

No Bee is an Island

A look at the micro-ecosystem within the beehive, and some experimental data with regard to formic acid and fermentation

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As students of the hive, we share in the understanding that an individual bee is not quite an entity itself, and conversely, the whole of the hive is more than just the sum of its individual bees. Easy to overlook are the multitudes of yeasts, bacteria, and other microorganisms that also inhabit, interact with, and contribute to the health and functions of the hive super-organism. Microorganisms enter the hive from the air, on pollen, on bees, in nectar, in water, and from drifting bees. There is, in fact, an active culture that it made up of thousands of known microorganisms that inhabit a healthy honeybee colony. It is our thesis that this complex environment is sensitive to chemical contamination, and that the introduction of antibiotics, fungicides, miticides, organic acids, essential oils, and other contaminants by beekeepers specifically, and otherwise through the environment, have contributed to the declining health and numbers of honeybee colonies seen in the U.S. since the mid-1980's.

The microbial ecosystem that exists in honeybees and within honeybee hives includes some 8,000 microbes¹ including hundreds of strains of yeasts in both pollen and nectar foraging bee intestines², and at least 107 molds, 81 yeasts and 29 bacteria in beebread³. Martha Gilliam posited that fermentation of pollen is necessary to open the outer shells of pollen granules so that the encased proteins and nutrients are released and accessible for the bees to digest⁴. Emerging adult bees acquire intestinal micro-flora through food exchange with other bees in the colony and through consumption of yeast containing pollen⁵. In this way, the colony maintains its microbial culture over time and from queen to queen.

Pollen is necessary for development in older larvae and for longevity in young adult bees. Young worker bees ingest large amounts of pollen in order to make royal jelly which is the sole food for queen development and the food for the first few days of the worker and drone larvae. Bees regulate hive temperature to kill pathogens using their flight muscles to raise temperatures⁶. Strong flight muscles are also necessary for over-wintering,

¹ <http://www.ars.usda.gov/is/AR/archive/aug98/bees0898.htm?pf=1>

² Carlos A. Rosa and Gabor Peter (eds.), Biodiversity and Ecophysiology of Yeasts, (Springer-Verlag Berlin Heidelberg, 2006) p.339

³ Wickelgren, Ingrid, "Scientist solves secret of bee bread", Science News, (11/05/88)

⁴ Gilliam, M., "Identification and roles of non-pathogenic microflora associated with honey bees" (abstract), FEMS microbiology letters, 1997, vol.155, n 1

⁵ Ibid.

⁶ Milius, S., "The whole beehive gets a fever", Science News, (May 27, 2000)

foraging, and mating. Flight muscles are built from pollen and good general nutrition. Without digestible pollen, young bees cannot develop properly, nor can nurse bees properly care for the young.

Pollen that has not properly fermented into beebread is not digestible by honeybees. It should be noted that irradiation of pollen supplements to eliminate risk of disease kills beneficial microbes as well as what are thought of as pathogens.

Simply as a thought experiment, think of your favorite fermented foods (pickles, beer, wine, sauerkraut, cheese, mead, etc). Knowing that the natural fermentation process is one in which yeasts, bacteria, fungi, etc all interact, would one expect that the direct applications of fungicides, antibiotics, organic acids, or other chemicals would not upset such a system?⁷ What impact does contaminating this environment have?

Balanced biological systems go awry when contaminated. A pond where detergent (phosphates) accumulates will often grow an “algae bloom”, choking out fish, insects, plants, and the ones higher up (and lower down) the food chain that rely on them, their dead matter, or their waste. Taking an antibiotic can upset the balance of flora in ones digestive tract, and an upset stomach (and associated, unpleasant symptoms) is expected with high doses. The “Dust Bowl” of the 1930’s was simply massive erosion caused by a combination of drought, and farming practices that didn’t respect the natural systems that prevent such erosion (grasses, micro-flora of untilled soil, etc.). Equilibrium in the above examples is undone by interfering with natural systems, when it is the natural systems themselves that we rely upon, and are ultimately incorporated within.

It occurs to us that despite periodic large scale domestic honeybee die-offs, beekeeping in the U.S. was thriving until the introduction of varroa mites. Since this time (mid 1980’s), the number of bees, and the number of beekeepers in the U.S. has been declining. With official reports of near 40% die offs in some of the major commercial operations so far this year and unofficial reports of some localities faring much worse, this trend does not appear to be changing. Encouragingly, bee school attendance in this area (Massachusetts) has been in record numbers, and doubtless there are hundreds of first year beekeepers, all hoping to keep their bees alive both with and without treatments. Although the influx of new beekeepers is good news, dead bees and discouraging statistics are likely to cut short the number of years they stay involved.

Co-incident to the introduction of the mites (and the devastating impact they had on beekeepers and feral populations), was the increase in the use of chemicals inside the beehive. It seems that the varroa crisis has placed us firmly on “the treatment treadmill” for varroa, tracheal mites, nosema, foulbrood, etc. This trend towards using chemicals

⁷ Many fermentation processes do use a single inoculant after sterilization. This is simply a refinement of natural fermentation. These processes use sterilizing agents that are removed before being inoculated with a specific culture, which is quite different than what we see in the beehive, or in an old fashioned pickle crock.

(and “natural” or “organic” treatments) in the hive could be, at least in part, responsible for upsetting the microbial balance within the hive. The fermentation of pollen into beebread is but one example of how chemical contamination can affect essential processes within the hive in ways that are difficult to observe directly.

Formic acid is recommended as a “softer” treatment than fluvalinate or coumaphos, and is supposed to be effective against both varroa and tracheal mites. It is widely available and used in a trickle or vaporized from a pre-made or home-made pad. We obtained a small amount of formic acid in liquid form (unknown concentration, but formulated for beekeeping use on a pad as mixed), and did some simple kitchen experiments to measure the effect of formic acid on the fermentation of bread yeast.

Into 6 sterilized 4 oz. baby food jars, we put 2 teaspoons of sugar and distilled water to just below the rim of the jar. One jar had no formic acid (control), and each of the other 5 jars had 1, 3, 5, 7, and 9 drops (from an eyedropper) of formic acid. The jars were held in a water bath (100-110F), and to each was added 1 teaspoon of yeast. Surgical gloves were secured around the necks of the jars, and inflation of the gloves was used to indicate the amount of fermentation.



Fermentation was non-existent at 9 drops (less than 1/8 teaspoon) and very slight at 5 (~1/16 teaspoon) and 7 drops. Results are pictured above; control is at far left. Photo was taken a couple of hours after inoculation took place. No further fermentation appeared to occur over the next 8 hours. Note the small amount of formic acid needed to retard or prevent fermentation in bread yeast.

Although formic acid is recommended as a safer alternative to other chemical treatments, we were able to stop yeast fermentation with only a few drops. A Mite-Away II pads

contains almost 51 teaspoons of 65% formic acid⁸. This simple experiment leads us to many questions:

- Has anyone studied the effects of various formic acid treatments (on-label and off-label) on pollen and beebread fermentation inside the hive?
- What are the effects of other treatments on pollen and beebread fermentation inside the hive, both alone and in combination?
- What are the effects on pollen fermentation from other agricultural chemicals coming from the environment?
- Is beebread ever tested for levels of fermentation and active yeast cultures?
- Is beebread pulverized before being analyzed in the lab? (It occurs to us that unfermented pulverized beebread might look similar in analysis to pulverized fermented beebread in the lab, but that the two might have very different nutritional yields to the honeybee in the hive).
- It is understood that various microorganisms have differing tolerances to acids, alcohol, and other toxins. What are the traits of microorganisms that are involved in the fermentation of pollen? What of the microorganisms involved in other processes within the hive?

At least one of the early reports on CCD observed:

“cursory examination of the gut contents revealed many pollen grains of unknown origin. The pollen grains seemed largely intact and many did not appear to be digested (which is abnormal).”⁹

To us, this seems to suggest that perhaps the pollen grains were not properly fermented before being ingested. Another puzzling (and thus far not well explained) reported symptom of CCD is the hive not being robbed out by wax moths or small hive beetles. It is known that both pests are attracted to fermented pollen, could it be that unfermented pollen does not act as an attractant?

In addition to the possible effects on fermentation, there are other well known consequences of using pesticides, antibiotics, fungicides, etc. in biological systems that might explain some of the “modern problems” facing beekeepers. Secondary infections are common causes for problems when treatments are used. In some cases, the treatment affects an organism that keeps another potentially threatening organism in check, unleashing a secondary infection. As an example, streptomycin administered to adult honeybee diets increases the yeast population in the bees, suggesting that bacteria are responsible for keeping yeast populations in check¹⁰. In other cases, when microbes and/or pests are eliminated, their food supply is suddenly available to other microbes and/or pests that are not susceptible to the same treatments as the target species. Again, the use of treatments within the hive has been growing since the first impact from varroa. Does it seem unreasonable to consider that some of the problems we are seeing in our hives industry-wide (CCD and otherwise) could be caused by, or be related to, such secondary infections?

⁸ http://www.miteaway.com/Mite-Away_IIi/mite-away_iii.html

⁹ http://www.doacs.state.fl.us/pi/plantinsp/apiary/fall_dwindle_report.pdf

¹⁰ ¹⁰ Carlos A. Rosa and Gabor Peter (eds.), *Biodiversity and Ecophysiology of Yeasts*, (Springer-Verlag Berlin Heidelberg, 2006) pp.341-342

Some molds and bacteria produce an antimycotic compound that attacks chalkbrood¹¹. The fungus that causes stonebrood kills nosema¹². The treatment for nosema (Fumidil) is a fungus produced toxin¹³, and the fungus that causes chalkbrood kills European foul brood¹⁴. It quickly becomes clear that there is a balance that must exist between all of these organisms (including honeybees), as they all support and protect each other. How has the introduction of antibiotics, fungicides, essential oils, organophosphates, pyrethroids, and even refined sugar, artificial pollen supplements and high fructose corn syrup affected such intricate balances within the hive? Can such relationships survive such interference intact? What are the consequences?

As a personal anecdotal observation, every year we have seen some chalkbrood and sacbrood in our over-wintered hives. We do not treat with anything. This year, we have more over-wintered hives than any other year, and the only significant difference in our management practice is that this year our bees are on small cell comb. We have not to date (mid-May), seen any chalkbrood or sacbrood in any of these hives, which we find interesting.

Honeybees have at their disposal many anti-microbial agents. In addition to toxins produced by microorganisms in the hive, bees use propolis and full strength honey to combat many types of infection. Dilute honey can of course also be used as a medium to grow microorganisms. One can imagine that with such tools, bees are capable of stimulating and retarding the growth of specific microorganisms based on need. In fact, honeybees are known to actively remove undesirable microbes¹⁵.

What we have written here is not a comprehensive overview with regards to what happens on a microbial level inside the beehive, what beekeepers have been putting into hives, or what this might actually be doing to the bees. People who buy honey (especially from a beekeeper) have no concept that anything at all goes into the hive. In some ways it is the only food left that is seen as “pure”. This disconnect between public perception and reality in the field is of great concern. The bulk of the contamination found within the hive is put there by the beekeeper, and is not the result of “chemical lawns”, farming chemicals, or environmental pollutants in general. This is a problem that is within the scope of the beekeeping community to solve from within. Only when the beekeeping industry (commercial, sideliner and hobbyist alike) puts a stop to the practice of putting foreign substances inside the hive will we be able to have a sense on what role contamination in the rest of our environment plays in the lives of honeybees.

¹¹ Gilliam, M., “Identification and roles of non-pathogenic microflora associated with honey bees” (abstract), FEMS microbiology letters, 1997, vol.155, n 1

¹² http://en.wikipedia.org/wiki/Nosema_apis

¹³ <http://www.bushfarms.com/beespests.htm>

¹⁴ <http://www.beesource.com/forums/showthread.php?t=216617&page=3>

¹⁵ Wickelgren, Ingrid, “Scientist solves secret of bee bread”, Science News, (11/05/88)