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Thermal conductivity of the ceramic beehives

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Abstract: *Beehive made of ceramic is a relatively novel concept in the feed of the beekeeping industry. One of the reasons behind the idea of changing the classical construction material of the beehives is the relatively better thermal conductivity of the ceramic material in comparison with the wooden. Previous field observations show that in wintertime the temperature in the ceramic beehive is with 1°C to 2°C warmer than the temperature measured in a wooden beehive from the same field. The present study aims to examine the thermographic characteristics of a ceramic beehive and to compare them with the most spread wooden type of hives. For the purpose, it was conducted a thermographic diagnostic of three beehives (two ceramic and one wooden) from the same field. The measurement is conducted with a thermal imaging infrared camera. For the analysis is used a licensed software FLIR Reporter Pro. The results of the comparative analysis show that in terms of balanced thermal distribution and creating a better internal environment, the ceramic beehives outperform the wooden one. What is more, the higher porosity of the ceramic material is proved to be a factor in the provision of a balanced thermal environment for the bee family.*
KEYWORDS*: CERAMIC BEEHIVE, THERMAL BALANCE, THERMAL DISTRIBUTION, BEEKEEPING*

INTRODUCTION

The idea for a beehive made of ceramics starts its development in 2012 with the first theoretical research and expert evaluation. In 2014 the prototypes of the beehive are produced and inhabited. The results from the initial experiments have been published in 2019 [1]. This idea inspired by the ancient ways of beekeeping is reasoned with the comparatively better characteristics of the constructional ceramics over the wood. Until they are well known and already proven in the scientific literature, there are still no publications that examine the real living environment which the ceramic tiles structure creates within the beehive. There are several indicators by which it can be evaluated such as temperature and humidity [2].

GENERAL OVERVIEW OF THE PROBLEM

The temperature within the hive is an extremely important factor for the survival of the bees but also for the quality of the bee products. The researches show that the optimal temperature in the breed is around 35-36°C [3]. Higher temperatures can cause the death of the family. Lower temperatures especially temperatures below 0°C will lead to protective diapause behaviour or will have a lethal effect. The extreme temperatures affect the bee products as well. Overheating causes wax melting and too-quick dehydration of the honey [4] while the low temperatures slow down the dehydration of the nectar which causes problems in the production of the honey. The bees have own regulation mechanisms to maintain the healthy temperature of the hive. Whenever the weather is too hot, they start fanning the hot air out or use evaporative cooling mechanisms. If the temperature gets too low they start generating metabolic heat by contracting their flight muscles [5]. Both these mechanisms consume high energy of the bees and increase their need for food.

The specific physics and mechanical parameters of the ceramic material make it more preferable for construction purposes in comparison with the wood. Such are the better isolation properties; the pore "breathing" structure; the homogeneous clay mix which assures equal physical properties at each part of the tile; and the lower percentage of water absorption. This leads us to the assumption that the ceramic material would be a better option for ensuring a more balanced internal environment of the breed. To test this hypothesis, we have conducted a thermographic diagnosis of both ceramic and wooden beehives and compared the results.

METHODOLOGY

For thermographic diagnosis are presented three different beehives – two ceramic and one wooden. The ceramic breeds are 10-frames Dadant-Blatt type of hives. The four walls of the brood box are four ceramic tiles with a high cavity (>66%) which are connected with construction glue on cement basis with fiber filaments. There are some constructional differences between both ceramic samples and the wooden hive. For the purpose of the present study they are labelled respectively Type 1, 2 and 3:

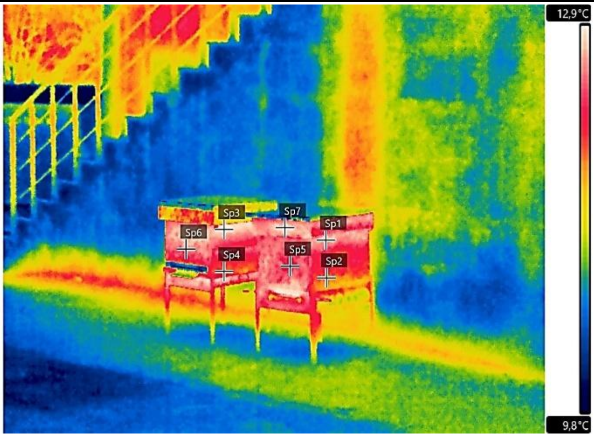
Table 1 *Test models*

	Brood box	Feeder	Roof	Floor	Stand
Type 1	Ceramics, high bottom	Wood	Wood covered with galvanized metal layer	Net, no thermal insulation	Metal
Type 2	Ceramics, deep bottom	PVC	Wood covered with galvanized metal layer	Net, 2 cm thermal insulation from expanded polystyrene	Metal
Type 3	Wood	Wood	Wood covered with galvanized metal layer	Net, no thermal insulation	Wood

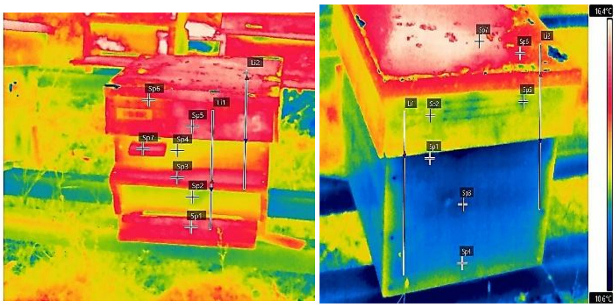
The measurement is conducted with a thermal imaging infrared camera. For the analysis is used a licensed software FLIR Reporter Pro. The measurement is conducted on November 13, 2019, in Chernoochene Village, Haskovo Municipality. The temperature outside is measured three times with Relative Humidity respectively: t= 9°C, RH= 96%; t=10 °C, RH= 95%; t= 11 °C, RH= 94%. The results from the capturing are colour images where the brighter tones stand for higher temperatures. For the purpose of the thermal diagnostics at the second stage of the measurement in each hive has been put a heat source (a bottle of hot water) in order to be observed the heat leakage and the heat distribution on the walls. The last stage of the diagnostics is capturing ceramic and wooden hives which are already inhabited with bees on the beekeeping field. The results obtained for all examined hives are compared.

RESULTS AND DISCUSSION

The beehives were first captured in their normal condition without bees inside.



Picture 2 *Ceramic beehives: Type one (left) and Type 2 (right)*



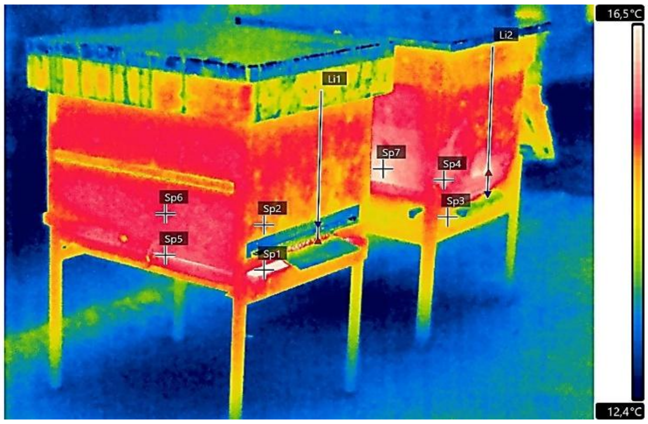
Picture 3 *Wooden beehive Type 3, Front(left and back)*

Table 2 *Measured temperature in normal conditions*

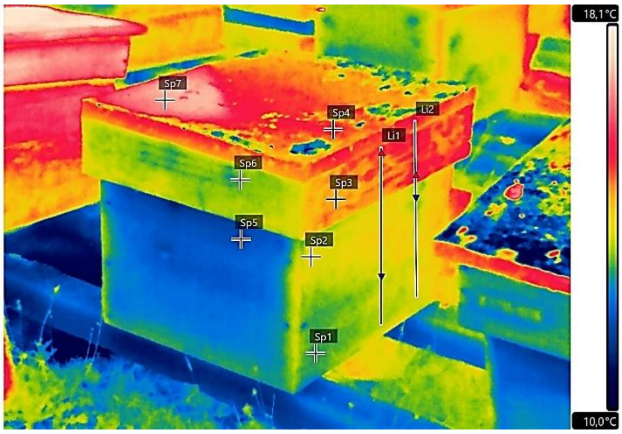
	Picture 1 [°C]	Picture 2[°C]	
		Front (T3)	Back (T3)
Sp1	12,7 (T2)	14,4	11,2
Sp2	12,0 (T2)	12,0	12,9
Sp3	13,0 (T1)	14,6	11,5
Sp4	12,1 (T1)	12,4	12,3
Sp5	12,3 (T2)	14,7	12,5
Sp6	12,7 (T1)	13,5	14,7
Sp7	12,8 (T2)	14,7	16,0

What can be observed from pictures 1 and 2 and the table with the measured temperature of the external walls leads us to the conclusion that the temperature of on the surface of the ceramic hive is distributed more balanced. The measured temperature in the different points of each ceramic hive have relatively the same values with a very small deviation. Differences are observed in the measured points where the element is made of wood. The entrance reducer of Type 1 is made of metal and this explains the lower temperature measured there. This information can be used for constructional improvements in the future. What we see in picture 2 is that the heat is not equally distributed in the front Dt(Sp1-SP2)=2,4°C, Dt2(Sp3-SP4)=2,2°C, Dt3(Sp5-Sp6)=1,2°C and back. The horizontal planes are heated more than the vertical (the walls) which we can say is due to more accumulated sun heat. The temperature differences could be explained with the wood's higher moisture absorption which accumulates different heat from the air. The higher measured temperature on the walls of the beehive can be due to sun exposer at the time the pictures have been taken. Considering the results for the temperature on the plane back of the wooden hive, it is obvious that although in one plane, the temperature in the different points is different which can lead us to the idea that there is moisture in the walls.

At the next stage at each of the beehives was put a heat source with the temperature of 39,9°C. The results after that are presented in Pictures 3 and 4 and Table 3.



Picture 3 Ceramic beehives with a heat source inside



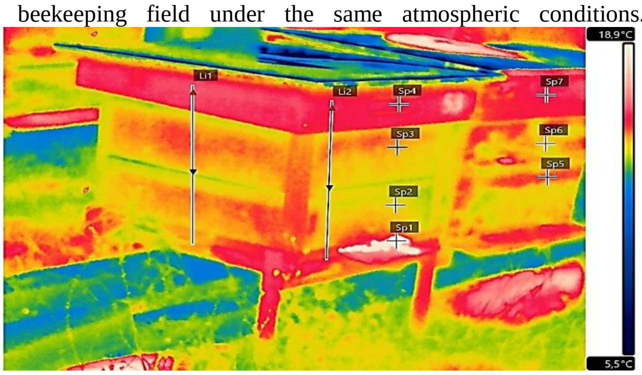
Picture 4 *Wooden beehive with a heat source inside*

Table 2 *Measured temperatures when a heat source is put in the hive*

	Picture 3 [°C]	Picture 4 [°C]
Sp1	17,3	13,0
Sp2	15,2	13,9
Sp3	14,6	14,5
Sp4	15,9	15,2
Sp5	16,3	11,9
Sp6	15,5	13,2
Sp7	16,6	17,0

Immediately before picture 3 was captured the heat source was moved from Type 1 to Type 2. The heat is moving from the internal walls to the internal cavity of the tiles where it heats the air and from there it moves to the external side of the tile. The heat in the two ceramic hives is distributed relatively balanced. The difference in Sp7 (Picture 3) is due to direct contact of the heat source to the hive's wall. The only imbalance is observed in the roof area which is made of wood. There is high contrast at Sp 1 (Pic.3) which is due to the exfiltration of hot air through the entrance reducer because it is not well compacted. The thermal decline drops significantly. Considering Picture 4, we see that the heat source leads to an increase in the temperature of those zones of the walls which are dyer. The backside of the wooden hive remains relatively cold (Sp5=11,9°C). At this stage of the analysis, we can conclude that for the ceramic hives in both conditions (with and without a heat source) the heat distributes in even pace to all ceramic parts of the hive. On the other hand, the moisture in the wooden brood prevents this to be observed there. The temperature differences in the different parts of a same wall of the wooden hive make the air move which can cause swirling inside the brood. Such would create a disturbance of the bee family.

The last stage of the diagnostics is the comparison between inhabited ceramic and wooden broods. Both of them are on a beekeeping field under the same atmospheric conditions.



Picture 5: *Inhabited hives: Ceramic (Left) and Wooden (Right)*

Table 3: *Measured temperatures in inhabited ceramic (left) and wooden (right) hives*

	Picture 5[^{o}C]
Sp1	22,4
Sp2	14,6
Sp3	14,9
Sp4	15,9
Sp5	15,4
Sp6	14,7
Sp7	16,0

The highest measured temperature is at point Sp1 which is due to the presence of bees there which have their own temperature so this point will be neglected during the analysis. The picture is taken at 10:58 when the temperature of the air is 9^{o}C, RH=96%, wind <2m/s. The ground of the field is wet because of rain. Despite the high humidity of the air we can see that the heat distribution on the ceramic walls is relatively balanced. For the wooden hive, we see more clearly a difference in the different points of measurement. This can be explained with the accumulated moisture at some parts of the wooden walls and changes the thermal properties of the material. At the image, we observe that the wooden walls are not tempered evenly and homogeneously which is visible from the high contrast zones. Here should be considered the dynamic nature of the evaluated hives. The captures have been done at a given moment which is part of a continuous movement of energy streams which characterizes the energy exchange and interchange of the brood. In the picture, we see that some parts of the wooden hive, as well as the periphery of both roofs are coloured in contrasting red. We can explain this with the moisture which the wood keeps as the water has higher thermal capacity and stores the accumulated heat for a longer period in comparison with the dry wood. In the conditions of thermal transition when a process of heat exfiltration takes place, it is normal for the wet zones to appear warmer than the dry zones. When the walls are ceramic, the thermal transition waste is lower which decreases the need for the bee family to self-produce an additional quantity of heat.

CONCLUSION

The results from the present study show that if the classical wooden walls of the brood structure are changed with ceramic tiles with a high cavity, this would increase the thermal comfort of the bee family because it will ensure a balanced environment in the brood. This statement is derived from the fact that the surface heat of the examined ceramic hives is distributed evenly on each tile. The wood and the ceramics have different porosity and they absorb different quantity moisture from the air. The higher moisture resistance of the ceramic walls improves the living environment and decreases the risks of development of different harmful microorganisms. This may reflect also to the quality of the bee products. At the same time, the unbalanced moisture storage of the wooden walls leads to a change of the thermal coefficient of some zones of the walls. Evidence for this are the contrast zones displayed on image 4. The absorbed water changes the thermal properties of the wood and when in the brood is put a heat source, and a thermal difference between both sides of the wall is created, some zones of it remain colder. When the source is removed and the temperature at both sides of the wooden wall is equalized, we observe that the wet zones become warmer than the dry zones. When it comes to the ceramic hives such events are not observed.

Considering the results of the study we can conclude that for the examined hives, the ceramic ones have better and even heat distribution while the moisture absorption is relatively low. Both factors result in a better living environment for the bees, creating conditions for lower energy waste of the family.

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