Phytochemical Helps Differentiate Workers from Queen Bees

The consumption of p-coumaric acid, a chemical found in honey and pollen, may help set a female honeybee on its course to becoming a worker instead of a queen.

By Ashley P. Taylor | August 28, 2015

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A newly hatched female honeybee larva can develop into either an egg-laying queen or a sterile worker. One determinant of a female bee's social caste, it turns out, is the insect's early-life diet. Future queens are fed nothing but royal jelly, a glandular secretion of so-called nurse bees, which feed both the larvae and the queen; queens continue this exclusive royal jelly diet throughout their lives. Future worker bees, on the other hand, are only fed royal jelly for their first three days; after that, they eat royal jelly mixed with fermented pollen, called beebread, and honey. Precisely what about these honeybee baby foods might help determine their developmental fates has long been an open question.

Consumption of the phytochemical *p*-coumaric acid, a phenolic substance found in beebread and honey but not in royal jelly, may be one factor that leads female larvae to become worker bees, according to a study published today (August 28) in *Science Advances.* Researchers from the University of Illinois at Urbana-Champaign "show that *p*-coumaric acid is a potent regulator of gene regulation and development in honey bees," Ryszard Maleszka, who studies genetics and epigenetics in honeybees at the Australian National University in Canberra but was not involved in the work wrote in email to *The Scientist*. This chemical, he continued, "has the capacity to suppress ovary development and it affects the expression of genes including those controlling organ sizes, epigenetic machineries and detoxification."

"The authors clearly show that *p*-coumaric acid represses genes that have been found in other studies to be associated with queen development," Peter Dearden, a geneticist and bee researcher at the University of Otago in Dunedin, New Zealand, who also was not involved in the work, wrote in an email. "Current models of caste development in bees rest on the idea that royal jelly contains a substance or substances that trigger, or enhance queen development. The development of different castes then rests on differential feeding of royal jelly."

"This paper doesn't directly challenge this model," Dearden noted, "but shows that a component of the diet which is excluded from royal jelly represses genes involved in queen development."

The researchers happened upon their results indirectly, said lead author May Berenbaum. The present study began as a follow-up to a 2013 study, in which Berenbaum's lab found that *p*-coumaric acid strongly activated genes involved in detoxification and immunity in adult worker bees. So the researchers wondered whether the chemical might also upregulate detoxification genes in larvae.

To find out, they raised two groups of larvae: one on a standard bee diet—royal jelly plus extra sugars and yeast extract—and another on the same diet plus *p*-coumaric acid. After three days, Berenbaum and her colleagues isolated RNA from the larvae, sequenced it, and then compared gene expression between the two larval groups.

In the larvae fed *p*-coumaric acid, Berenbaum said, "we saw a whole bunch of detoxification genes upregulated, even more immunity genes upregulated, and then—which was a surprise to us—a whole bunch of genes which were previously shown to be involved in caste determination. . . . In retrospect, it made a lot of sense."

Polymers of *p*-coumaric acid are the main compound of pollen-grain walls, and *p*-coumaric acid monomers are released when the pollen is fermented into beebread. Also found in honey, the phytochemical is "in almost every bite that a bee eats—except for queens and queen-destined larvae," said Berenbaum.

Considering the data suggesting *p*-coumaric acid might repress queen development, the researchers next raised two groups of larvae on a diet of royalactin—the main protein in royal jelly (and a standard diet for in vitro queen-rearing)—with or without the addition of *p*-coumaric acid. This time, they let the bees develop through the larval and pupal stages until the bees emerged as young adults. The researchers then compared ovarian development between the two groups. Bees exposed to *p*-coumaric acid during developed had smaller ovaries than those reared without the phytochemical.

The result supports the idea that consumption of *p*-coumaric acid, along with other phenolic compounds found in honey and beebread, leads to "a form of chemical castration" of future worker bees, the authors wrote in their report. But *p*-coumaric acid is probably only part of the caste-determination story, Berenbaum added.

"Royal jelly is important for producing queens," she said, "but, apparently, plant products are important for producing workers."

W. Mao et al., "A dietary phytochemical alters caste-associated gene expression in honey bees," *Science Advances*, 2015.

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honeybee, honey bees, eusociality, chemical biology and bees

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> *Whether the pronounced regulatory effects of nectar and pollen phytochemicals on honey bees are widespread among social hymenopteran pollinators in general or are unique to the highly eusocial honey bee remains an open question, the answer to which may shed light on the impact of diet and food processing on the evolution of eusociality.*

That claim seems far too modest give the fact that "The honeybee already serves as a model organism for studying human immunity, disease resistance, allergic reaction, circadian rhythms, antibiotic resistance, the development of the brain and behavior, mental health, longevity, diseases of the X chromosome, learning and memory, as well as conditioned responses to sensory stimuli (Kohl, 2012)."

The conditioned responses to food odors and to pheromones appear to link the physiology of reproduction in all living genera from nutrient-dependent microRNAs and adhesion proteins to healthy longevity unless protein folding is perturbed by the accumulation of viruses and viral microRNAs that pirate the energy that is required for DNA repair.

Thus, the authors appear to have linked what is known about quantum physics to quantum biology via phytochemicals and quantum smell to quantum consciousness in the context of the nutrient-dependent pheromone-controlled cell type differentiation of honeybees and symbiosis that extends across all species from the nutrient-dependent pheromone-controlled physiology of reproduction in microbes.

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