

# THE CONSTRUCTION OF TWO COPIES OF ANCIENT GREEK CLAY BEEHIVES AND THE CONTROL OF THEIR COLONIES' HOMEOSTASIS

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The Greek word for the bee (*Μέλισσα* honey-licker) has been used from poets to describe the beauties of nature and from philosophers to name everything that is pure and virgin. The image of the bee has been depicted from the prehistoric times. In Mesolithic Spain, we find a famous wall painting with the harvest of wild bee honey (**Fig. 1**). In Egypt, its images were standing for "Lower Egypt", and with proper use of the word bee and a royal name, meant "all upper and lower Egypt"<sup>1</sup>. Archaeological evidence in Tel Rihov in the Jordan valley, illustrated the Biblical reference of the Land of Israel, as the "Land of milk and honey"<sup>2</sup>.

In ancient Greece beside art, bees are present in everyday life, in matters of religion, in economy and nutrition, music and, occasionally, in astronomy. It has been worshiped since the Minoan Crete as a symbol of eternity, wisdom, and an embodiment of virtue. Bee was famous for its prophetic abilities, and it was the soul of the dead who would leave the body after his exhalation<sup>3</sup>.

The first beekeeper was Aristaeus, son of Apollo and Cyrene (**Fig. 2**). He was raised by Horai with nectar and ambrosia, and the nymphs Brisai (*βριτώ-βλίττω* to take the honey from the comb, *Brító-* variant of *μέλισσα* "bee"<sup>4</sup>) taught him apiculture. Through the island of Kea he spread the secret of beekeeping to the humans<sup>5</sup>, and thus the coins<sup>6</sup> of the island have as a symbol the bee<sup>7</sup>.

Honey bee has been a part in several divinities adorations, from which we will selectively refer to some of them<sup>8</sup>. Perhaps the most famous link between bees and gods is the one with Zeus. As an infant, he was raised by nymphs called *Melissai*, or by *Melissa*, daughter of king *Melissos*. The title of Zeus *Melissaios* was probably so common in Crete because of that myth<sup>9</sup>. An interested fact in this myth, is the

4 Elderkin 1939.

5 Diodorus Bibl. IV 81.

6 Historia Numorum p. 411.

7 Cook 1895. Elderkin 1939. Thomaidis 1979.

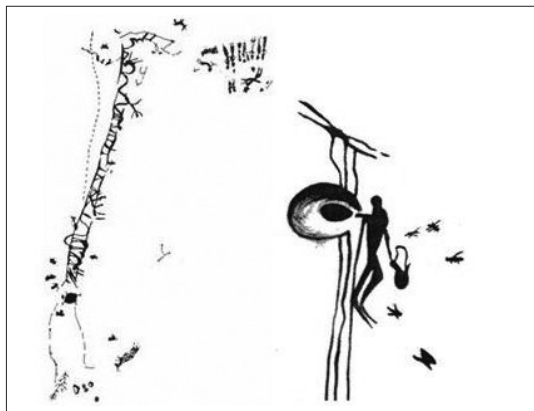
8 Chrisostomidou composed a catalogue, summarizing the gods that bees were connected to (Chrisostomidou 2010 pp.43-44).

9 Cook 1895. Elderkin 1939. Chrisostomidou 2010.

1 Sheppard et al. 2001.

2 Mazar et al. 2008.

3 Cook 1895.



**Fig. 1** Wall painting in caves of Spain, in Valencia and Arana, around 6000 B.C. (photo from Eva Crane, *The world history of Beekeeping and honey hunting*).



**Fig. 2** Aristeus between lions, in an oinochoe around 600-550 B.C., National Museum of Athens inv. No 16285 (photo from the Beazley Archive).

noise that Kourites made with their shields, in order to cover the cry of the infant. The noise (*μελιτοπηχεῖν*) near flying wild swarms was a common technique for capturing them<sup>10</sup>. Furthermore it was a common thought that the origin of the bee was from Crete, according to the 2<sup>nd</sup> c. B.C. poet Nikandros<sup>11</sup>.

The importance of the insect in the circle of life was obvious in Eleusinian Mysteries, where the bee symbolized the circle of life and death. Just like bees, Demeter was responsible for the fertilization of plants and crops. The priestesses of the goddess and her daughter Persephone were called *Melissai* (bees). Furthermore, Persephone's nickname *Melitodes*, can be translated as "the honeyed one"<sup>12</sup>.

The pure nature of the bee got associated with the virgin goddess Artemis, and the occasionally deadly sting with the arrow of Artemis. Bee was the symbol of the goddess in Ephesus, and her priestesses were also called *Melissai* or *Melissonomos* (*Μελισσονόμος* "beekeeper"). A common byname of Artemis, was Britomartis (*Βριτόμαρτις* the bee maiden)<sup>13</sup>.

The honey was first mentioned at the Homeric Epics, with the references to rituals for the dead<sup>14</sup>. Anaxagoras (510-428 B.C.), Democritus of Abdera (460-370 B.C.), Hippocrates (460-377 B.C.), and Aristotle (384-322 B.C.), are known for their studies on bees. The nutritional value of honey was promoted by the Pythagoroi, the followers of Pythagoras, who owned their prosperity on a diet based on honey and bread<sup>15</sup>.

Honey was used in ceremonial activities, such as libation for the dead, and offering to the gods<sup>16</sup>. An interesting fact is the use of wax for lighting, as remains of it on lamps and conical cups of Later Minoan I (1600-1450 B.C.) revealed<sup>17</sup>. Beeswax was widely used in art, in the construction of copper statues, as a motif for earrings and necklaces, as a theme for pottery painting and for tomb decoration.

The financial benefits of the beekeeping were extended from the beekeepers to the merchants and to the state. The state would enforce taxes both for beekeeping, also for the trading of the products. A great example for that system, was the Militian state, that Tragaia was part of, and had an important apiary, as the archaeological findings proclaim<sup>18</sup>. The Zenon Archive informs us about the tax obligations. Also such details can be spotted at the sign of Teo, and in the treaty between Miletus and Pisades<sup>19</sup>. During the 3<sup>rd</sup> century B.C. the cost for a quantity of 3.3 l. (*χούς*) was about 3 ½ drachmae and 9 oboloi, and for 39.4 l. (*μετριητής* = 12 *χόες*) varied from 16 to 37 drachmae<sup>20</sup>.

Attic honey was by far the most famous, harvested on the sacred mount of Hymettus. It was a special gift for habitants outside of Athens basin. Great honey production took also place in Isthmia, Crete, Kea,

<sup>13</sup> Elderkin 1939.

<sup>14</sup> Odyssey K 519.

<sup>15</sup> Chrisostomidou 2010.

<sup>16</sup> Cook 1895. Elderkin 1939. Chrisostomidou 2010.

<sup>17</sup> Eversed et al. 1997

<sup>18</sup> Triantafillidis 2012.

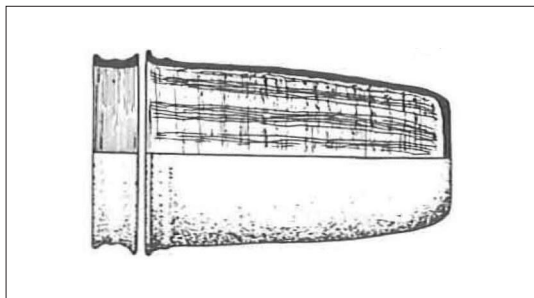
<sup>19</sup> Ibid.

<sup>20</sup> Chouliara – Raiou 2000.

<sup>10</sup> Harisis and Harisis 2011.

<sup>11</sup> Chrisostomidou 2010.

<sup>12</sup> Sanchez – Parodi 2009.



**Fig. 3** Horizontal clay beehive (type 1) from Vari Attica, with the expansion ring (photo from Crane E., Graham A.J. 1985, "Bee hives of the ancient world. 2", *Bee World* 66 (3), 148-170).

Leros, Kalymnos, Sicily and Hyblaia Megara<sup>21</sup>. The exportation of attic honey, spread throughout the Mediterranean Sea, was an indication for the significance to the economy. Considering the extent of this export, also the reputation of this honey, is obvious the existence of organized apiculture, already in time of Solon (640-553 B.C.)<sup>22</sup>. Probably, the Greeks had knowledge in the biology and behavior of a skep, and they had been practicing beekeeping using fitting expertise, like the construction and use of hives, as it is justified by the numerous findings all over the country.

As to the placement of the apiaries, the revetment walls were used in Agathonisi<sup>23</sup>, and probably in other regions too. Also, in the interior of city walls, is proven to host beehives<sup>24</sup>. Perhaps the court-yard was the perfect choice, but the flat rooftops should serve well<sup>25</sup>. Solon foresaw the need the apiaries, to be placed with a distant of each other, of at least 100 m. (300 Greek feet), to prevent any confusion regarding to the ownership of the combs<sup>26</sup>.

There was a range of materials used for hives, as it is mentioned by several Roman authors, such as Vir-

gil<sup>27</sup>, Columella<sup>28</sup>, Varro<sup>29</sup>, Pliny<sup>30</sup> and Palladius<sup>31</sup>. Those materials were mostly used by the Romans, but it is possible that the Greeks were also familiar with some of them for the construction of hives.

The cork was highly recommended because of the ability to provide an even temperature. Barks of the tree should be removed in a way to form a cylinder. Perhaps the hives were sewn together. Another material was ferula, probably woven together, or shaping a rectangular box. Ferula was also high standing, because of its insulating attitude. Furthermore withy, willow and plans that could also be woven together, were in common use, and mud should be applied on the gaps. Wood was also used, in particular boards, from trees such as oak, fig, pine and beech, shaped like boxes, perhaps similar to the modern Langstroth beehives. A way to simulate the natural home of wild bees was the use of hollow logs. It is unknown whether the logs were found hollowed, or were carved to become hollow<sup>32</sup>.

Non botanical materials were also used. Dung was not in high recommendation, because of its flammability, however fireproof enclosures could prevent ignition. Brick hives were heavy to move, so they were not praised. Clay was a common fabric in ancient Greece, but it was in fully absence at Rome, because the authors claimed that it assimilated the exterior temperature, thus it would not provide a viable environment for the bees<sup>33</sup>.

There are two types of ceramic beehives, horizontal and vertical. The horizontal type (from now on the horizontal type will be referred as type 1 (**Fig. 3**) has been found in ancient Egypt dated back to the late Old Kingdom (2400-2133 B.C.) (**Fig. 4**)<sup>34</sup>. The first findings in classical Greece are in Vari in Attica, dated at the 5<sup>th</sup> century B.C.<sup>35</sup>. The main advantage is the fact that they can be stacked in several layers (**Fig. 5**). The shape is cylindrical and the mouth diameter is bigger than that of the base. Rims are usually flat on top, and have a projecting profile. Ceramic lids should cover the hives, and they appear to have holes which would host a handle and the entrance for bees (**Fig. 6**). A

27 Virgil Georgics IV. 33

28 Columella Res Rustica IX.6.1-4.

29 Varro De Re Rustica III.16.15-17.

30 Pliny Historia Naturalis XXI.47.80.

31 Palladius Opus Agriculturae I.38.

32 Francis 2012.

33 Ibid.

34 Crane and Graham 1985.

35 Jones et al. 1973.

21 Aktseli 2000.

22 Jones et al. 1973. Thomaides 1979. They were not harvesting honey from wild bees.

23 Triantafyllidis 2012.

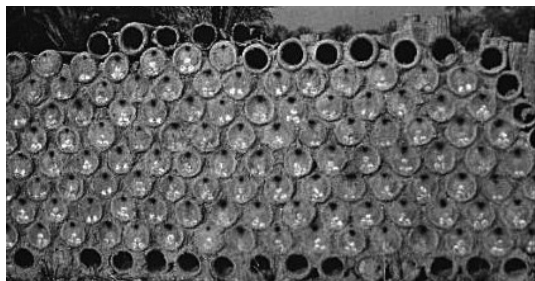
24 Lüdorf G. 1999, Leitformen der attischen Gebrauchskeramik: Ber Bienenkord. *Boreas*, 21/22, 41-169 cited in Mavrofridis G. 2006, "Μελίσσια «εντός των τειχών» στην αρχαία Ελλάδα", *Μελισσοκομική Επιθεώρηση* 20 (4), 227-230.

25 Rottrof 2002.

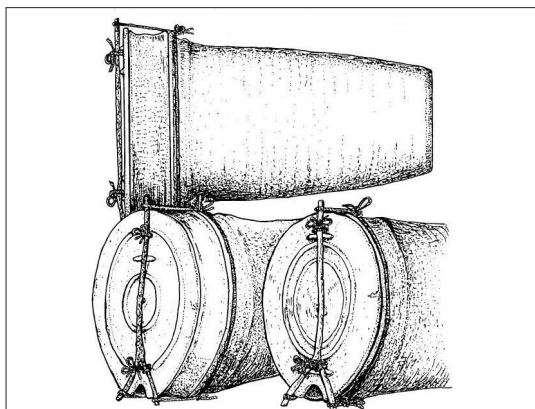
26 Thomaides 1979. Aktseli 1996.



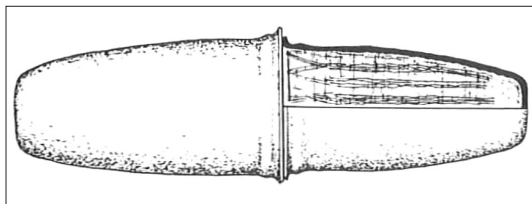
**Fig. 4** Horizontal hives on layers and bees, Egyptian tomb in Padasa, approx. 610 B.C. (photo from Sheppard W. S., Shoukry A., Kamel S., 2001 "The Nile honey bee – the bee of ancient Egypt in modern times", *American Bee Journal* 141 (2), 260-263.)



**Fig. 5** Modern stack of 400 cylindrical hives, near Assiut Egypt (photo from Crane E., Graham A.J. 1985, "Bee hives of the ancient world. 2", *Bee World* 66 (3), 148-170).



**Fig. 6** Horizontal beehives from Trachones, Attica, Hellenistic period (photo from Anderson-Stojanovic V.R., Jones J.E. 2002, "Ancient beehives from Isthmia", *Hesperia* 71, 345-376).



**Fig. 7** Two horizontal beehives, as a coffin from Marathon (photo from Crane E., Graham A.J. 1985, "Bee hives of the ancient world. 2", *Bee World* 66 (3), 148-170).



**Fig. 8** The engravings inside a horizontal beehive from Isthmia (photo from Anderson-Stojanovic V.R., Jones J.E. 2002, "Ancient beehives from Isthmia", *Hesperia* 71, 345-376).

rope would ensure the sealing of the hive, as it would be pulled and secured behind the rim<sup>36</sup>. A remarkable usage for hives, have been found in Marathon and in West Necropolis of Eretria, as coffins (**Fig. 7**). Two horizontal hives, placed mouth to mouth, shaped a coffin to host, in the case of Marathon, a 7 years old boy<sup>37</sup>.

Special feature, are the engravings along the whole length of the interior side of the wall, which would cover the one third of the vessels, and are probably made by a tool like a comb (**Fig. 8**). Sometimes are vertical and rarely skew. We are not sure about the use of those engravings, maybe they were made for guiding the bees to build honeycombs<sup>38</sup> or it was a kind of habitude, but at some point they stop being carved<sup>39</sup>. Another suggestion is that they were part of the beekeepers effort to harvest more wax and honey<sup>40</sup>. The fact that these scorings did not cover the whole vessel, seriously decrease the number of vessels recognized as beehives. Of course there would stamps on the outside surface to declare the owner

<sup>36</sup> Jones 1976.

<sup>37</sup> Jones 1976. Themelis 1978. Crane and Graham 1985.

<sup>38</sup> Anderson-Stojanovic and Jones 2002.

<sup>39</sup> Jones 1976.

<sup>40</sup> Jones et al. 1973.

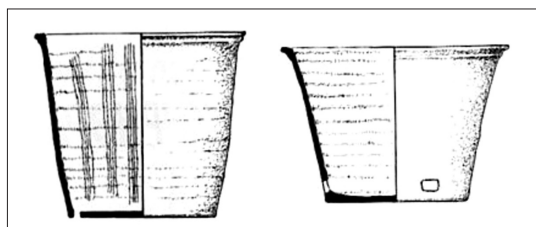




**Fig. 9** Honey thieves chased by bees, amphora (type b) with the manner of Princeton Painter, 550-530 B.C. British Museum inv. No B177. (photo from the Beazley Archive).



**Fig. 10** Honey thieves chased by bees, amphora (type b) of Swing Painter, 550-530 B.C., Basel Antikenmuseum inv. No Z364. (photo from the Beazley Archive).



**Fig. 11** Vertical beehives (type 2) from Isthmia 3rd-2nd c. B.C., (photo from Anderson-Stojanovic V.R., Jones J.E. 2002, "Ancient beehives from Isthmia", *Hesperia* 71, 345-376).

of the hives. Stealing honey was not uncommon, as a matter of fact, there are two attic amphorae showing this exact scene, both dated in 550-530 B.C. The first amphora from the British Museum<sup>41</sup> (**Fig. 9**), could be relevant to a myth that Antoninus Liberalis<sup>42</sup> tells us, about four Cretan thieves, that went to steal honey from the cave that Rhea gave birth to Zeus. The god punished the thieves by transforming them into birds. The second amphora from Basel<sup>43</sup> could be depicting the same incident, but there are no names like the other vase, and there are only three men on the frame (**Fig. 10**).

Important finds, are the expansion rings (**Fig. 3**), used to magnify the capacity of hives, and accommodate the honey harvest. As to their attachment with the main body, a rational hypothesis is the application of propolis or wax. It is possible that the rings were precursor of the movable combs. The unsmoked honey, a delicate honey quality, came from expansion rings<sup>44</sup>. The benefit of them, apart from the capacity matter, was that the beekeeper did not have to disturb the entire swarm. The usual height was 0.08 m. and could reach 0.14m.

The height of the type 1 hive, was 0.40-0.70 m., the lip diameter 0.25-0.41 m. (Vari 5<sup>th</sup> century B.C. 0.32-0.40 m.<sup>45</sup>, Tragaia 2<sup>nd</sup> century B.C. 0.24-0.41 m.<sup>46</sup>, Isthmia 5<sup>th</sup> century A.D. 0.25-0.27 m.<sup>47</sup>), rim diameter 0.29-0.35 m., base diameter 0.15-0.32 m.

Vertical hives (we will refer to them as type 2) seem to be post dated to type 1 (**Fig. 11**). A number of those have been found in Attica, Isthmia, Chios and Crete. Ancient kalathos is the vase that type 2 hive looks like. Most famous example is ΟΡΕΣΤΑΔΑ hive (late 3<sup>rd</sup> century B.C.), found in Isthmia by O. Brooner in 1955 (**Fig. 12-13**)<sup>48</sup>. Initially it was identified as lenos (ληνός), a vessel for squeezing grapes but later research results proved that it was a beehive<sup>49</sup>.

41 Inv. No B177. Para. 134. CVA Great Britain 4, London British Museum 3 pl. 32. Beazley recognizes the manner of the Painter of Princeton.

42 Antoninus Liberalis *Metamorphoses* 19.

43 Inv. No Z364. Para 134.21. CVA Basel Antikenmuseum 1 pl. 30.2-4. Beazley attributes the amphora to the Swing Painter.

44 Jones 1976. Triantafillidis 2012.

45 Graham 1975.

46 Triantafillidis 2012.

47 Anderson-Stojanovic and Jones 2002.

48 Brooner 1958.

49 Kardara corrected the lenos explanation as a beehive (Kardara 1961), but a few years later Kardara and

Just like horizontal hives, type 2 hives had also a smaller base diameter than the mouth. Honey combs modulation, was again guided (if we accept this interpretation) by scorings along the vessel. Wood, stones, straw, brush smeared with mud, and clay lids, should be used for closing the hives. The square flight hole was situated just above the base. Beneath the rim, or in the middle body, were the handles of round cut.

The height was 0.29-0.45 m. (Isthmia 0.29-0.33m., Vari 0.40-0.45 m.), mouth diameter was between 0.29-0.39 m. (Isthmia 0.31-0.38 m., Tragaia 0.29-0.33 m., Vari 0.33-0.39m.), and base diameter 0.18-0.27 m.

Several inscriptions have been found on hives of both types, scratched before the baking. The purpose was to announce either the potter, or the owner of the apiary. Perhaps the owner encarved his symbols (special rings could be used as stamps)<sup>50</sup> after the purchase of the vessels, so he could count his hives and got them registered on the public documents.

The inscription ΨΕΛΙ was found on a hive fragment at Tragaia (fig. 14). It could be restored as (KY) ΨΕΛΙ(ON) and therefore be the first identification by archaeological data, of the vessel hive (κυψέλιον). The fragment was a part of type 1 beehive, dated on 2<sup>nd</sup> century B.C. On another horizontal hive, is written ΨΑΛΙΑ ΔΑ, which can be read as ΚΥΨΑΛΙΑ ΔΑΜΟΣΙΑ (public beehive). The letter Δ, shaped either by dots or stamped on hives, was probably the owners sign. A beautiful stamped bee, found in the same apiary, must have been imprinted on the interior of a rim<sup>51</sup>.

Roman authors suggested against the use of ceramic beehives<sup>52</sup>, but they are very frequently found

Papadopoulou proposed a new identification of the vessel as a clepsydrae (Kardara and Papadopoulou 1984). Finally, in 2003 chemical analysis disclosed remnants of was to several beehives from Isthmia, where among them was also ΟΡΕΣΤΑΔΑ beehive (Evershed et al. 2003).

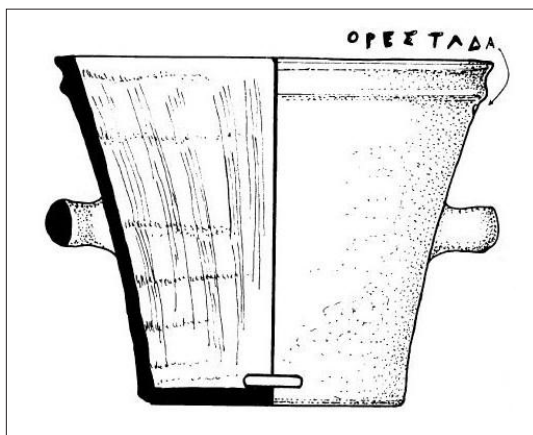
<sup>50</sup> Harisis and Harisis 2011.

<sup>51</sup> Triantafillidis 2012

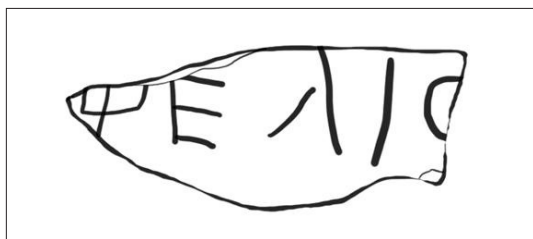
<sup>52</sup> Columella Res Rustica IX.6.2 «*Deterrima est conditio fictilium, quae et accenduntur aestatis vaporibus, et gelantur hiemis frigoribus. Reliqua sunt alvorum genera duo, ut vel ex fimo fingantur, vel lateribus extruantur: quorum alterum iure damnavit Celsus, quoniam maxime est ignibus obnoxium; alterum probavit, quamvis incommodum eius praecipuum non dissimulaverit, quod, si res postulet, transferri non possit.*» Varro De Re Rustica III.16.17 «*Alvi optimae fiunt corticeae,*



**Fig. 12** ΟΡΕΣΤΑΔΑ beehive (photo from Anderson-Stojanovic V.R., Jones J.E. 2002, "Ancient beehives from Isthmia", *Hesperia* 71, 345-376).



**Fig. 13** ΟΡΕΣΤΑΔΑ beehive (photo from Anderson-Stojanovic V.R., Jones J.E. 2002, "Ancient beehives from Isthmia", *Hesperia* 71, 345-376).



**Fig. 14** Fragment of horizontal beehives with ΨΕΛΙ inscription, from Agathonisi, 2nd-1st c. B.C. (photo from Triantafillidis P. 2012, "Πήλινες κυψέλες από την Αρχαία Τραγαία (Αγαθονήσι)", *Δωδεκανησιακά Χρονικά* 25, 632-653).



**Fig. 15** Horizontal clay hive before (A) and after (B) establishment of a honey bee colony

on archaeological sites in several regions in Greece. This contradiction led J. E. Francis to experiment on this matter. She used a cylindrical horizontal clay beehive of the 19<sup>th</sup> century A.D., similar to those of Minoan Crete. The installation took place in a village near Hierapetra, on a garden, at July 2003. For two days she recorded the internal and external temperature. It is of great importance to mention that the hive was empty and no colony was settled in it. The results favored the Roman authors opinion, as the rising temperature in the interior, was rapidly escalating during daytime, and even after the sunset when the exterior temperature was cooler, it was preserved high enough. However, as she also points out, the authors were not beekeepers, as they were not familiar with the ability of bees to control the temperature.

Based on this research, we decide to move a step forward, install swarms on both type 1 and 2 hives, and compare the temperature results between them, and also between modern Langstroth beehives. With the valuable help of the Hehe-Art Ceramics, Creativity and Human Developing, we created accurate imitations of clay hives (**Fig. 15-16**). Beyond of the reconstruction of the ancient hives, we intended to study the development of the installed colonies and compare different biological and behavioral factors with colonies in modern hives.

Two colonies with a population of about 10000 honey bees each were settled in the clay beehives. For the control, a colony of equal strength was used, settled in a wooden Langstroth beehive. All colonies were headed by sister queens.

During preliminary studies, we recorded brood and population area temperatures, by using the BARIONET recording system (accuracy  $\pm 0,1C$ ). After the establishment of colonies in the beehives, sensors were adjusted at the middle of brood area and between the two external frames, covered by honey bees. Recordings were continuing for a period of 24 days.

The results showed that brood temperature was stable, presenting no difference between the three types of hives, while the peripheral temperature was slightly higher, thus no significant, in the clay hives. More specific, the average temperatures in brood areas were 35.14° C (SEM=0.055) for horizontal clay hive (HC), 35.2° C (SEM=0.058) for vertical clay hive (VC) and 35.08° C (SEM=0.051) for Langstroth hive

*detrimentae fictiles, quod et frigore hieme et aestate calore vehementissime haec commoventur».*





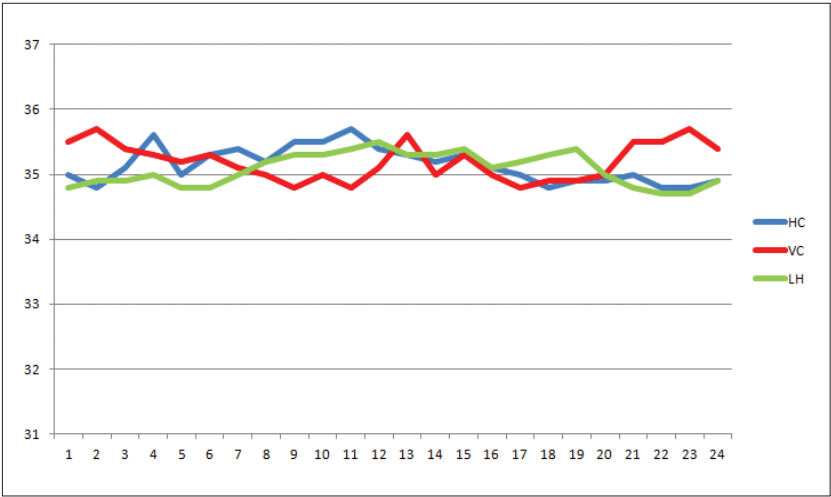
**Fig. 16** Vertical clay hive before (A) and after (B) establishment of a honey bee colony

(LH). One-Way Analysis of Variance (ANOVA) showed that temperature differences between the three hives were not greater than expected by chance ( $p=0.3373$ ). A sample of brood temperature variation is presented in fig. 17.

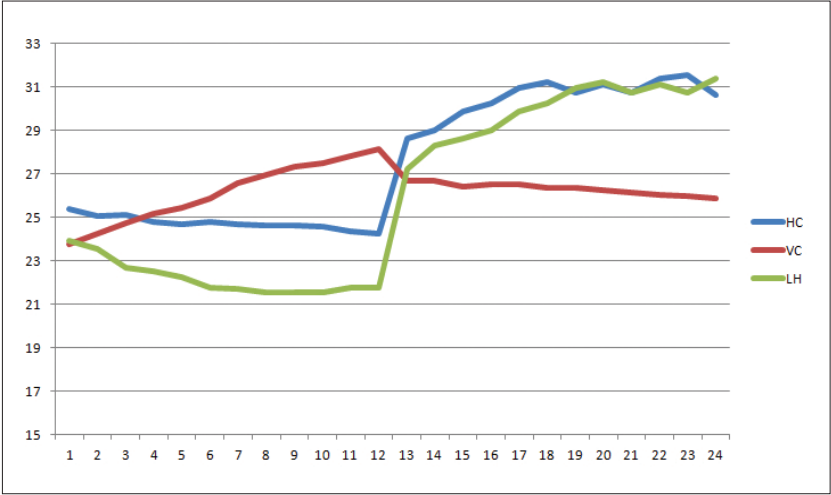
The average temperatures in external frames were  $27.63^{\circ}\text{C}$  ( $\text{SEM}=0.612$ ) for HC,  $26.22^{\circ}\text{C}$  ( $\text{SEM}=0.210$ ) for VC and  $26.08^{\circ}\text{C}$  ( $\text{SEM}=0.837$ ) for LH. Kruskal-Wallis Test (Nonparametric ANOVA) showed that temperature differences between the three hives were not greater than expected by chance ( $p=0.338$ ). A sample of temperature variation is presented in fig. 18.

The results obtained by this study, clearly showed that the ancient Greek clay beehives offered ideal conditions for the development of honey bee colonies. Homeostasis, in terms of temperature variation, was normal and optimum for the rearing of brood and the functioning of adult population. Colonies established in clay colonies presented no adverse behavioral or biological effects. Strength of colonies (in terms of adult population and brood area) as well as wintering procedures was normal and colonies survived for two continuous years before re-established in Langstroth beehives for commercial manipulation.





**Fig. 17** Temperature variation within 24 hours in brood area. HC: Horizontal clay hive, VC: Vertical clay hive, LH: Langstroth wooden hive.



**Fig. 18** Temperature variation within 24 hours at external colony frames. HC: Horizontal clay hive, VC: Vertical clay hive, LH: Langstroth wooden hive.

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