Comparison of colony performances of honeybee (Apis Mellifera L.) housed in hives made of different materials

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ABSTRACT
Numerous flowering plants rely on bees for pollination. Any natural or anthropogenic factor that threatens colony survival can have a large impact on plant production. This study investigates the effects of manmade hives built from different materials and how these may influence colony growth. Ten each of three hive types were selected, wooden, polystyrene and composite insulated hives. Factors of adult bee numbers, brood development, nectar flow period weight gain, bee flight activity, aggression response, and honey yield were selected markers of hive development. Statistically, each hive type produced significant variation (p < .05). The greatest overall productivity across all factors was for insulated hives made of composite material, with honey production approximately 35% times that of wood, 14% times that of polystyrene and in terms of the development of honeybee colonies, the average of other hives is 10.2 times.

HIGHLIGHTS
- Relative humidity and temperature are important environmental factors for honeybees.
- Insulated hives, increased honey yield.
- High temperature and humidity inside the hive made honeybees more aggressive.

Introduction
Due to the changing farming practices such as oilseed rape and greater demand for high crop yield, there is more demand for bees (Woody 2014). Apiculture provides additional revenue (it is not always a full-time job) with low start-up costs and in the right environment such as near farms, hives may be self-sustaining (Omran 2011). Beekeeping is seen as an indispensable branch of agriculture and studies in this field are becoming widespread in the world. Beekeeping is a nature-dependent production system and climate and vegetation are the main factors affecting beekeeping. Genotype, internal hive factors and external ambient factors such as temperature and humidity are very important in the efficiency of honeybees (Cetin 2004; Abou-Shaara et al. 2012; Tan et al. 2012; Abou-Shaara 2014). The hive can be made more comfortable for honey bee colonies by using materials that can isolate heat and humidity.

Although there is a lot of research on apiculture in the world, there are very few studies on hive types and hive making materials, which are of great importance for beekeeping. The high-temperature difference is seen in high altitude areas between day and night. Beekeeping is carried out in high altitude places in summer and honeybees are affected a lot this situation. Honeybees in uninsulated hives can be difficult to adapt to these temperature changes, and even larvae in the brood area can be damaged.

The worker bees move from the edge frames to the middle frames at night (when the temperature is low), and they consume the honey in the stock to heat the brood area. So keeping the inside temperature of the beehive between 33 and 36°C is very important for honeybee colonies (Petz et al. 2004; Shaw et al. 2011). Studies have shown that the deviation from this range in incubation temperature, the hatch rate, the colour of the bees, wing morphologies, learning capabilities, adult bees brain development and resistance to diseases are adversely affected (DeGrandi-Hoffman et al. 1993; Tautz et al. 2003; Groh et al. 2004; Ken et al. 2005). In addition, honeybees' activities outside the hive decrease when the ambient temperature rises excessively (Al-Qarni 2006; Costa et al. 2007; Blazyte-Cerkesiene et al. 2010).
Honeybees move out of the hive and ventilate to protect the brood area inside the hive from excessive heat during the daytime when the weather is very hot. This situation increases the labour force and decreases the yield. Some studies have been conducted in U.S.A. (Owens 1971; Detroy et al. 1982), Norway (Villumstad 1974) and other countries to minimise winter death of the honeybee colonies by maintaining hive temperatures. Some researchers have found that isolating the hive considerably reduces the consumption of honey (Detroy et al. 1982). Honeybees have to consume honey or fanning their wings to keep the hive atmosphere in habitable condition. The fact that honeybees are angry or calm affects the yield considerably. In addition to genetic factors, environmental factors may cause honeybees to become angry. The most important environmental factors are temperature and humidity (Southwick and Mortz 1987).

The aim of this study was to assess how effective the hive making materials are on the physiological and behavioural characteristics of honeybees and which making material would be the most ideal.

**Materials and methods**

This study was carried out in Bayburt University Apiculture Application and Research Station (at 40° 17’ 13” N latitude, 40° 56’ 13” E longitude, and 2137 m altitude) in Turkey, between 5 June 2018 and 30 August 2018. During the trial period, humidity and temperature data in the hive and apiary were recorded daily. Daily maximum and minimum temperature and humidity values interior of the hives and apiary were recorded at 13:00 pm during the test period (the beginning of June to the end of August). HOBO® UX100-023 External Temp/RH data loggers were used to determine the maximum and minimum temperature and humidity in the hive and apiary. The external probe of the data logger was inserted between the top bars of the frames in the middle of the hive by drill the inner cover. In order to determine the maximum and minimum temperature and humidity values in the apiary, the data logger was placed in the shade.

At the beginning of the experiment, the queens of all colony were exchanged with young mated queens. For consistency, each colony consisted of full food stock, five frames with sealed brood areas and four additional frames all full of bees. Colonies were divided into three groups: wooden hives, polystyrene hives, and insulated hives (in the hive making, a material consisting of insulating foam between two thin wooden sheets was used). All colonies were equalised to nine frames on 10 June 2018. Five of these frames were covered with sealed brood area.

From the date (10 June 2018) of the equalisation to the date (30 August 2018) of the honey harvest, the frames covered with bees were counted 30-day interval and recorded as a measurement of the adult bee development.

For each colony in the application groups, the sealed brood area was measured at the beginning of each month between 10th June to 30th August in 2018 and was calculated by using PUCHTA method as cm² (Fresnaye and Lensky 1961; Kandemir et al. 2000). To determine the nectar flow period weight gain of the colonies, the experimental hives were weighed at the beginning of the nectar flow period and before the harvest (Genç 1994).

Three test colonies from each group were randomly chosen to determine the flight activity of the experimental groups. For this, flying bees were counted for 60 s at 10:00 am. This procedure was repeated seven times 10-day interval (Firatlı and Budak 1992).

At the end of the season, honey was harvested. Honey harvesting is made only of honey supers. The number of the hive was written on each frame that was taken during the harvest. Before extraction, the frames were weighed and recorded as the honey yield of the experimental honeybee colonies (Genç and Aksoy 1993; Carbonari et al. 2016)

A black suede oval ball with a size of 4 × 5 cm was used to determine the aggression tendency. The suede ball was shaken in front of the flight hole for 1 min, at the same time in the randomly selected colonies of each trial group. This process was repeated seven times 1-week intervals apart from June 15 at the end of each application, the number of bee sting on the suede ball was determined and evaluated as the measure of aggression tendency of the groups (Firatlı and Budak 1992; Akyol and Kaufanoğlu 2001; Güsterit et al. 2012).

All data were analysed using ANOVA (IBM SPSS 22 statistics software; IBM SPSS Statistics, Armonk, NY). The models used for measure repeated ANOVA (MANOVA) and simple ANOVA. The significance level was taken as p < .05 in all analyzes. Tukey’s HSD post hoc test was used to compare the means.

**Results and discussion**

Development of brood area, the number of frames covered with bees (development of honeybee colonies), weight gain of the application groups, the number of bees going from the hive, honey yield, number
of bee sting, average maximum and minimum temperature, and humidity values in the hive are presented in Table 1.

The amount of the brood area is the most important criterion for determining Colony development (Genç et al. 1999). When looking at the development of the brood area, the honeybee colonies in the insulated hives had the development of brood area rate of 23.99% more than the wooden hives and 6.47% more than the polystyrene hives. The average of polystyrene hives and insulated hive showed no statistically significant effect; however, they showed significant differences with respect to wooden hives (\( p < .05 \)). According to the results, the most intensive brood production period was the month of July with the highest nectar flow. The results we obtained regarding the brood activity were more than most of the previous studies (Akyol and Kaftanoğlu 2001; Karacaoglu et al. 2003; Arslan et al. 2004). The appropriate hive conditions increase the production of brood, which leads to an increase in the number of adult bees.

All of the application groups showed a continuous increase in the adult bee population and reached the highest level towards the end of the nectar flow period. The best results for adult bee development were obtained from isolated hives. In this study, it was found that bee colonies in the insulated hive had a frame covered with bees 16.25% more than wooden hives, but there was no statistical difference between wood, polystyrene and insulated hives (\( p < .05 \)). It was found that the data gained from insulated hives related to adult bee development were higher than in previous studies (Güler 2000; Şahinler and Kaya 2001; Dodoloğlu et al. 2004; Şahinler and Gül 2004).

The more adult bees, the greater the amount of nectar carried to the hive. On the contrary, a large number of young worker bees in the hive cause the consumption of nectar brought from outside. Insulated hives have raised more brood than other hive types in earlier periods, so their weight increases were more. In terms of mean weight gain from the start of the production season to the end, the insulated hives were 27.90% higher than the polystyrene hives and the polystyrene hives were 19.76% higher than the wooden hives. Hive types affected the weight increase in the season of production (\( p < .05 \)). In terms of weight gain of the nectar flow period, the highest value was measured from insulated hives, while the lowest value was measured from wooden hives. These values are lower than other studies (Dodoloğlu et al. 2004). However, it is much higher than the results obtained by Taha (2014).

If the hive can protect the bee colony from the cold of the night, the bees come out of the hive to work early in the morning. Otherwise, they expect the sun to rise and the hive to warm up. This leads to a loss of workforce and time. The number of bees entering and exiting the hive is an indication of the

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### Table 1. The effect of wooden, polystyrene and insulated hive types on some behavioral characteristics with colony performance parameters of honey bees.

|                           | Wooden hive Mean | \( p \) Value | SEM | Polystyrene hive Mean | \( p \) Values | SEM | Insulated hive Mean | \( p \) Value | SEM |
|---------------------------|------------------|---------------|-----|------------------------|---------------|-----|---------------------|---------------|-----|
| Development of honeybee colonies (pieces frame/colony) | 9                | 0.19          |     | 17.97b                 | 0.00          |     | 20.18b              | 0.00          |     |
|                           | 24.03c           | 0.48          |     | 25.72c                 | 0.00          |     | 18.30c              | 0.30          |     |
|                           | 16.43c           | 1.04          |     | 19.10c                 | 0.30          |     | 19.10c              | 1.418         |     |
| Development of brood area (sealed brood/cm²) | 3195.60d         | 42.39         |     | 3222.40a               | 0.00          |     | 3393.40a            | 0.00          |     |
|                           | 5545.50c         | 48.17         |     | 6913.50f               | 0.00          |     | 7228.10c            | 0.00          |     |
|                           | 4283.67h         | 47.22         |     | 5032.70p               | 0.00          |     | 5529.50b            | 0.00          |     |
|                           | 4341.67c         | 180.50        |     | 5062.20a,b             | 0.13          |     | 280.81              | 5383.67b      | .64 |
| Weight gain of the application groups (kg/colony) | 34.86c           | 0.48          |     | 41.75b                 | 0.00          |     | 53.40c              | 0.00          |     |
|                           | 80.95a           | 1.60          |     | 93.15b                 | 0.00          |     | 103.62a             | 0.00          |     |
| Honey yield (kg/colony)   | 17.08a           | 0.61          |     | 20.17a,b               | 0.07          |     | 23.04b              | 0.09          | 1.17|
| The number of bee sting of the honeybee colonies in the application groups | 3.04a            | 0.18          | 0.26 | 4.05b                  | 0.59          |     | 3.69b               | 0.18          | 0.25|
|                           | 55.72a           | 0.75          |     | 66.94c                 | 0.00          |     | 61.41b              | 0.00          | 0.84|
|                           | 24.69a           | 0.27          |     | 37.29c                 | 0.00          |     | 29.99b              | 0.00          | 0.51|
| Maximum and minimum temperature and humidity values in the hive | 38.61b           | 0.11          |     | 33.90a                 | 0.49          |     | 34.24a              | 0.49          | 0.28|
|                           | 20.10a           | 0.26          |     | 24.97b                 | 0.81          |     | 24.82b              | 0.81          | 0.11|
|                           | 55.72a           | 0.75          |     | 66.94c                 | 0.00          |     | 61.41b              | 0.00          | 0.84|
|                           | 24.69a           | 0.27          |     | 37.29c                 | 0.00          |     | 29.99b              | 0.00          | 0.51|

SEM: standard error of mean.

\( a, b, c \)\( p < .05 \).
working power and willingness of the bee colony to work. Measurements were made to determine how the hives made of different materials affected the willingness of the colonies to work. As a result of these measurements, it was found that the colonies in the insulated hives were 19.03% higher than the average of other types of hives (polystyrene and wooden). Hive types have been effective on bee numbers that fly out of the hive (p < .05). The minimum average number of bees that fly out of the hive was determined in wooden hives, and the maximum number was determined in insulated hives. The data we obtained were consistent with the values reported by Dodoloğlu and Genc (2002) but were higher than those reported in previous studies (Genc et al. 1999; Dodoloğlu et al. 2004). The honey bees, which are found in hives with good heat insulation, do not have to make ventilation or heating in hives. Instead, they go out to collect nectar or pollen.

The number of worker bees in the colony, the race of bee, the age of the queen, the health of the colony, the flower density in the field, the nectar flow time, the number of colonies in the area, the climate and weather conditions are the factors affecting the honey production. It is very important to store the nectar that is carried into the hive by honey bees without consuming it. Unsuitable hive conditions and external environment conditions increase the consumption of stored honey. Honey bees do thermoregulation in hives to hold the constant of the brood area temperature at 32–34 °C. Honey bees consume honey to provide the energy necessary for this. This reduces the amount of honey to be harvested from the hive. Traditional beekeeping is mostly made in wooden hives. This means 34.89% less honey harvest compared to beekeeping made with insulated hives. This study showed that the insulated hives can give 14.23% more honey than polystyrene hives and 34.89% more than wooden hives. Honey yields, polystyrene, and insulated hives significantly increased compared to the wooden hive (p < .05). This value is higher than the values reported by Chaudhary (2001) and it is smaller than the value reported by Wineman et al. (2003) and Akyol and Kaftanoğlu (2001). In contrast to our results, as a result of a study, Kleinschmidt (1993) reported that colour, ventilation, and hive body design have no effect on honey production.

The anger of honey bees is affected by the genetics of bees, hive factors, and external environmental factors. All beekeepers want to work with calm-temperament bees that have high yields and low-stung reflexes. We can’t influence external environmental factors as beekeepers, but we can make bees calmer if we optimise the internal conditions of the hive. The amount of humidity, air circulation, and temperature in the hive is one of the most important factors that provoked the honey bees. Since the humidity rates in wooden and insulated hives are at a more reasonable level, bees in these hives have shown a more docile behaviour. The reason why bees in the polystyrene hives are more aggressive can that the hive humidity level is higher. Polystyrene and insulated hives increased the aggressiveness of bees statistically (p < .05).

The most important factors in beekeeping are temperature and humidity. Environmental temperature and humidity affect plant growth and flowering rates and duration. The amount of temperature and humidity in the hive affects the amount of brood area, the amount of honey storage, aggression tendency, and the flight activity. When the internal temperature of the hive rises honey bees goes out of the hive, try to cool the interior the hive by wrapping the outside, or by pumping clean air through the flight hole and attempting to throw out the dirty air. This causes loss of work, time and honey. In high altitude regions, honey bees spend energy to cool the hive during the day, while they spend energy to heat it at night. They need to eat plenty of honey to provide the energy needed for these jobs. If heat insulation and air circulation of the hives are good, the workload of honey bees is reduced and their efficiency increases.

Since thermal insulation of wooden hives not sufficient, the average minimum temperature is lower than in other hives (polystyrene, insulated) types. The insulated and polystyrene hives were significantly influential in preventing the internal temperature from falling too much, but the wooden hives were unable to provide this (p < .05). However, the minimum temperature values are always higher than outside. This study supports the conclusion that the presence of honey bees in the previous studies (Simpson 1961; Ohashi et al. 2008) on thermoregulation of honey bees increases the internal temperature of the active hive. This study, in a study, conducted to investigate the effect of honey bee colonies in wooden and foam hive, supported the conclusion that the internal temperature of the hive in cold weather is higher than the outside temperature.

When the maximum temperature in the hive is examined, the highest value is in the wooden hive, followed by an insulated hive and polystyrene hive. The statically insulated hive and the polystyrene hive were in the same group, but the wood hive was in the other group. The polystyrene hive had the
highest maximum-humidity value because it couldn’t provide good ventilation, followed by the insulated hive and wooden hive. Hive types were effective in terms of maximum-humidity ($p < .05$). The highest average minimum-humidity value was measured from the polystyrene hive and the lowest value was measured from the wooden hive. Hive construction materials were effective on the minimum value of humidity ($p < .05$). All three hive types (wooden, polystyrene, insulated) were in different groups.

The temperature and relative humidity values of the apiary in which the study is carried out are shown in Figures 1 and 2. The apiary was built at high altitude (2137 m). So, there is sudden increases and decreases in temperature value. The highest temperature measured during the production season was 40.5 °C, while the lowest temperature value was 9.8 °C (Figure 1). The highest relative humidity value was 98% during the experiment, while the lowest relative humidity was 24% (Figure 2). The high relative humidity is necessary during the intensive brood production period but is not request during the honey ripening period and the wintering period.

Conclusions

The wood hives are robust and natural, but their thermal insulation is not very well. In addition, since wooden hives are heavy, it is difficult to carry at migratory beekeeping. Migrant beekeepers may be preferred polystyrene hive because of their lightweight, but these hives can be easily damaged in the apiary and they have poor ventilation characteristics. Mice easily gnaw polystyrene hives in the warehouse. Sunlight does more damage polystyrene hives than other hives. Insulated hives are one of the most suitable types of beehive in terms of beekeeping due to their durability, lightness, good ventilation, heat insulation and the naturalness of the surfaces in which bees come into contact.

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