***Nestduftwärmebindung* – a useful hypothesis or just 'complete nonsense'?**

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I welcome the contribution to the discussion of sustainable beekeeping presented in the Summer 2011 issue by Wally Shaw, a member of the Science and Evidence Advisory Group to Her Majesty's Government's 'Healthy Bees Plan'. Despite his choice of article title – *Sustainable Beekeeping (All you need to know and didn't like to ask)* – I was disappointed to find nothing in the article about how the three main themes of sustainability, economic, social and environmental, apply to beekeeping. Instead, the author concentrated solely on a fourth theme of sustainability that has to be included with the other three when we are working with the living world, namely the husbanded animals, i.e. the bees. For an attempt at characterising sustainable beekeeping under all four themes I refer readers to my book.[1] Here I would like to concentrate on correcting a few misconceptions which might result from Shaw's article regarding top-bar hives, especially Warrés, and to develop our understanding of Johann Thür's concept *Nestduftwärmebindung* – which could be translated as the retention of nest scent and heat, and which the article attempted to rebut.

*Top-bar beekeeping*

Most of the article made perfectly good sense to me, even including his criticism of the use of foundationless comb with a comb spacing larger than that commonly found in nature. He cites Warré as specifying 36 mm. The narrowest spacing I have ever found in a feral nest was in a 225 x 225 mm chimney flue where the mean distance between comb midribs was 29 mm.[2] However, several Warré beekeepers are experimenting with 9 instead of 8 combs per box, giving a spacing of 33 mm. Shaw says that natural combs always have 31-32 mm spacing. The above observation of 29 mm obviously contradicts that, as do many examples of feral combs where the spacing is as much as 40 mm.[3]

Shaw writes that inspecting combs on top-bars is a seasonal bee inspector's nightmare. If this is true, then I suggest that the National Bee Unit give their inspectors training in the design, operation and inspection of top-bar hives so that they can go out into the field with confidence and not have nightmares. In case a particular beekeeper does not have the additional tools, the inspector will need to be equipped with a comb cutter appropriate for the type of top-bar hive type, horizontal or vertical, a comb holder and a torch. For Warré combs the cutter is 'L'-shaped,[4] and the holder a simple 'U' frame.[5] Shaw rightly raises the problem of the covering of bees on the comb obstructing the view into cells. Leaving aside for now the fact that the bees in this situation are desperately trying to cope with a catastrophic fall in comb temperature, there is a simple way of shifting them. I have noticed that where the bee inspector has not shaken off enough bees, he gently blows on the area of the comb that he wants to view more clearly. The bees move away and a good view into cells results.

I am glad that Shaw raised this matter of inspecting near-natural comb, as it gives me this opportunity to say that I would like to see the whole inspection serviced modernised. This could be done on the basis of relatively recently published screening methods, in order to accommodate the trend towards more apicentric beekeeping. However, to develop this suggestion would require a lengthy article of its own.

Shaw thinks that using top-bar hives turns the clock back. However, he may not have been aware that the Frenchman Émile Warré's 'People's Hive' is exactly contemporaneous with the UK's 'National Hive'. A precursor of the National was adopted by the Ministry of Agriculture in 1920, and it became a British Standard in 1946.[6] There even seems to be an element of harmonising between the terms 'People's Hive' and 'National Hive'. And, of course, the Warré is decades more modern than the Langstroth. Warré developed his hive early last century and the first editions of his book *Apiculture pour Tous*,[7] which contains plans of the hive, came out shortly after WWI. Based on experiments with 350 hives, he evolved his own from direct experience of the frame hives of Dadant, Voirnot and de Layens, all fairly common in France at that time. The 5th edition of his book, as well as presenting the top-bar version of the People's Hive, also contains the frame version, which is slightly larger. He presented both versions, he said, in order to respect the freedom of his readers. By the 12th edition, the one my wife and I translated, he had come down firmly on the side of the top-bar version.

Shaw identifies as a further problem of top-bar hives the fact that honey is harvested from brood comb and this may be detrimental to honey quality. I have examined this claim elsewhere and thus will not use space here to present the other side of the picture.[8] Furthermore, in three seasons of harvesting brood comb honey, I have not found any deterioration in honey quality. Customers often prefer this honey to honey spun out of supers. Wales' biggest organic honey packer informs me that honey from African top-bar hives sells well.[9] Before I took up beekeeping we used to buy it by the seven pound tub.

Shaw devotes a couple of paragraphs to the theory that small cells in the brood nest help bees cope with pests and disease. Although I am no advocate of the small cell theory, I do feel it is worth giving it some attention, especially as anecdotal support for the theory abounds. In a recent article in *The Beekeepers Quarterly* I have reviewed the literature on the question of whether small cells help bees cope with Varroa.[10] Of the total number of peer-reviewed papers, the number from researchers who have found that they don't is currently in the majority, possibly because most experiments have been of too short a duration.

*Nestduftwärmebindung*

In this German term, the Austrian beekeeper Johann Thür conceived the following:

> In order efficiently to utilise this costly, life-supporting and life-giving heat, nature has enabled the bee, a super-organism comprising colony and comb, to keep the heat in, to retain it. This retained heat is a mass of warm air, impregnated with scent, and thus germ-free. It suppresses harmful bacterial activity and hinders the occurrence of diseases. [...] The warm air is not lost downwards, because it is lighter. And it is kept in at the sides and above, through the cul-de-sacs in the naturally constructed comb. Only the used air of respiration drops downwards, laden with carbon dioxide, and at the open bottom margins of the comb it is exchanged with fresh circulating air. These open comb lower margins can be regarded as the mouth of a central breathing process that, with the help of the bees sealing the margins, breathes just the right amount of fresh air and organically prevents an excess penetration of cold air.

For a fuller presentation of this idea, the retention of nest scent and heat, please see my translation of two chapters from Thür's book.[11]

Shaw argues that *Nestduftwärmebindung* is 'complete nonsense' and can be rebutted with one word, 'homeostasis'. However, it is clear from the short extract above, and in Thür's chapters that homeostasis is implicit in his concept *Nestduftwärmebindung*. An alternative, more free translation would be 'maintenance of the nest atmosphere', which sounds to me just like homeostasis. Contrary to what the name might suggest, homeostasis is never a static thing. There can be huge inputs and outputs of a particular parameter in the system. The point is that in the beehive, the bees maintain a particular parameter, be it temperature, $O_2$, $CO_2$ or humidity, within limits of varying degrees of narrowness.

The maintenance of heat is usually easily understood by beekeepers. In a typical feral nest, the combs are stuck to the top of the cavity, usually in unbroken fixings, and attached to the sides of the cavity by fixings that are sometimes interrupted by what Tom Seeley calls, peripheral galleries.[12] Round the tops and edges of the combs there is no bee space. Bee space was an invention, not a discovery, by Rev. L. L. Langstroth, for the convenience of the beekeeper. The gaps between natural combs, which are largely cul-de-sacs, help the bees keep the nest warmth in during the large part of the year, especially in the UK, when thermal loss, rather than thermal gain, presents the greater challenge to colony survival.

Were the air flows of 50-400 L/min that Shaw cites (from an unnamed source) to be those that apply to the nest, then Thür's *Nestduftwärmebindung* hypothesis would indeed be hard to substantiate. Any beekeeper is familiar with the vacuum-cleaner like sound of a colony drying down nectar on a summer evening after a good flow. One need only put one's face to the entrance to feel the blast of warm, moist fragrant air. But those flows quoted above are almost certainly hive entrance flows and do not reflect the actual state of affairs in the brood nest, least of all in its core. As Shaw admits even the lower value is typical only for summer, the higher being for a heavy nectar flow. Furthermore, the values very likely apply to hives managed for unnaturally large populations and honey stores, through a combination of swarm suppression and supering. They are less likely to apply to colonies in their natural or near-natural state. It is worth noting in passing that this could hold true for a significant proportion of apiological research which is done on managed colonies of bees raised and kept long-term in frame hives. If so, the results would be a science of artefacts.

But colony ventilation does not work like a vacuum cleaner. On the contrary, as a detailed study has shown, it breathes in and breathes out at about 2.9 breaths a minute in a way not too dissimilar to the ventilation of a vertebrate, only in the hive the expiration is active and the inspiration passive.[13] The tidal volume averages 147 ml which corresponds to 0.42 L/min, far lower than the Shaw's flow figures, the minimum of which probably applies to colonies under ambient heat stress. And flow rates at the edges of the inter-comb spaces are highly likely to be even lower, particularly in the cooler parts of the year when heat retention is of prime concern, especially when brood is being reared. So I do not think Thür's conception of the nest atmosphere is blown away by Shaw's cited air flow rates.

As regards humidity, Shaw writes: 'There are claims that high humidity (up to 80% RH) in Warré hives helps control Varroa'. However, he does not cite the source of these claims. What is more likely is that the Warré hive and its very infrequent opening *at the top* allows the bees to maintain the humidity that they desire. Shaw's discussion of humidity hinges on the relative humidity needed to keep honey dry. However, absolute humidity has been found to be higher in the brood compared with in the honey stores,[14] and in cells relative humidity may need to be above 90% for optimum brood development.[15] Humidity, like several other hive atmosphere parameters, is very likely finely structured three-dimensionally. Overall measurements with sensors of insufficient resolving power mask this structuring. Furthermore, it is the integrity of this structuring that is temporarily broken when combs are removed.

In the term *Nestduftwärmebindung*, Thür's concept of the retention of *nest scent* presents the greater challenge to our understanding. Thür does not enlarge on it in his book. What could he have possibly meant? I will here try to offer some leads which are more of the nature of possible lines of future enquiry than existing fact. Thür appears to focus on the antiseptic properties of the hive atmosphere, so I will deal with this aspect first. It is of course very unlikely to be 'germ free', even if only because there are beneficial micro-organisms in the hive, for example the lactobacilli involved in the fermentation of pollen and the destruction of foulbrood pathogens. But there could be compounds from nectar or, more likely, propolis that are present in the hive atmosphere as vapours, aerosols or particulates. These compounds could include the essential oils found in nectar and in propolis (e.g. mono and sesquiterpenes) and the wide range of other compounds found in propolis, some of which, for example phenolic acids and esters, flavones, flavanones, have antiseptic properties.[16] Whether significant amounts of compounds from nectar or propolis enter the hive atmosphere would be a matter for future research.

That the hive atmosphere may have medicinal properties is already evidenced by its use in apitherapy in Germany for treating people with serious lung problems. Patients inhale the hive atmosphere through a face mask and tube connected to the crown board.[17]

The hive atmosphere has been found to contain the two volatile fatty acids, formic acid and acetic acid.[18] Both have antimicrobial properties and formic acid is used as an acaricide. What those substances are doing, if anything, in the hive atmosphere has yet to be revealed.

Pheromones represent a further class of constituents of the hive atmosphere that are worth considering in the context of scent retention. Thür, publishing in 1946, made no reference to them. This is not surprising, as the term 'pheromone' was not coined until 1959. Shaw argues that 'the only pheromones that have high volatility are those that are used outside the hive'. Apart from the fact this statement is incorrect, as we shall see, it is clear that although the ability of a compound to enter the gaseous state, i.e. it having a satisfactory vapour pressure, no doubt affects the *amount* of the compound that does so, there are other factors in pheromone action such as the affinity and responsiveness of chemoreceptors on the receiver that can bring about a big response with a very small number of molecules. For example, 9-ODA, probably the best known of the queen pheromones has a vapour pressure of only 0.00000177 mm mercury (Hg) at 25ºC, but if we put some of it on the end of a long fishing rod and wave it about in a drone congregation area on a sunny day, the results can be quite spectacular. How relatively low 9-ODA's vapour pressure is can be illustrated by comparing it with that of one of the alarm pheromones, isopentyl acetate, which is 4 mm Hg at 20ºC, or with the more familiar substance already mentioned, acetic acid, which is 12 mm Hg at 20ºC. But if 9-ODA, and the other related compounds that synergise its effect can act over tens of metres distances in the open,[19] we can see how much easier it would be for them to act over the millimetre distances encountered in the cramped confines of the nest. This is not, however, intended to sideline the very important routes for pheromone transmission, namely by direct contact either bee-to-bee, or bee-to-comb.

There are at least 15 glands in the honey bee that secrete pheromones, and from some of them the list of compounds already identified runs to dozens. Altogether about 50 compounds are known to be essential to proper function of the society.[20] As more are being discovered, it not unlikely that the total number of compounds involved in intra- and extra-colony chemical communication will be found to extend into three figures. Yet despite the 40 years that have elapsed since the first honey bee pheromone was identified, research into the roles of all these compounds is still in its infancy, or at best its youth. Whilst it is true that a large class of the higher molecular weight honey bee pheromones have low vapour pressures, it is clear from the foregoing example that we cannot rely on vapour pressure for playing down the role of pheromones in the properties of the nest atmosphere, including those involved in maintaining colony integrity and function. This is all the more likely for the fact that colony temperature can rise in parts to 40ºC or more, which is at least 15ºC higher than the temperature for which vapour pressure is commonly cited. The cosane and cosene dance pheromones are released and active in the hive atmosphere despite having vapour pressures in only the $10^{-7}$ to $10^{-5}$ mm Hg range.[21] Furthermore, there are pheromones of much higher volatility active in the nest, for example E-b-ocimene, a key hormone in the intimate relationship between queen and workers and between brood and workers, having a vapour pressure of 1.56 mm Hg at 25ºC.[22]

If we keep in mind the fact that colony life goes on in the dark and the bees must rely on tactile, vibrational, acoustic and chemical signals for their communication with one another, it would appear that there is a role to play for pheromones not only in the general milieu of the nest atmosphere but also in its differentiation or structuring in three dimensions. What comb removal does to this structuring, if present, can only be imagined. We can be fairly sure though, that bees generally put things right in a matter of hours or days.

*Concluding remarks*

In the light of the foregoing, I think that Thür's concept of the retention of the nest scent and heat, is of value in understanding how to optimise colony health. *Nestduftwärmebindung* is seems to be an alien concept to some frame beekeepers, to judge by the effort they put into rebutting it. I hope this surrebuttal will provoke an interesting adduction by readers of further evidence and counter-evidence.

In relation to his comparison of frame hives with top-bar hives, Shaw's concluding remark is: 'A quick fling with a top bar hive can be quite interesting for an experienced beekeeper but this is no way to form a lasting relationship with your bees.' Beekeepers should be free themselves to determine the nature of the relationship that they want with their bees, and to choose the hive that seems appropriate to them. Many beginners choose top-bar hives at the outset, often despite being told of the advantages of frame hives, one of which is that it is usually a lot easier to find a mentor close at hand. Most stay with them because they find top-bar hive beekeeping more satisfying. Furthermore, several commercial beekeepers have turned to the Warré hive, one of whom used to manage 2,000 Langstroths. I would like to see diversity in beekeeping rather than the uniformity that could arise from the straitjacket of Langstrothism. It is encouraging that existing diversity is being catered for by the hive manufacturers. For example, there are already several Warré hive manufacturers in the UK, and Thornes inform me that they will be selling them this autumn (2011).

A huge step forward would be to see comparisons of the performance of top-bar hives with frame hives, particularly as regards colony health, by the various agencies in the bee disease industry, for example the UK's National Bee Unit. Such comparisons would need to be well resourced, and in different localities to accommodate climatic and forage differences.

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