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The Effect of Thermal Insulation on Honey Bee hives Activity

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Abstract:

A study was aimed to investigate the effect of thermal insulation on bee hives activity from April 26th to May 30th, during which temperatures from 32°C to 45°C. Three treatments were used including the first used fiberglass insulation and a wooden box containing a Lancaster hive; the second used a white-painted wooden hive containing a Lancaster hive; and the third served as a control, consisting solely of a Lancaster hive. The results showed that the first treatment was superior in both the thermal insulation properties of the air surrounding the hive and the temperature inside the hive. It also increased the area of brood, honey, and pollen by 32.50, 1214, 426, and 220 square meters, respectively. The final weight of the hives was 22.7, 21.70, and 16 kg, respectively. The average number of frames per hive was 6.882, 6.716, and 6.049, respectively.

Keywords: *Thermal Insulation, Bees, hives, Lancaster hive*

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تأثير العزل الحراري على نشاط خلايا نحل العسل

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الخلاصة

هدفت هذه الدراسة إلى بحث تأثير العزل الحراري على نشاط خلايا النحل خلال الفترة من 26 أبريل إلى 30 مايو، حيث تراوحت درجات الحرارة بين 32 و45 درجة مئوية. استُخدمت ثلاث معالجات: الأولى باستخدام عزل من الألياف الزجاجية وصندوق خشبي يحتوي على خلية نحل من نوع لانكستر؛ والثانية باستخدام خلية نحل خشبية مطلية باللون الأبيض تحتوي على خلية نحل من نوع لانكستر؛ أما الثالثة فكانت بمثابة مجموعة ضابطة، وتتكون من خلية نحل من نوع لانكستر فقط. أظهرت النتائج تفوق المعالجة الأولى من حيث خصائص العزل الحراري للهواء المحيط بالخلية ودرجة الحرارة داخلها. كما زادت مساحة الحضنة والعسل وحبوب اللقاح بمقدار 32.50 و1214 و426 و220 مترًا مربعًا على التوالي. وبلغ الوزن النهائي للخلايا 22.7 و21.70 و16 كيلوغرامًا على التوالي. كان متوسط عدد الإطارات لكل خلية 6.882 و 6.716 و 6.049 على التوالي.

الكلمات المفتاحية: العزل الحراري، النحل، خلايا النحل، خلية نحل لانكستر

Introduction

Honeybees are cold-blooded animals that cannot easily regulate their body temperature. Physically, the country's climate is often negative and fluctuating at the beginning of the summer season. The negative effect of high hive temperatures leads the bees to consume more nectar for cooling or to dedicate their energy to collecting water instead of nectar. This results in uneven evaporation of water from the nectar and delays honey ripening. Temperature is a crucial factor affecting the development of larvae and pupae in insects, leading to reduced brood activity and ultimately a weakened colony in the future (Nellen and Goothard, 1998). Honeybees can survive in ambient temperatures ranging from -20°C to +48°C, and even from -40°C to +60°C. However, they perform best at temperatures between +21°C and +35°C. If the temperature drops significantly in winter (below +14°C), the bees cease moving to collect honey (a carbohydrate source) and pollen (a protein source) and form a winter colony.

When the temperature drops below +6°C, the winter colony takes on a shape adapted to cold climates and does not involve the dormancy or hibernation characteristic of most insects; honeybees remain active within the winter colony. The center of the hives, or nucleus, is generally maintained within the 20–30°C range in broodless colonies. Maintaining a suitable temperature range of 33–36°C inside beehives is crucial (Petz et al. 2004). This stable temperature is essential for the normal growth and development of larvae. Deviations from this optimal temperature range can occur when the ambient air temperature changes, affecting the growth period of immature bee stages and their foraging rate (Tautz et al. 2003). Ambient temperature also significantly impacts foraging activity (Al-Carni 2006 and Blazyte-Cereskiene et al. 2010). Furthermore, very low temperatures below 10°C can inhibit foraging activity (Joshi and Joshi 2010). The queen bee is the mother of the hive and is always surrounded by worker bees, who provide her with food and protection. The queen's primary goal is reproduction; if she has sufficient food and mates, she can lay thousands of eggs daily [7].

Worker bees are responsible for the maintenance of the hive, performing vital functions such as collecting energy from nectar and pollen (food), caring for larvae, producing wax and honeycomb, looking after the queen, and defending the hive against invaders. New queen bees are born through a process similar to that of worker bees, hatching from fertilized eggs. However, queen larvae feed exclusively on royal jelly, a protein-rich secretion that enables them to grow to sexual maturity. In contrast, worker larvae feed on royal jelly only in their first few days, after which they feed on a mixture of nectar and pollen known as bee bread. [9] Once a new queen bee reaches maturity, one of two processes typically occurs. If the old queen no longer secretes a sufficient amount of pheromones, the worker bees kill her, making way for the new queen in a process called queen replacement. This may be due to the evaporation of pheromones caused by high temperatures, or sudden temperature changes may trigger queen replacement, swarming, and the construction of queen hives out of season. Otherwise, the colony will divide. Therefore, the bees' awareness of temperature changes is crucial.

Thermal insulation of honeybee hives is essential to maintain a constant temperature inside the hive (approximately 34-36°C for brood), especially during warmer months. This is achieved using insulating materials such as polystyrene foam, electric bee blankets, or even natural materials like straw and burlap, while ensuring good ventilation to prevent dampness. This reduces honey consumption by the bees and increases the colony's survival rate. The importance of thermal insulation and regulating hive life, this study aimed to determine the effect of various packaging materials on the performance, development, growth, and honey production of honeybee colonies. The study included the following: The effect of covering beehives in summer on brood and egg area, pollen area, and honey. Total honey and pollen weight of the hive.

Materials and Methods

Preparing the Colonies

Three (3) hives of hybrid bees (the local Iraqi strain) *Apis mellifera* L. were selected. Each colony contained (5) frames. The colonies were of similar strength, one year old, and the hive box and frames were made of the same type of wood and were identical in shape. They were free from diseases and pests. The hives were balanced in terms of queen age, worker brood area, pollen and honey areas, and the swarms were similar in weight.

The hives were transferred to modern Lancasteroth hives, identical in construction, wood type, and shape, and placed in the same location at a height of 50 cm from the ground. Samples were taken simultaneously for all three treatments. The hives were placed in a sunny location, with their entrances positioned away from wind and rain. When choosing insulation material, factors such as cost, ease of application, and availability should be considered, bearing in mind that availability varies depending on the region.

Types of Packaging

1- First Treatment: Wooden boxes were used to place the entire hive inside, separated from the main hive by one centimeter on both the right and left sides. The dimensions were 58 cm in length, 46 cm in width, and 21 cm in height. The wood used was 2 cm thick, including the cover and base, and covered with a layer of thermal insulation (aluminum and fiberglass) on all six sides except for the bee exit. The temperature was measured using a digital thermometer with a 15 cm sensor, connected to the device by a 25 cm wire.
2- 2- Second Treatment: The second hive had the same specifications as above, but without insulation. It was simply painted with three coats of white oil paint to reflect sunlight.
3- 3- Third Treatment: A Lancastroth hive was used without any insulation, but it retained its natural wood color. 4- Studying the Effect of Different Treatments on Internal Bee Activity:

Calculating Brood Area

To demonstrate the effect of different treatments on brood area, the brood area (workers and drones) for each hive was calculated in square inches (Al-Naji, 1980) using a transparent glass frame divided into squares (each square measuring 2 inches). The brood area was calculated based on the method of Jeffrey (1958) by placing a brood frame and measuring its area on each side of the glass frame. This process was carried out from the beginning to the end of the experiment.

Calculating Honey Area

The honey area was calculated in the hives treated using the same method as in the previous section.

Calculating Pollen Area

The pollen area was calculated in the hives treated using the same method.

Calculating Egg Area

The egg area was also calculated in the hives treated using the same method.

Figure (1) Measurement Method for the Area of the Wax Frame Contents in 2 inches

Study of the Total Growth of Treated hives

To study the effect of the treatments on the total growth of hives, the study was conducted in two parts as follows:

Calculating the Average Number of Frames Added to the hives

The number of frames in each colony was calculated based on the initial number of frames in each hives at the beginning of the experiment being five frames (for each hive and in all treatments). The number of wax frames added was calculated (according to the cell's needs). By calculating the total number of frames at the end of the experiment for the colonies, we obtain the growth achieved in each hive, and this is compared with the number of frames in the control treatment colonies.

Statistical Analysis:

The statistical design used was a Completely Randomized Design (CRD) for each laboratory treatment and a Complete Randomized Block Design (CRBD) for the field experiments. The results were statistically analyzed using an Analysis of Variance (ANOVA) table, and the results were compared using the Least Significant Difference (LSD) test at the 0.05 level. To test the significance of comparing results (Al-Sahouki and Wahib, 1990).

Results and Discussion

The results showed that the treatment with thermal insulation and the wooden box was superior to all other treatments, providing the highest thermal insulation at 35.25°C, compared to the wooden box treatment, which reached (36.47/38.62)°C respectively. This is attributed to the insulation of the glass wool and the aluminum layer, which reduced the thermal conductivity of the air trapped between the wooden box and the hive inside. This agreed with Sanz *et al.* (2024).

The temperature inside the hive was distinguished by its superiority in reducing thermal conductivity into the hive and maintaining stable temperature fluctuations. The first treatment yielded the lowest average temperature of 32.50°C, while the other treatments yielded 34.88/36.83°C respectively. This difference naturally has behavioral and other effects on brood rearing and the number of eggs lay by the queen, as it is very suitable for raising offspring. This is consistent with [49] found, despite the large variation in external temperature. The temperature inside the beehives remained stable at a level between 24 and 32°C. Initial results suggest that the physical properties of the thermal insulation may be key to maintaining this temperature, and further experiments using internal heat sources confirmed these findings. These experiments, which compared beehives insulated with assembled black cork to ordinary beehives, demonstrated the ability of assembled black cork not only to retain heat but also to maintain low humidity levels. Controlling humidity is crucial for preventing the spread of pathogenic fungi, as confirmed by [50].

Table (1) Effect of Thermal Insulation on Honey Bee hives

Treatments	Air temperature in the first box	Air temperature inside the hive	Brood area	Honey area	Pollen area	Number of frames
packaging and wooden box	35.25	32.50	1214.	426.	220.	6.882
Wooden box	36.47	34.88	1414.	180.	171.	6.716
Control	38.62	36.83	943	275	127	6.049
Lankstrooth hive	1.138	0.991	185.0	129.6	62.9	
LSD	35.25	32.50	1214.	426.	220.	6.882

This can be attributed to the inverse relationship between temperature and humidity: in an environment with a constant amount of water vapor, an increase in temperature is associated with a decrease in humidity. These results highlight the superior thermal insulation properties of assembled black cork, demonstrating its ability to improve the thermal regulation of beehives. This feature becomes particularly important during the colder months, as spring approaches, a challenging period for beehives, as noted in reference [51].

Regarding the brood area, which included eggs, larvae, and pupae only, the second treatment was distinguished by the highest brood area, reaching 1414 square inches. This did not differ significantly from the first treatment, which yielded 1214 square inches. This difference may be attributed to genetic differences in the queen's characteristics, resulting in a higher number of ovarian tubes, or to the temperature in the second hive being 2.38°C lower than the first, which favored the queen. Al-Ali (2011) stated that the optimal temperature for egg-laying is 35°C, resulting in a greater number of eggs being laid and subsequently developing into larvae (200 square inches). However, this measurement was taken during the study period, which lasted approximately two months, up to the fifth month. The study indicates that the temperature will certainly differ in the sixth, seventh, and tenth months, as it can reach 52°C.

The results showed the highest honey area in the first treatment, reaching 426 square inches. This may be due to the foraging bees focusing more on collecting nectar compared to the other treatments, which yielded honey areas ranging from 180 to 275 square inches, a difference that did not significantly vary. The difference between the two treatments may be due to the increased effort exerted by foraging bees in collecting water to cool the hive and feed the young in hives with elevated temperatures. The first treatment resulted in the highest pollen area, reaching 220 square inches, compared to the second treatment, which had 171 square inches. This difference may be attributed to the consumption of pollen for feeding and making bee bread to nourish newly emerged larvae and workers. This second treatment resulted in the highest brood area, while the control treatment had the lowest, at 127 square inches. These results are agreed with the findings of [16]. In their study, hives with black clumped cork exhibited less temperature fluctuation throughout the day, and the bees required less time to reach the desired temperature after the hive was opened.

The materials selected in this study proved effective as high-quality thermal insulators with low thermal permeability. This ensured that the temperature inside the hives remained lower than the control hive temperature throughout the 60-minute test period. Maintaining an optimal internal temperature is vital for the hive's habitability. The ideal internal temperature for a brood nest ranges from 32 to 36°C [43], from 34 to 35°C [44], and from 30.7 to 37°C [45]. This temperature stability, known as homeostasis, is crucial for bee colonies. As noted [46], prolonged exposure to internal temperatures above 38°C negatively impacts larval metamorphosis and brood development, and shortens the lifespan of adult bees. Therefore, in a broader context, and given the rising temperatures due to climate change, the findings support prioritizing the design of beehives using natural insulating materials to effectively combat high summer temperatures. Based on the results, black clumped cork and rock wool provide the best insulation values compared to the other materials.

Figure (2) thermal insulators and treated hives

In recent decades, beehives made from synthetic materials such as polystyrene and polyurethane have been developed and tested, achieving better results in cold climates [16-18]. Traditional wooden beehives do not exhibit these drawbacks. Historically, beehive construction was influenced by the availability of suitable materials, as noted [19]. These materials ranged from earth materials, such as sun-dried clay and fired clay, to plant-based materials, such as hollow logs, cork bark, woven cylinders, tree trunks, and wooden planks. In Mediterranean regions, cork bark cylinders were commonly used. Cork is known for its superior insulating properties compared to wood and has traditionally played an important role in beehive construction. Although cork was among the earliest materials used in beehive construction, along with fired clay, wicker, and hollow logs [20], published studies on the use of these natural fibers in modern beehive designs are limited.

This temperature regulation process requires energy from the bees, which they obtain through honey consumption, directly impacting honey production. This research highlights the potential for improving traditional wooden Langstroth hives by incorporating a layer of cellulose lignin fibers as thermal insulation. These materials maintain comfortable temperatures inside the hive during the summer and reduce energy consumption for heating in the winter. This allows for more stable thermal regulation within the hive in the face of external temperature fluctuations, potentially improving the quality of life for bees, ensuring their better survival in the face of climate change or unstable weather conditions, and providing direct benefits to beekeepers. In conclusion, the results of this study underscore the importance of improving hive insulation and implementing a real-time hive monitoring system to track the daily cycle within each hive. Consequently, these findings are expected to significantly contribute to the conservation and adaptive management of bee colonies. This could have immediate implications for bee survival, increased production, and reduced costs by eliminating unnecessary management measures.

Conclusion

The study concludes that heat transfer is very influential on the hive and its contents, from wax production to pheromone release, brood growth, and more. Heat transfers automatically from a body with a higher temperature to a body with a lower temperature, and vice versa. When we want to regulate the ambient temperature to ensure the hive comfort, some form of heat exchange is necessary, such as cooling, which is essential when the weather is hot in the summer. Heat is transferred by one of the main methods: conduction, convection and Radiation. Heat can also be transferred by a combination of these methods simultaneously. Conduction: It is known that when two bodies touch, heat is transferred from the body with the higher temperature to the body with the lower temperature. Heat transfer between the two bodies stops when their temperatures equalize and thermal equilibrium is achieved. The transfer of heat between bodies means the transfer of thermal energy from the hot part to the cold part and from the particles to the cold part. As a result of the collision between these particles and the adjacent particles, some of their thermal energy is transferred to them, i.e., their vibration amplitude increases.

So, the process continues until all the particles acquire the same rate of thermal energy, at which point the transfer of heat stops. Heat transfer in solids occurs via thermal conductivity, a process of molecular collisions. Wood is a less efficient conductor of heat than metals. Wood has long been a popular material in beekeeping due to its good mechanical properties, stability, ease of machining, affordability, and satisfactory insulating properties. However, other organic materials, such as cork or wood fiberboard, may offer better insulating properties.

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