hive relative humidity (%)	Mean hive relative humidity (%) ± SD
Control	40.00	84.00	44.00	94.00	48.00	70.69	64.38^{a}±15.448
T1	47.00	92.00	45.00	87.00	45.00	70.69	73.18^{b}±14.834
T2	45.00	89.00	44.00	86.00	44.00	70.69	70.91^{ab}±14.670
T3	46.00	89.00	43.00	83.00	43.00	70.69	70.62^{ab}±14.621

a, b = superscripts for sample mean separation using Tukey-HSD Multiple Range Test

Columns sharing similar superscripts are not significantly different at P>0.05

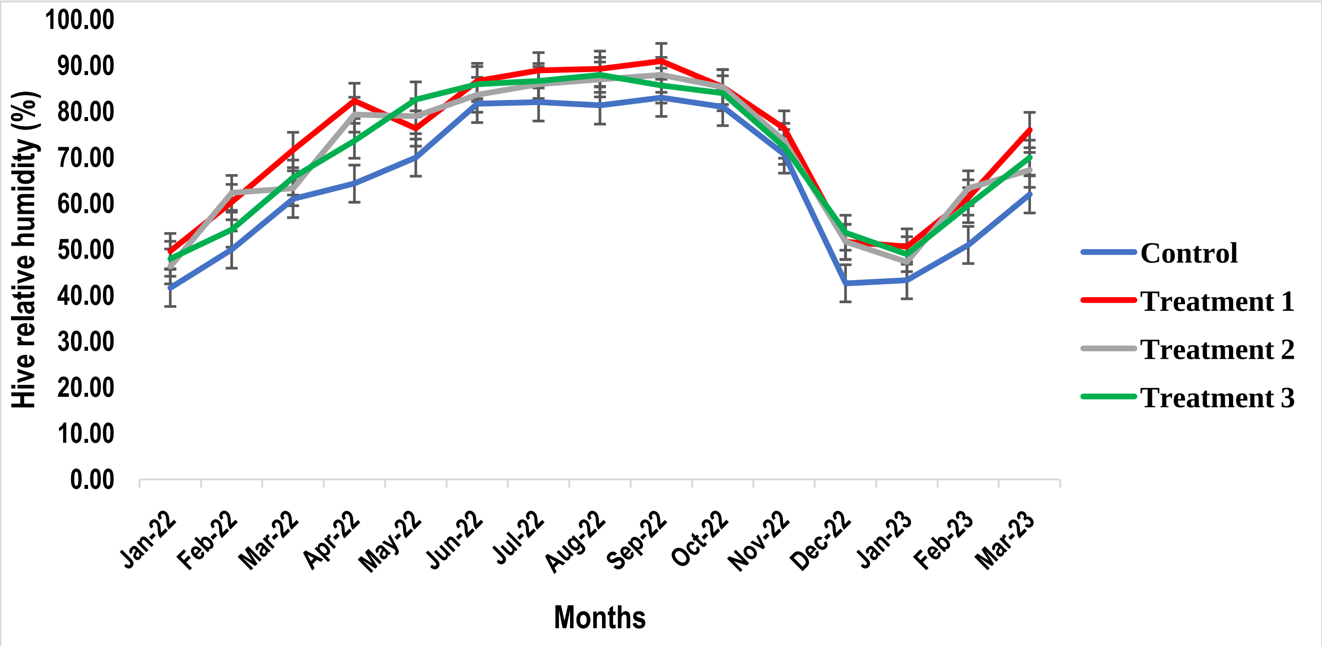

Figure 4: **Mean relative humidity of hive cover designs at different months of the study period**

Table 3 revealed that the overall colonisation of the African honeybees was 41.67% based on hive cover designs. The colonisation of the African honeybees was observed to be highest in theControl (100%) followed by T1 and T3 (33.33%) but no colonisation was observed in T2 (Plate 1) (0.00%) during the study period. The hive cover designs did not significantly affect colonisation rates of African honeybees (p=0.26).Figure 2 shows the monthly colonisation of African honeybees during the study period. The colonisation of the Control (Plate 2) was observed in the months of July, October, and November, 2022 while that of T1 and T3 (Plate 3 and 4) occurred in December, 2022. However, there was no significant difference in the colonisation of African honeybees among the various months (p=0.24).

Table 3: Colonisation of African honeybees as influenced by different hive cover designs at different months of the study period

Hive Cover Designs	No. of Hives Installed	Months of colonisation															Total hives colonised (%)
		2022												2023			
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	
Control	3	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	3(100.00)
T1	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1(33.33)
T2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0(0.00)
T3	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1(33.33)
Total (%)	**12**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**2**	**0**	**0**	**0**	**5(41.67)**

Plate 1: T2 showing no colony formation

Plate 2: ColonisedControl hive showing honeybees at the hive entrances

Plate 3: ColonisedT1 showing honeybees in the hive

Plate 4: ColonisedT3 showing honeybeeson the frame bars

DISCUSSION

The result of this study revealed that the insulating materials used for hive cover designs significantly affected the microclimate (temperature and relative humidity) of hives. This indicates that the use of different insulating materials altered the internal microclimate and this supports previous studies by Lepkova *et al*. (2022) who reported that the microclimate in hives made out of different materials used to design hives greatly influenced the thermal insulation properties the hives. The mean hive temperature values (30.40 - 31.86 °C) recorded during this study fall within the recommended hive temperature range for proper development of honeybees.Earlier studies suggested that maintaining the optimum hive temperature range (from 33 to 36°C) is critical to beekeeping due to the sensitivity of the development cycles in immature bees to high temperatures (Gajardo-rojas*et al*., 2022). This observation is in line with the study by Abd-Elmawgood *et al*. (2015) who reported that hive temperature values of 30 - 36 °C are suitable for brood development of honeybee.This study also corroborates with the study by Park *et al*. (2021) who reported that despite the change in external temperature, the internal temperature was maintained above 31°C. Contrastingly, the hive temperature values was slightly higher than that of Tuo *et al*. (2020) and Floris*et al*. (2020) who reported that bee's activity evolves within adequate temperature range of 34°C and 35°C.

Hive cover designs also affected the internal relative humidity of the hives significantly and the range of values (64.38 - 73.18%) fall short of the optimal relative humidity (52.05%) reported by St. Clair *et al*. (2022) . This range falls below the relative humidity values (75.04- 77.94%) earlier reported in the study area by Ononye and Akunne (2019) who compared the effect of entrances on hive microclimate . The reason for difference in the relative humidity values could be the variation in the effect of the various insulating materials used for hive cover design. The result also revealed that hive cover insulated with plywood had the lowest relative humidity when compared to those of polyvinyl chloride ceiling and foam. This is similar to the observation by St. Clair *et al*. (2022)who recently reported that the development of modern insulation materials with higher proprieties could serve as better alternatives wood in the beekeeping industry.

The hive cover designs used in this study did not significantly affect colonisation which indicates that colonisation rate may not be dependent on hive cover designs.The wood based designs (plywood and warped wood) recorded the highest colonization by African honeybees when compared with those of foam and PVC during the study period. This supports the observation by Akinbi *et al*. (2021) who also reported that plywood based hives recorded higher percentage colonization when mounted in cocoa farmland and plantation than natural forest. This study agrees with that of Bykov and Zaitsev (2021) who reported 91.67% colonisation by honeybee colonies housed in wooden hives. The highest colonization in Control hives could be attributed to the fact that honeybees preferred wood based designs which mimics their natural nest in the wild. Dupleix *et al*. (2020) earlier noted that wooden habitat benefits the bees' well-being because they can analyse heat insulation, humidity control, naturalness and smell. This supports the work by Sahin *et al*. (2020) who stated that the natural surface appearance and color of wood are very important quality criteria in the utilization, especially for outdoor applications.

Based on the findings of this study, the months of colonisation by the African honeybees housed in control hives was July, October, November while T1 and T3 colonized in December, 2022. The colonization of African honeybeeswas not significantly different among the various months and this differs from the work by Adedeji*et al*. (2014) who reported that season has a substantial impact on hive colonisation in the South-South region of Nigeria. Earlier reports on different months of hive colonisation by African honeybees have been given to fall within February – April (Adedeji and Aiyeloja, 2014) and October – February (Adedeji*et al*., 2014). The result of this study is also in contrast with those of Ononye and Akunne (2017)whoreported August to October as the colonisation months of African honeybees in the study area. Other independent studies (Goulson*et al*., 2015; Cham, 2017) attributed variation in the rate of colonisation of hive types to some environmental and anthropogenic factors while the high colonisation was attributed to differences in vegetation cover. The delay in colonization observed in T2 could imply that the hive cover designs was unfavourable and was not preferred by the honeybees. This corroborates with the work report by Akinbi *et al*. (2021) who attributed delay in hive colonisation of honeybees to unfavorable microclimatic conditions in a natural forest ecosystem. This study supports the work by Oluwaseyi *et al*. (2022) who posited that favorable environmental conditions promoted rapid colonization of by honeybees.

Conclusion

Hive cover designs significantly affected the microclimate of hives but did not significantly affect colonisation of African honeybees. The months of July, October, November may be suitable for the colonisation of African honeybees in the study area. The use of wood-based hive cover designs should be adopted in the study area but more durable woods should be selected.

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