Sticking with Propolis:
A review of its importance to honeybee hive health.

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Introduction

Propolis is a colony-level defense against pathogens (Simone-Finstrom and Spivak, 2010) and can be considered an example of Richard Feynman's idea that "nature uses only the longest threads to weave her patterns so that each small piece of the fabric reveals the organization of the entire tapestry" (Duarte, 2010). Honeybees use propolis in their hives to caulk, seal, line, strengthen, preserve, repel, repair and varnish (Schmidt and Bachman, 2008). It acts as a moisture barrier to keep humidity stable as needed for brood development, and it prevents moisture influx during heavy rains.

In addition to using it throughout the hive, honeybees spread propolis at entrances where incoming forages walk across it before entering the hive. Similar to humans wiping their feet at the front door carpet, honeybees minimize the number of foreign pathogens coming into the hive when foragers walk across the highly microbial propolis. Indeed, the word propolis is formed with two root words: *pro* -- in front of; and *polis* – the city, suggesting that many of the attributes of propolis were known from early Greek times. Indeed, Aristotle and Pliny both noted in their writings of the use of propolis for human health (Ghisalberti, 1979).

While its uses for human health have long been known, the sticky, glue-like properties of propolis have at times been considered a hindrance in beekeeping. Some beekeepers consider propolis to be the bane of their existence. It is everywhere in the hive, becomes brittle in cold weather and like glue in warm weather, and once its on your clothes, it's there for good. Even 21st Century training in this beekeeper's career included instruction from experienced beekeepers to clean out as much propolis as possible with each hive inspection.

This paper, however, reviews research that supports the crucial importance of propolis to the hive. This paper also describes some of the anti-pathogenic action of propolis. Moreover, this paper advocates *sticking with propolis*, and developing beekeeping skills to support the innate ability of the honeybee to build a stronger, more resilient hive through its use of propolis rather than cleaning out propolis for the sake of easier beekeeping.

Insects and social immunity

The use of propolis in a honeybee hive is an example of how a colony maintains *social immunity* – how individual behaviors of group members effectively reduce disease and parasite transmission at the colony level. Examples of social immunity are found throughout the insect world. Colonies exhibit hygienic behavior through grooming, removing dead material, removing diseased brood and other such actions (Simone-Finstrom et al, 2009). Resins used for propolis are collected to respond to possible pathogen levels.

In ant colonies, propolis-enriched environments act as an external immune defense and may reduce the investment of individual immune response (Simone-Finstrom et al, 2009). In other words, the insects have to use fewer resources for individual immune defenses when the hive is enriched to act as a barrier against pathogens.

Honeybees have a reduced number of immune pathways and individuals have fewer physiological defenses than other insects. Other traits have evolved at the individual and colony level to compensate. The collection and use of propolis is an example of colony level defense against pathogens (Simone-Finstrom et al, 2009). For example, Apis dorsata, the giant honeybee, uses propolis to strengthen where comb attaches to tree branches while Apis florea, the dwarf honeybee, uses it at entrances to prevent ant invasion (Simone-Finstrom et al, 2009).

Apis mellifera – the common honeybee founds in the United States – has the most widespread uses of propolis. Some species of Apis mellifera collect more propolis than others: grey mountain Caucasian collect more than dark forest bees, Italians collect very little; Carniolans use more wax than propolis (Simone-Finstrom et al, 2009).

Bankova (2005) contends that propolis is the most important chemical weapon of honeybees against pathogens. Siimone-Finstrom et al (2010) suggest that resins that go into propolis may be collected regardless of the hive pathogen levels, noting that the antimicrobial properties may benefit individual bee immune response and increased colony fitness, thereby offsetting the energy cost to individual bees to collect the resins.

Plant origins, volatile constituents and chemical actions of propolis

"(B)ees have the ability to find in their environment and use as propolis sources the best agents to protect their hives against bacterial and fungal infection" (Garadew et al, 2002).

Honeybees use the propolis sources available to them. Chemical differences from different propolis sources vary from country to country. Remarkably, while propolis sources are unique to the local area and differ from colony to colony, samples are surprisingly similar in their action. All samples were found to have similarly high antibacterial, antifungal and antiviral activity (Bankova, 2005; Ghisalberti, 1979; Schmidt and Bachman, 2005).

"The fact that different chemistry leads to the same type of activity and in some cases even to activity of the same order of magnitude is amazing" (Garadew et al, 2002). For example, in the Northern temperate zone, propolis comes primarily from the buds of alder, beech, birch, conifers, chestnut, and elm trees (Ghisalberti, 1979). These trees supply flavonoids, phenols, acids and esters in propolis. In South America, however, propolis sources contain coumanic acids and diterpene alcohols. But, regardless of the source and the primary chemicals, the action of propolis in the hive is similar.

A closer look at the actions of some of the chemicals found in propolis helps to explain their usefulness in the hive (Schnaubelt, 1995):

Alcohols are gentle, immune stimulating and hormone balancing. These include mono-, sesqui- and diterpene alcohols.

Phenols have actions similar to alcohols, but are stronger. They provide antiseptic and antibacterial actions, modulate the immune function as needed, and stimulate healing.

Aldehydes are antiviral, anti-inflammatory and calming.

Coumarines are in a family of acids including caffeic acid (not related to caffeine) and ferulic acid, all of which are used in pharmaceuticals for sunscreens and UV blockers, and as optic filters for molecules excited by light (think of transition lenses). Caffeic acid is a metabolite product of nature, closely related to phenol, with antioxidant properties and immune system modulators. These acids are widely distributed in plants in defense, pigment, and external system functions.

Propolis also contains beeswax; traces of up to 300 other chemicals; vitamins B, B2, B6, C and E; such minerals as calcium, aluminum, and manganese; and a variety of volatile oils (Ghisalberti, 1979).

Propolis and bee health

Beehives are highly susceptible to fungal diseases because of the large amount of food stored at relatively high temperature and humidity (Nui et al, 2010). In the hive, fungi compete with bees for food and can produce mycotoxins that are toxic to bees. Research suggests that propolis in the hive reduces the bacteria load and thereby reduces the need for honeybee immune gene expression. In other words, propolis in the hive enables bees to work less hard to stay healthy.

It is not fully understood how bees tolerate high levels of mycotoxins in the hive, but it is known that they are able to metabolize and transform toxins into non-toxic products through their use of the P450 enzymes. It is thought that propolis may enhance the activity of the P450 enzyme (Nui et al, 2010) to enable this action to take place. Simone-Finstrom and Spivak (2010) report on work of R. M. Johnson that continues today in which it has been found that oral propolis upregulates three P450 genes, at least one of which metabolizes flavonoids found in honey, pollen and propolis.

Flavonoids are ubiquitous in the plant kingdom (Ghisalberti, 1979). According to scientists at the Linus Pauling Institute at Oregon State University, "Flavonoids are a large family of compounds synthesized by plants that have a common chemical structure. Over the past decade, scientists have become increasingly interested in the potential for various dietary flavonoids to explain some of the (human) health benefits associated with fruit- and vegetable-rich diets."

In addition to being anti-pathogenic, it is thought that flavonoids may potentiate enzymes that detoxify hydrocarbons, show anti-inflammatory action and help with tissue regeneration (Ghisalberti, 1979). Bees have fewer P450 enzymes than some other insects, but may compensate by effectively regulating their small number of P450 genes with the use of phytochemicals, and especially propolis (Simone-Finstrom et al, 2010).

Johnson shows that propolis inhibits in-vitro fungal growth, and suggests that the antimicrobial action was due to the levels of flavonoids and phenols in propolis. Johnson's research shows that bees died earlier when P450 inhibitors were used. Conversely, bees lived longer with mycotoxins when higher levels of propolis were present.

The exciting work on honeybee health continues, and may give important insights to how propolis aids honeybee hive health. This is doubling exciting because its focus is on how to use existing hive substances to strengthen the hive, rather than how to introduce foreign chemicals to counteract damage done in the hive.

For example, evidence that propolis serves as a natural mechanism of disease resistance may have the potential to be applied as in-hive treatments. Green propolis from Brazil has been shown to be effective against American Foulbrood, as has Minnesota propolis, but to a lesser degree (Simone-Finstrom and Spivak, 2010).

Propolis has been found to temporarily reduce the spread of disease even though it did not eliminate it from the hive. In petri dishes, varroa mites exposed to low dose propolis in a 10 percent alcohol solution caused 100 percent mite mortality. Exposure as low as 0.5 percent cause a narcotic effect, leading to reduced mite heat production and metabolic rate. Preliminary tests show that propolis treatments (spraying on walls or empty combs) may reduce the number of female mites produced in a single cell. And, because propolis has more than 300 chemicals, it may prove difficult for varroa mites to develop resistance against the full suite of compounds (Simone-Finstrom and Spivak, 2010).

What is a beekeeper's appropriate response?

The work to understand the importance and uses of propolis in the hive has implications for the beekeeper. First and most obvious is the need to work hives without stripping them of the crucial propolis while maintaining hives in a manageable way.

Next, thoughts come to mind of how to supplement work already being done by bees that forage for propolis. Simone-Finstrom and Spivak (2010) advocate that hive wooden ware with rough, unworked and untreated wood on the inside of the hive would replicate what bees find in the wild – rough wood needed to be filled in and propolized to make the hive inhabitable.

Such hive components differ greatly from the smoothly finished wood products used to build hives today. A compromise could easily be reached with hive components that are smooth and finished on the outside and rims, but rough and unworked on the inside. Smooth outsides meet the human need for aesthetics and manageability, smooth rims help hive boxes fit together tightly, unworked insides encourage bees to pack the hive with propolis, thereby building a healthier hive.

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