Monitoring of temperature and humidity in hives made of different material by an electronic recording system during the autumn and winter period of the development of bee colonies

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Abstract

The changes of temperature and humidity in hives made of different material (wood, polystyrene, ceramics) during the autumn-winter period (2020–2021) from the development of bee colonies are tracked. Bee colonies settled in 10-frame hives Dadan-Blatt system with lattice and solid bottoms are used. To control the temperature and humidity in the beehives, an electronic recording system is used with sensors installed in each hive and one sensor for monitoring the outside temperature and humidity. During the studied autumn-winter period the temperature in the hives (average for the period and by months) is higher and the humidity lower compared to the values of the outside temperature and humidity, regardless of the material of the hive and the type of bottom (lattice or solid). The highest average temperature in the autumn period (September, October, November) is found in the ceramic hive with a solid bottom (29.15 ± 6.51 °C), and the minimum value is reported in the polystyrene hive with a solid bottom (19.01 ± 8.47 °C). During the same period, the maximum value of the humidity indicator for the hives with a lattice bottom is observed in the ceramic hive (50.74 ± 8.92%) and the minimum in the polystyrene hive (45.91 ± 9.62%). For beehives with a solid bottom, the highest average humidity is found in the polystyrene hive (55,14 ± 6,96%), and the lowest in the wooden hive (44.69 ± 5.00%).

During the winter period (December, January, February) the highest average temperature is found in wooden hives (10.15 ± 5.61 °C and 11.89 ± 5.16 °C), and the lowest in polystyrene hives (7.44 ± 5.12 °C and 7.61 ± 4.23 °C), regardless of the type of bottom. The largest difference from the outside temperature (5.11 °C on average) is observed in the wooden hives – 5.04 °C with a lattice bottom and 6.78 °C with a solid bottom, respectively. The lowest average value of the humidity indicator is reported in the wooden hives, regardless of the type of the bottom (69.70 ± 14.16% and 55.45 ± 10.04%), and the highest in the polystyrene hive with a lattice bottom and the ceramic hive with a solid bottom (in 70–75%). The difference between the average values of the humidity indicator in the hives compared to the external humidity (79.24%) in the hives with lattice bottoms is less than 10%. In the hives with solid bottoms the differences vary in the range of 6–24% with the highest being in the wooden hives.

Key words: beehives, temperature, humidity, monitoring

Мониторинг на температурата и влажността в кошери, изработени от различен материал чрез електронна записваща система през есенен и зимен период от развитието на пчелните семейства

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Резюме

Проследени са промените на температурата и влажността в кошери, изработени от различен материал (дърво, полистирол, керамика) през есенно-зимния период (2020–2021 г.) от развитието на пчелните семейства. Използвани са пчелни семейства, заселени в 10-рамкови кошери, система Дадан-Блат, с решетъчни и плътни дъна. За контрол на температурата и влажността в пчелните гнезда е използвана електронна записваща система с монтирани датчици във всеки кошер и един датчик за проследяване на външната температура и влажност. През изследвания есенно-зимен период температурата в кошерите (средно за периода и по месеци) е по-висока, а влажността по-ниска в сравнение със стойностите на външната температура и влажност, независимо от материала на кошера и вида на дъното (решетъчно или плътно). Най-висока средна стойност на температурата през есенния период (септември, октомври, ноември) е установена при керамичния кошер с плътно дъно (29,15 ± 6,51 °C), а минималната стойност е отчетена при полистиролния кошер с плътно дъно (19,01 ± 8,47 °C). През същия период максималната стойност на показателя влажност за кошерите с решетъчно дъно е наблюдавана при керамичния кошер (50,74 ± 8,92%) и минимална при полистиролния кошер (45,91 ± 9,62%). За кошерите с плътно дъно най-висока средна влажност е установена при полистиролния кошер (55,14 ± 6,96%), а най-ниска при дървения кошер (44,69 ± 5,00%). През зимния период (декември, януари, февруари) най-висока средна стойност на температурата е установена при дървените кошери, а най-ниска при полистиролните кошери, независимо от вида на дъното. Най-голяма разлика спрямо външната температура (средно 5,11 °C) се наблюдава при дървените кошери – съответно 5,04 °C с решетъчно дъно и 6,78 °C с плътно дъно. Най-ниска средна стойност на показателя влажност е отчетена при дървените кошери, независимо от вида на дъното, а максимална при полистиролния кошер с решетъчно дъно и керамичния кошер с плътно дъно. Разликата между средните стойности на показателя влажност в кошерите спрямо външната влажност на въздуха (79,24%) при кошерите с решетъчни дъна е под 10%. При кошерите с плътни дъна разликите варират в границите 6–24%, като най-висока е при кошерите от дърво.

Ключови думи: пчелни кошери, температура, влажност, мониторинг

Introduction

The evolutionary development of honey bees has led them to a social way of life. Temperature regulation in the beehive is of great importance for the normal development of the bee colony. In the various activities performed by honey bees in the colony (warming the nest, guarding the home, collecting nectar and pollen, raising brood, rearing queen bees, etc.), bees maintain optimal limits of temperature and humidity (Eskov, 1981, 1983; Abou Shaara et al., 2017). This is possible thanks to the well-developed thermo- and hydroreceptors and the CO_2 receptors. The temperature maintained by the colony members in the bee nest is characterized by high stability, especially in the brood area (Eskov, 1981; Petz et al., 2004; Ohashi et al., 2009; Stabentheiner et al., 2010). A number of studies (Owens, 1971; Villumstad, 1974; Detroy et al., 1982) are linked to the minimization of winter death of bee colonies by maintaining the temperature in the hives. Vorobeva et al. (2020) accept the maintenance of an optimal microclimate in the bee nest (temperature, humidity, ventilation) as a task of great importance related to the winter hardiness of bee colonies.

Monitoring the microclimate in bee nests is also necessary due to the introduction in beekeeping practice of hives made of different materials (polystyrene, ceramics, etc.), in which the insulation characteristics are different from wood (Detroy et al., 1982; Erdogan, 2019; Lepkova et al., 2019, 2020). According to Detroy et al. (1982), a hive that provides better insulation significantly reduces honey consumption. The comparative analysis made by Erdogan (2019) shows that wooden hives are durable, but they are heavy and with not very good thermal insulation, while the polystyrene hives are light, suitable for mobile beekeeping, but with not very good ventilation characteristics. According to Lepkova et al. (2020) the different amount of moisture absorbed by wood and ceramics is due to the different porosity of these materials. In ceramic hives, due to the higher moisture resistance of the material, it is possible to prevent the development of various microorganisms and to create a healthy environment for bees.

At the present stage technologies are effectively used in agriculture, incl. in beekeeping (Altun, 2012). Studies by a number of authors have shown that temperature and humidity in hives can be controlled by technological solutions (Fehler et al., 2007; Tani and Cugnasca, 2007; Shao and Xin, 2008; Eskov and Toboev, 2009; Erdogan et al., 2009). Pulli and Zheng (2005) point out that the analysis of data obtained through wireless networks is common. In their experiments, Altun (2012) uses sensors to measure the temperature and humidity in the hives, and the data from them are sent to a GSM central system via a wireless sensor network system. The software developed in the central system guarantees that the beekeeper will be informed via GSM in case of a problem.

In this regard, the control of changes in temperature and humidity in the bee nest during the different periods of development of bee colonies is crucial. On the other hand, the control of temperature and humidity in hives made of different material will make it possible to assess the suitability of these materials for rearing bee colonies, respectively their impact on the physiology and behaviour of bee specimens and the colony as a whole during the different periods of their lives. The application of modern technological solutions for monitoring the microclimate in bee nests will facilitate the control activities of beekeepers, which is why it is a topical issue of importance for beekeeping science and practice.

The objective of the study is to trace temperature and humidity changes in hives made of different material (wood, polystyrene, ceramics) via an electronic recording system during the autumn and winter period of the development of bee colonies (preparation for wintering, wintering, beginning of active work).

Materials and methods

The study was carried out at the Training Apiary of the Beekeeping Section of the Faculty of Agriculture, Trakia University, Stara Zagora during the beekeeping seasons of 2020 and 2021. Bee colonies settled in 10-frame hives Dadan-Blatt system were used. The hives are made of different material – wood, polystyrene and ceramic. The bee colonies are with queen bees of the same age and origin supplied by the Bulgarian Beekeepers' Breeding Association (BBBA).

To control the temperature and humidity in the beehives, an electronic recording system was used with sensors installed in each hive (Fig. 1 A and B) and one sensor for monitoring the outside temperature and humidity (Fig. 1 C).

A B C

Fig. 1. Electronic recording system

Фиг. 1. Електронна записваща система

A B C

Fig. 2. Type of hives: A – polystyrene; B – wooden; C – ceramic

Фиг. 2. Вид кошери: А – полистиролен; В – дървен; С – керамичен

Three groups of bee colonies are formed depending on the material of the hive. Each group has two beehives – one with a lattice bottom and the second with a solid bottom (Fig. 2).

The monitoring of temperature and humidity in beehives covers the autumn (September, October and November 2020) and winter (December 2020, January and February 2021) periods of bee colony development. The above-mentioned periods cover preparation for wintering, development during the winter (wintering), beginning of active work.

The data from the recording system are read every 30 minutes and downloaded twice a week. They are statistically processed on a computer – Statistica 14.

Results and Discussion

Autumn period

The data about temperature values average for the three months in the autumn period (September, October, November) are given in Table 1. It is evident from the table that during the studied period temperature in the beehives is higher and humidity is lower compared to the values of ambient temperature and humidity regardless of the beehive material and the type of bottom (lattice or solid one).

For hives with lattice bottom the average temperature for the season varies within narrow limits – from 25.27 ± 6.88 °C (wooden hive) to 26.77 ± 10.95 °C (ceramic hive) – Table 1. The indicated values are higher compared to the ambient temperature (16.64 ± 8.03 °C average for the period) and the difference is the greatest in the ceramic hive (10.13 °C), followed by the polystyrene hive (9.27 °C), and the lowest one is in the wooden hive (8.63 °C).

A reason for the results obtained regarding the higher internal temperature in the ceramic hive (even with a lattice bottom) compared to the other two types of hives could be the accumulation effect of the ceramic material (Lepkova, 2019, 2020). The smaller difference between internal and ambient temperature in the wooden hive with a lattice bottom could be related to the poor thermal insulation of the wood material (Erdogan, 2019).

For hives with solid bottom a wider range of the average seasonal temperature has been established (from 19.01 ± 8,47 °C to 29.15 ± 6.51

Table 1. Temperature and humidity in hives of different materials – average for the autumn and winter season
Таблица 1. Температура и влажност в кошери от различни материали – средно за сезон есен и зима

Type of hive / Вид кошер	Season / Сезон	Temperature, °C / Температура, °C			Влажност, % / Humidity, %		
		n	mean	SD	n	mean	SD
Polystyrene hive / Полистиролен кошер – Lattice bottom / мрежесто дъно	Autumn / есен	1806	25.91***	7.49	1806	45.91***	9.62
	winter / зима	3365	7.44	5.12	3365	74.01***	8.65
– Solid bottom / плътно дъно	autumn / есен	2511	19,01***	8.47	2504	54.48***	9.04
	winter / зима	3872	7,61	4.23	3872	68.20***	4.27
Wooden hive / Дървен кошер – Lattice bottom / мрежесто дъно	autumn / есен	1917	25.27***	6.88	1917	47.28***	11.10
	winter / зима	3757	10.15***	5.67	3757	69.70***	14.16
– Solid bottom / плътно дъно	autumn / есен	1513	26.95***	7.81	1512	44.69***	5.00
	winter / зима	1955	11.89***	5.16	1955	55,45***	10.04
Ceramic hive / Керамичен кошер – Lattice bottom / мрежесто дъно	autumn / есен	2726	26.77***	10.95	2727	50.74***	8.92
	winter / зима	3598	8.20	5.24	3598	70.13***	10.21
– Solid bottom / плътно дъно	autumn / есен	2400	29.15***	6.51	2400	55.14***	6.96
	winter / зима	2612	8.18	4.90	2612	73.06***	5.84
External conditions / Външни условия	autumn / есен	2759	16.64	8.03	2759	64.71	19.93
	winter / зима	2136	5.11	5.41	2136	79.24	17.96

***$P \leq 0,001$

°C), the maximum value having been recorded in the ceramic hive and the minimum one in the polystyrene hive (Table 1). The average temperature for the period in the polystyrene hive with a solid bottom is only 2.37 °C higher than the recorded ambient temperature. In the wooden and ceramic hive the differences between the internal and ambient temperature are 4–5 times greater compared to the polystyrene hive – 10.31 °C and 12.51 °C, respectively.

As is evident from Table 1, the observed differences in the temperature values between hives with a lattice and solid bottom have greater level of probability ($P \leq 0.001$).

During the same period the maximum value of the humidity indicator for hives with a lattice bottom was observed in the ceramic hive and the minimum one in the polystyrene hive (Table 1), the difference between the two values being about 5%. The comparative analysis between the humidity recorded inside the hives and that of the surrounding environment (64.71%) shows differences of 14% (ceramic hive) and 19% (polystyrene hive).

For beehives with solid bottom, the highest average humidity was found in the polystyrene hive and the lowest one – in the wooden hive, the difference between the maximum and minimum value being twice as large as that of the hive with lattice bottom (10.45%) – Table 1. Based on the above results and the data on the reported average ambient humidity (64.71%) it can be commented that hives made of wood absorb moisture very well and optimal humidity is maintained in the bee nest.

The observed differences in the humidity values between the hives with lattice and solid bottom have high degree of reliability ($P \leq 0.001$) – Table 1.

The comparative analysis between the obtained results for temperature and humidity in hives made of different material and with different types of bottom shows from medium to high degree of reliability (Table 2). The reported differences in terms of average autumn temperature between polystyrene and wood, polystyrene and ceramic hive have a reliability of $P \leq 0.01$, and in terms of humidity between polystyrene and ceramic hive.

Fig. 3 presents graphically the results about the average temperature in the hives and outside them by months. In the months of September and October, similar values of the average temperatures were found for the polystyrene and wooden hives with higher values in the hives with solid bottom. The highest average values for the temperature in the months of September and October were reported in the ceramic hives with higher temperature in the hive with lattice bottom compared to the one with solid bottom. In November the minimum values for this indicator were found in polystyrene hives, with higher average temper-

Table 2. Reliability of differences in temperature and humidity values in hives of different material – autumn period

Таблица 2. Достоверност на разликите в стойностите за температура и влажност при кошери от различен материал – есенен период

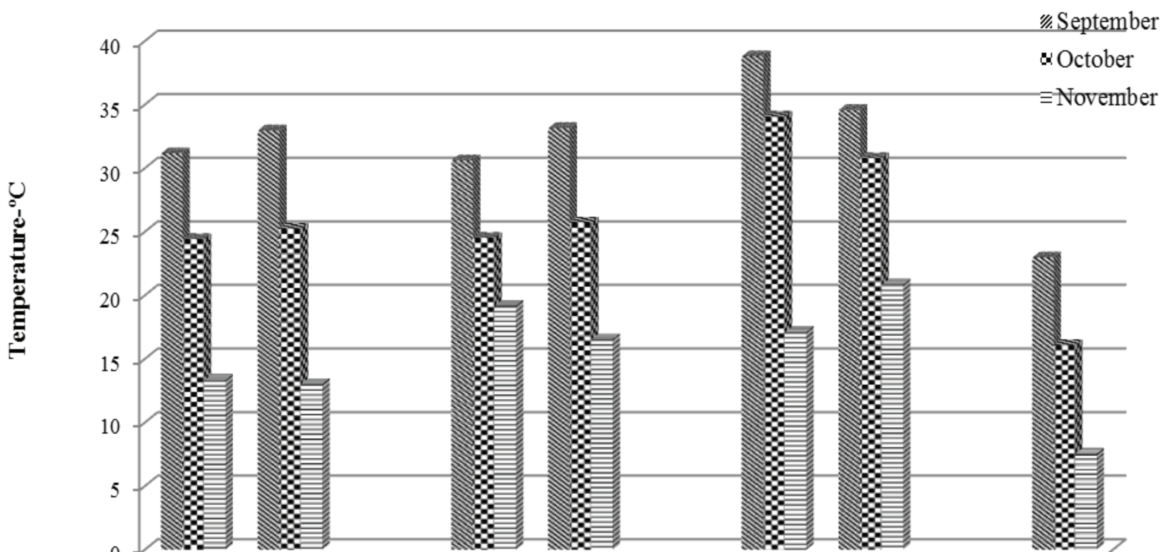
Type of hive / Вид кошер	Temperature, °C / Температура, °C	Humidity, % / Влажност, %
Beehives with lattice bottoms / Кошери с мрежести дъна		
polystyrene/wooden hive / полистиролен/дървен кошер	$P = 0.007^{**}$	$P = 0.000^{***}$
polystyrene/ceramic hive / полистиролен/керамичен кошер	$P = 0.004^{**}$	$P = 0.000^{***}$
wooden/ceramic hive / дървен/керамичен кошер	$P = 0.000^{***}$	$P = 0.000^{***}$
Beehives with solid bottoms / Кошери с плътни дъна		
polystyrene/wooden hive / полистиролен/дървен кошер	$P = 0.000^{***}$	$P = 0.000^{***}$
polystyrene/ceramic hive / полистиролен/керамичен кошер	$P = 0.000^{***}$	$P = 0.004^{**}$
wooden/ceramic hive / дървен/керамичен кошер	$P = 0.000^{***}$	$P = 0.000^{***}$

ature in the hive with lattice bottom (Fig. 3). In the wooden hives, like the polystyrene ones, the temperature is higher in the hive with lattice bottom, while for the ceramic hives the higher value is reported in the hive with solid bottom.

The analysis of the results presented on Fig. 3, shows that in September and October the difference between the average temperature values in the bee nests and the ambient temperature varies from 7.63 °C to 17.96 °C for the hives with lattice bottom and from 9.15 °C to 14.7 °C for the hives with solid bottom. This difference is the greatest in ceramic hives, regardless of the type of bottom. In November, at average ambient temperature of 7.52 °C, the difference compared to the temperatures recorded in the hives is the smallest in the polystyrene hives – 5.8 °C a beehive with lattice bottom and 5.48 °C a beehive with solid bottom. For the wooden and ceramic hives with lattice bottom, the differences found range from 9.58 °C (ceramic hive) to 11.64 °C (wooden hive), which is an indicator of good heat retention in hives made of wood. In the same type of hives, but with a solid bottom, there are differences in the range of 9.02 °C – 13.31 °C, with the greatest difference in the ceramic hive. Based on these data, it can be commented that when ambient temperatures decrease, the ceramic hive retains the accumulated heat very well when it has a solid bottom.

Fig. 4 shows the results of humidity monitoring in September, October and November.

In polystyrene hives in September and October, higher humidity was reported in the hive with lattice bottom, and in November in the hive with solid bottom (Fig. 4). With regard to wood-



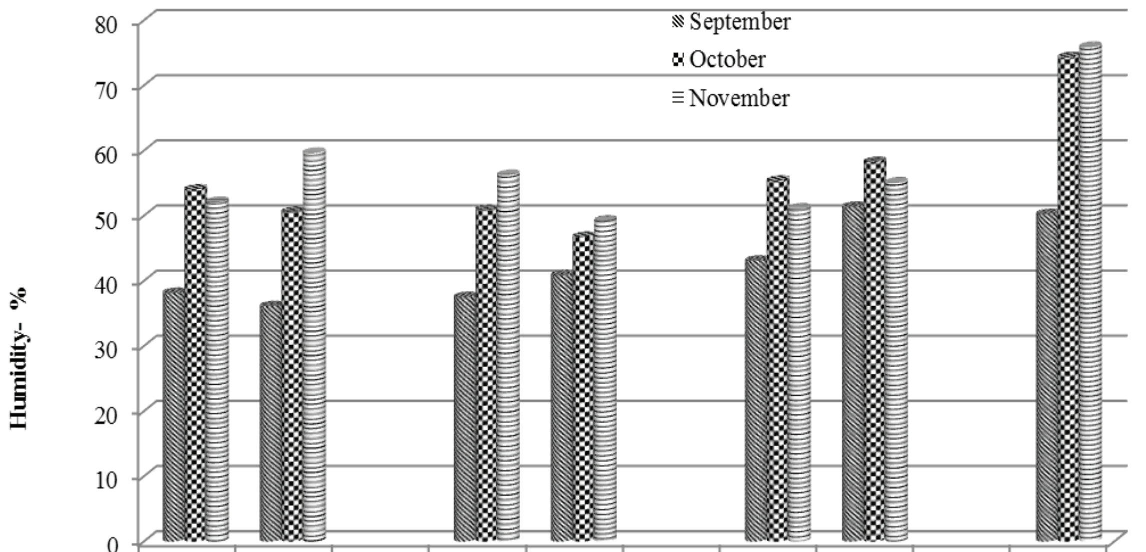
	Ph-lb	Ph-sb		Wh-lb	Wh-sb		Ch-lb	Ch-sb		External conditions
September	31,15	32,95		30,6	33,14		38,77	34,56		22,97
October	24,41	25,22		24,51	25,71		34,03	30,77		16,07
November	13,32	13		19,16	16,54		17,1	20,83		7,52

Fig. 3. Temperature monitoring average by months – autumn period

Legend: Ph-lb: Polystyrene hive – lattice bottom; Ph-sb: Polystyrene hive – solid bottom; Wh-lb: Wooden hive – lattice bottom; Wh-sb: Wooden hive – solid bottom; Ch lb:Ceramic hive – lattice bottom; Ch-sb: Ceramic hive – solid bottom

Фиг. 3. Мониторинг на температурата средно по месеци – есенен период

Легенда: Ph-lb: Полистиролен кошер – мрежесто дъно; Ph-sb: Полистиролен кошер – плътно дъно; Wh-lb: Дървен кошер – мрежесто дъно; Wh-sb: Дървен кошер – плътно дъно; Ch-lb:Керамичен кошер – мрежесто дъно; Ch-sb: Керамичен кошер – плътно дъно



	Ph-lb	Ph-sb	Wh-lb	Wh-sb	Ch-lb	Ch-sb	External conditions
September	38,12	36,09	37,51	40,84	43,08	51,35	50,23
October	54,02	50,57	50,91	46,73	55,36	58,25	74,29
November	52,12	59,65	56,26	49,24	51,07	55,03	75,92

Fig. 4. Humidity monitoring average by months - autumn period

Legend: Ph-lb: Polystyrene hive – lattice bottom; Ph-sb: Polystyrene hive – solid bottom; Wh-lb: Wooden hive – lattice bottom; Wh-sb: Wooden hive – solid bottom; Ch-lb:Ceramic hive – lattice bottom; Ch-sb: Ceramic hive – solid bottom

Фиг. 4. Мониторинг на влажността средно по месеци-есенен период

Легенда: Ph-lb: Полистиролен кошер – мрежесто дъно; Ph-sb: Полистиролен кошер – плътно дъно; Wh-lb: Дървен кошер – мрежесто дъно; Wh-sb: Дървен кошер – плътно дъно; Ch-lb:Керамичен кошер – мрежесто дъно; Ch-sb: Керамичен кошер – плътно дъно

en hives, higher average humidity value in September was found in the hive with solid bottom, and in the months of October and November in the hive with lattice bottom. The latter is probably due to the increased humidity outside the hives, the difference compared to September being 24.0–25.7% more. In the ceramic hives in all three months (September, October and November) higher humidity was reported in the hive with solid bottom.

The data from Fig. 4 show that in October and November the ambient humidity increased to 74.0–75.9%, but in the hives it was lower and remained in the range of 46.7–59.7%. The information from the beekeeping literature shows that the optimal humidity for bee colonies is from 50% to 90%, depending on the strength of the bee colonies, the season and other factors (Nenchev and Zhelyazkova, 2010).

Winter period

The data about the average temperature values for the three months of the winter period (December, January and February) are given in Table 1. Similar to the autumn period and during the studied winter period the temperature in the hives is higher and the humidity is lower in comparison with the ambient temperature and humidity values, regardless of the hive material and the type of bottom (lattice or solid).

The results in Table 1 show that during the winter period the maximum temperature was reported in the wooden hives and the minimum one in the polystyrene hives, regardless of the type of bottom. The data analysis regarding the differences between the established average ambient temperature (5.11 °C) and the average temperature for the period in the hives shows that the influence of the ambient temperature in the wooden hives is the weakest. The difference is the smallest, respectively the greatest in the influence of the ambient temperature in the polystyrene hives, 2.33 °C (lattice bottom) and 2.5 °C (solid bottom), respectively.

As can be seen from Table 1, the observed differences in temperature values between the hives with lattice and solid bottom have high degree of reliability ($P \leq 0.001$) for the hives made of wood. In polystyrene and ceramic hives these differences are statistically unproven.

During the winter period, the maximum value of the humidity indicator for the hives with lattice bottom was observed in the polystyrene hive (74.01 ± 8.65%) and the minimum one in the wooden hive (69.70 ± 14.16%) – Table 1. The comparative analysis between the humidity reported inside the hives and that of the environment (79.24%) shows differences of 5.2% (polystyrene hive) and 9.5% (wooden hive).

For beehives with solid bottom, the highest average humidity was found in the ceramic hive (73.06 ± 5.84%), and the lowest one in the wooden hive (55.45 ± 10.04%) – Table 1. The analysis of the data regarding the differences between the reported average ambient humidity (79.24%) and the average for the period humidity inside the hives shows that the lowest was the influence of ambient humidity in the wooden hives – difference 23.79% compared to 11.04% for the polystyrene hive and 6.18% for the ceramic hive. These results and the data about the reported average ambient humidity confirm the trend established in the autumn period – hives made of wood absorb humidity very well and optimal humidity for the bees is maintained in the bee nest.

The observed differences in the humidity values between the hives with lattice and solid bottom have high degree of reliability ($P \leq 0.001$) – Table 1.

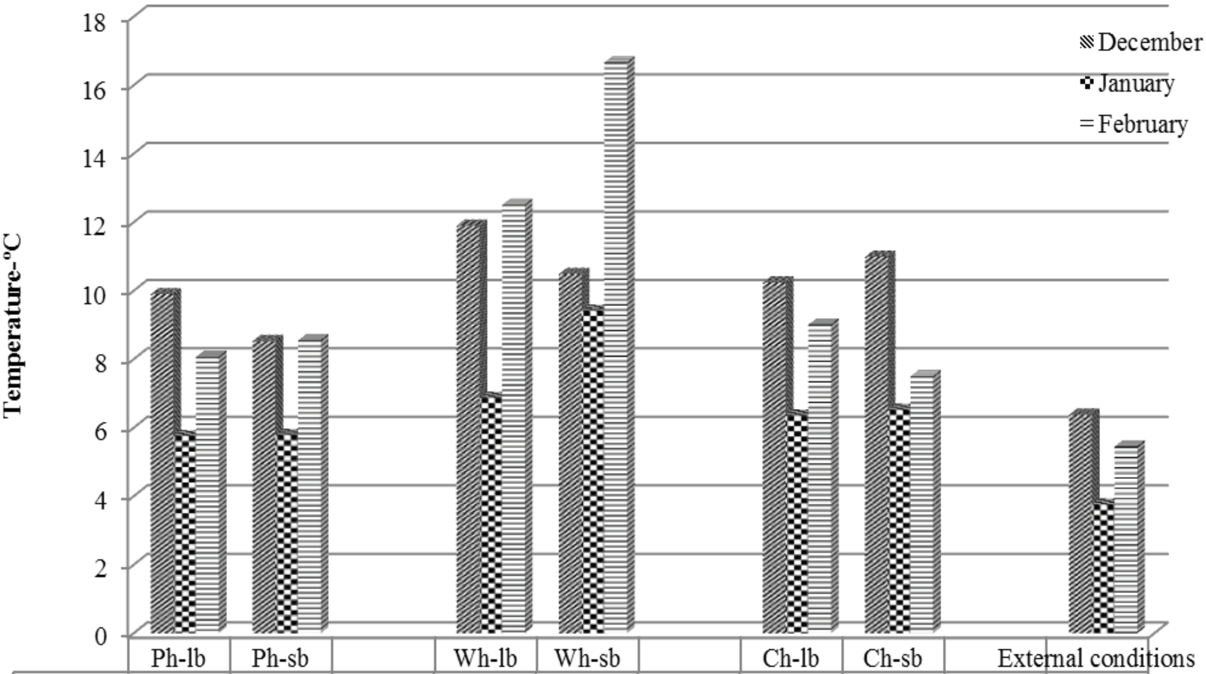
The comparative analysis between the obtained results for temperature and humidity in hives made of different material and with different type of bottom shows high degree of reliability – Table 3.

Fig. 5 presents graphically the results about the average temperature in the hives and outside them by months. In the case of polystyrene hives in December higher values were found in the hive with lattice bottom, and in January and February close values of the average temperatures were reported, 5.75–5.78 °C for January and 8.07–8.55 °C for February, respectively. In December for the wooden hive the average temperature is higher in hives with lattice bottom, and in January and February – in the hive with solid bottom. For the ceramic hives in December and January the reported temperatures with lattice and solid bottom vary within narrow limits, 10.24–10.99 °C and 6.35–6.52 °C, respectively.

Table 3. Reliability of differences in temperature and humidity values in hives of different material – winter period

Таблица 3. Достоверност на разликите в стойностите за температура и влажност при кошери от различен материал – зимен период

Type of hive / Вид кошер	Temperature, °C / Температура, °C	Humidity, % / Влажност, %
Beehives with lattice bottoms / Кошери с мрежести дъна		
polystyrene/wooden hive / полистиролен/дървен кошер	$P = 0.000^{***}$	$P = 0.000^{***}$
polystyrene/ceramic hive / полистиролен/керамичен кошер	$P = 0.000^{***}$	$P = 0.000^{***}$
wooden/ceramic hive / дървен/керамичен кошер	$P = 0.000^{***}$	$P = 0.137$
Beehives with solid bottoms / Кошери с плътни дъна		
polystyrene/wooden hive / полистиролен/дървен кошер	$P = 0.000^{***}$	$P = 0.000^{***}$
polystyrene/ceramic hive / полистиролен/керамичен кошер	$P = 0.000^{***}$	$P = 0.000^{***}$
wooden/ceramic hive / дървенерамичен кошер	$P = 0.000^{***}$	$P = 0.000^{***}$



	Ph-lb	Ph-sb		Wh-lb	Wh-sb		Ch-lb	Ch-sb		External conditions
December	9,9	8,53		11,9	10,49		10,24	10,99		6,38
January	5,75	5,78		6,87	9,41		6,35	6,52		3,75
February	8,07	8,55		12,51	16,66		9,01	7,5		5,45

Fig. 5. Temperature monitoring average by months - winter period

Legend: Ph-lb: Polystyrene hive – lattice bottom; Ph-sb: Polystyrene hive – solid bottom; Wh-lb: Wooden hive – lattice bottom; Wh-sb: Wooden hive – solid bottom; Ch-lb: Ceramic hive – lattice bottom; Ch-sb: Ceramic hive – solid bottom

Фиг. 5. Мониторинг на температурата средно по месеци-зимен период

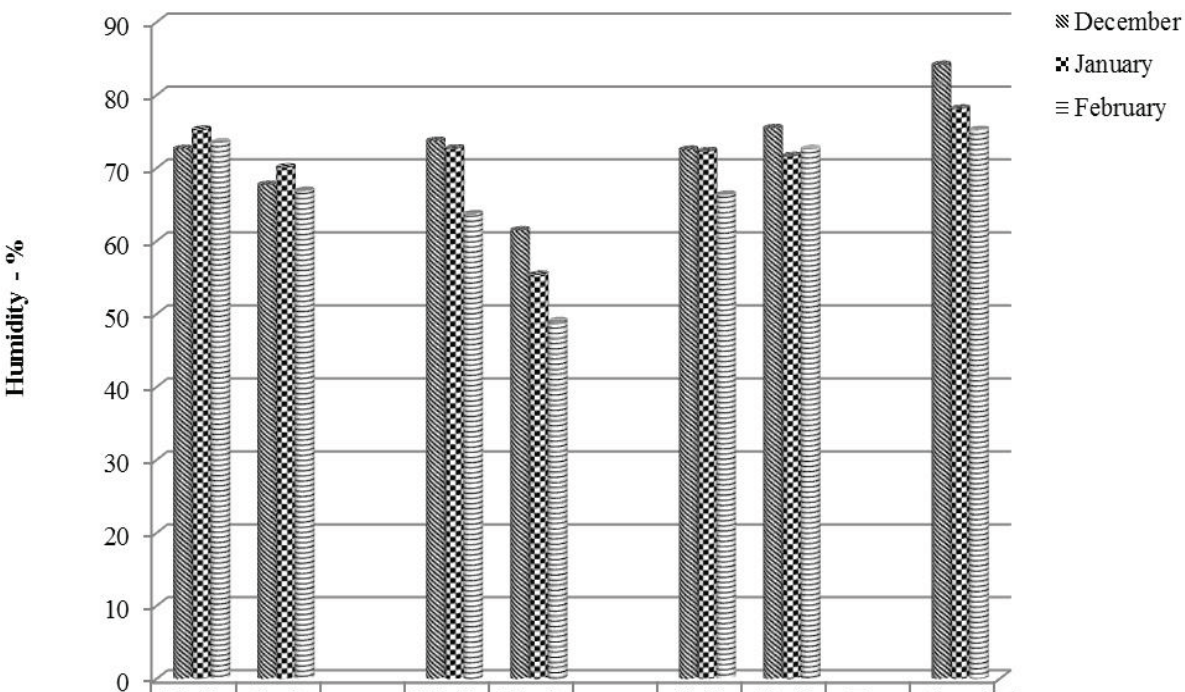
Легенда: Ph-lb: Полистиролен кошер – мрежесто дъно; Ph-sb: Полистиролен кошер – плътно дъно; Wh-lb: Дървен кошер – мрежесто дъно; Wh-sb: Дървен кошер – плътно дъно; Ch-lb:Керамичен кошер – мрежесто дъно; Ch-sb: Керамичен кошер – плътно дъно

In February the average temperature value is higher in the hive with lattice bottom.

The data from Fig. 5 show that in the months of January and February, with average ambient temperature of 3.75 °C and 5.45 °C, the highest temperature values were found in the wooden hives (compared to polystyrene and ceramic hives), regardless of the type of bottom. The reported temperatures in the wooden hives in January were 1.8–2.5 times higher, and in February – 2.3–3.1 times higher compared to the ambient temperature.

Fig. 6 shows the results of humidity monitoring in December, January and February. It can be seen from the graph that in the case of beehives with solid bottom the minimum humidity values in bee nests were found in the wooden hives (from 48.96% to 61.41%) and the maximum ones in the ceramic hives (from 71.43% to 75.43%). The indicated maximum values during the three months of the studied winter period are lower than the measured ambient humidity and are within the limits of the optimal humidity for the bee colonies – 50–90% (Nenchev and Zhelyazkova, 2010).

In the case of hives with lattice bottom, the minimum humidity value in the bee nests in December and January was established in the ceramic and polystyrene hive, and in February – in the wooden hive. The highest average humidity in January and February was reported in the polystyrene hive, 75.2% and 73.44%, respectively.



	Ph-lb	Ph-sb		Wh-lb	Wh-sb		Ch-lb	Ch-sb	External conditions
December	72,57	67,65		73,67	61,41		72,47	75,43	84,09
January	75,2	70,03		72,62	55,34		72,27	71,59	78,09
February	73,44	66,86		63,65	48,96		66,33	72,56	75,18

Fig. 6. Humidity monitoring average by months – winter period

Legend: Ph-lb: Polystyrene hive – lattice bottom; Ph-sb: Polystyrene hive – solid bottom; Wh-lb: Wooden hive – lattice bottom; Wh-sb: Wooden hive – solid bottom; Ch-lb:Ceramic hive – lattice bottom; Ch-sb: Ceramic hive – solid bottom

Фиг. 6. Мониторинг на влажността средно по месеци-зимен период

Легенда: Ph-lb: Полистиролен кошер – мрежесто дъно; Ph-sb: Полистиролен кошер – плътно дъно; Wh-lb: Дървен кошер – мрежесто дъно; Wh-sb: Дървен кошер – плътно дъно; Ch-lb:Керамичен кошер – мрежесто дъно; Ch-sb: Керамичен кошер – плътно дъно

The results obtained in the present study are the beginning of a more extensive study, the objective of which is to assess the suitability of materials other than wood for rearing bee colonies, respectively their impact on the physiology and behaviour of bee specimens and the colony as a whole during the different periods of their life and to give recommendations for the beekeeping science and practice for the expediency of monitoring the temperature and humidity in bee nests with regard to the development of the colonies. Important for the practice will be the results regarding the winter hardiness of bee colonies, settled in hives of different material and wintered on a dense and lattice bottom.

Conclusions

It was established that during the studied autumn-winter period the temperature in the hives (average for the period and by months) is higher and the humidity lower in comparison with the ambient temperature and humidity values, regardless of the hive material and the type of bottom (lattice or solid).

During the autumn season, the average temperature in hives with lattice bottom varies within narrow limits – from 25.27 ± 6.88 °C (wooden beehive) to 26.77 ± 10.95 °C (ceramic beehive). For beehives with solid bottom, a wider range was established for the average temperature (from 19.01 ± 8.47 °C – polystyrene hive to 29.15 ± 6.51 °C – ceramic hive). It was found that the difference between the maximum and minimum value of the humidity indicator for beehives with solid bottom (from 44.69 ± 5.00% – wooden hive to 55.14 ± 6.96% – polystyrene hive) being twice as large as the one in the hive with lattice bottom (from 45.91 ± 9.62% – polystyrene hive to 50.74 ± 8.92% – ceramic hive). The observed differences in the temperature and humidity values between hives with lattice and solid bottom are of high reliability ($P \leq 0.001$).

It was found that during the winter period (December, January, February) in the wooden hives the average temperature is highest (10.15 ± 5. 61 °C and 11.89 ± 5.16 °C) and average value of the humidity indicator is lowest (69.70 ± 14.16% and 55.45 ± 10.04%), regardless of the type of bottom. The lowest average temperature was established in the polystyrene hives (7.44 ± 5.12 °C and 7.61 ± 4.23 °C), regardless of the type of bottom. High humidity (70–75%) was found in the polystyrene hive with lattice bottom and in the ceramic hive with solid bottom. The observed differences in temperature values between hives with lattice and solid bottom are of high reliability ($P \leq 0.001$) only for wooden hives made and statistically unproven for polystyrene and ceramic hives. Differences in humidity values between the hives with lattice and solid bottom are of high reliability ($P \leq 0.001$).

The comparative analysis between the obtained results for temperature and humidity in hives made of different material and with different type of bottom in the autumn period shows from medium ($P \leq 0.01$) to high ($P \leq 0.001$) degree of reliability, and in the winter period – high degree of reliability ($P \leq 0.001$).

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