Opinion

Why do honeybees exploit so few plant species as propolis sources?

Abstract

Propolis is a honeybee product containing beeswax and resin stemming from plants. It provides protection to the hive against microbial infection. Potential plant sources of resin with antimicrobial secondary metabolites are plentiful, but the mouthparts of honeybees enable them to exploit only a narrow diversity of species.

Keywords: apis mellifera, bee health, biological activity, botanical origin, complementary food, propolis, immunity, phenolic substances, plant resins

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Introduction

Propolis is a resinous material produced by honeybees (*Apis mellifera*) from beeswax and resins collected from plants. Propolis has been used medicinally since antiquity and is presently regarded a complementary food. The chemical composition of propolis is complex. The majority of the constituents isolated from its resin are phenolic substances, although terpenoids also have been frequently isolated.[1] A wide diversity of biological activities of propolis and its constituents are known, e. g. antioxidant, antimicrobial, anticancer, immune-stimulant, antidiabetes, antiulcer and wound-healing.[2]

Two types of propolis have deserved the greatest attention: temperate propolis and Brazilian green propolis.[2] The former is produced by bees from exudates of apical buds of poplar trees (*Populus* spp.; Salicaceae),[3] while the latter derives from young leaves (leaf primordia) and vegetative buds of *Baccharis dracunculifolia* (Asteraceae), a species from Central and south-east Brazil.[4] The chemical composition is dependent on the locality of the hives and the local flora. Many other types of propolis, each with a characteristic composition, have been reported. In addition to the mentioned green propolis, other types of Brazilian propolis are known:

i. red propolis from the northeast coast, derived from exudates of *Dalbergia ecastophyllum* (Leguminosae);[5]

ii. black propolis from Amazonia, derived from exudates of flowers of *Clusia* (Clusiaceae);[6]

iii. Yellow and brown propolis, produced in several regions of the country, mostly with unknown botanical origin.[7]

Considerable variation on the composition of propolis may occur in the same geographic area.[8] Irrespective of locality and type, in general propolis has high contents of phenolic substances and high antioxidant and antibacterial activity. Some of these characteristics have been recommended for standardization[3] and evaluation of propolis quality.[9]

It has been claimed that many plant species have been reported as sources of resin for propolis production. Indeed, if we take into account plant sources of all types of propolis from Europe, Asia, Oceania, Africa and Americas we come up with a considerable number of species. However, if we center our focus on Brazil, one of the top countries regarding propolis production and a country whose propolis is among the most studied in the world, it is surprising the low number of species which have been reported as propolis sources. In addition to the plants listed above (*Baccharis*, *Clusia* and *Dalbergia*), recently it has been shown that *Mimosia tenuifolia* (Leguminosae) from northeast Brazil is source of resin for a new type of green propolis.[10] Few other plant species have been suggested as sources of Brazilian propolis, among them *Araucaria heterophylla*[11] and *Hyptis divaricata*.[12] Such paucity of plant species providing resin for propolis production is amazing, especially taking into account that Brazil houses over 56,000 native plant species, amounting to about 19% of all world plant diversity.[13] Of course, the strong asymmetry between the wide available plant diversity and the narrow spectrum of plant sources of propolis holds not only for Brazil, but for all other parts of the world.

A quite different picture characterizes the diversity of plants exploited as sources of nectar and pollen. Many species, distributed in a large number of plant families are bee pollinated. Requisites of flowers to be honey bee hosts are essentially an open corolla, olfactory and visual cues, such as blue or yellow pigments and/or ultraviolet absorbing phenolic substances.[14] Pollen and nectar, in combination, provide moisture, sugars, lipids, proteins, amino acids and other nutrients. Functional substances may also be provided by pollen, such as carotenoids, flavonoids and other phenolic substances.[15] Thousands of extant plant species have co-evolved with insects bearing lapping and chewing mouthparts, such as honeybees.

Instead, the resin collected by honey bees from certain plants (generally different from those providing nectar and pollen) has a distinct biologic meaning for the hive. In addition to physical purposes of sealing holes and crevices on the nest, propolis is important as a means to provide resistance against health problems caused by microorganisms. It has been argued that propolis enhances the social immunity of the hive, by acting as an important antimicrobial layer.[16] After parasite infection of the hive, it was observed an increase of the number of individuals foraging for resin, a behavior that was interpreted as self-medication at the colony level.[17] This hypothesis is consistent with the multiple reports of antibacterial, antifungal and antivirus activities by propolis and its isolated constituents.[2] Among secondary plant metabolites, phenolic compounds are widely known to have antimicrobial activity.[18] Another class of secondary

metabolites with antimicrobial activity is represented by terpenoids.[19] Most types of propolis, including the two most commercialized types (temperate and Brazilian green propolis), have high contents of phenolic compounds. Terpenoids, including mono-, sesqui-, di- and triterpenes are also frequent in propolis, often as major constituents.[8]

Plants need to fulfil at least two requisites to be used by honey bees as sources of resin for propolis production. A first requisite is the provision of material with chemical composition compatible with the role of defensive barriers against pathogens. In this regard, the proportion of plants fulfilling this requisite is vast. Several families of angiosperms, such as Clusiaceae, Leguminosae, Malpighiaceae, Myrtaceae, Rutaceae and Sapindaceae, just to name a few, are characteristically rich in phenolic compounds. Many species have terpenoids and other biologically active substances in secretory structures, e.g. laticifers (which produce and store latex), secretory glands and resin channels. Other plants secrete exudates, some of them continuously, others in response to injures.

The second requisite seems to be the main constraint that honey bees have to face, a barrier that probably limits the number of plant species providing propolis resin. Not all plant exudates are available for collection by honey bees. Latex, some resins and gums often are too sticky to be collected by bees. In addition, latex and some resins solidify in contact with air and turn out a material too hard to be manipulated by honeybees. Exudates that bees normally collect, for example from apical buds of poplars[2] or from flower stigmata of *Clusia*,[6] are nearly solid films which are amenable to be scraped from the plant surface and be attached to the hind honeybee legs. Vegetative plant organs, such as barks and leaves, often have relatively abundant load of antimicrobial secondary metabolites. However, most of these materials are too hard to be cut with the mouth mandibles of honeybees. In contrast, army ants, many beetles, and grasshoppers are chewing insects with mouths armed with potent mandibles or jaws, which are efficient at cutting even thick and hard plant parts, a reason why they often behave as crop plagues. Although honey bees also behave as chewing insects when they collect plant resins, their mouth mandibles are delicate, as compared with mouth parts of typically chewing insects, such as leafcutter ants and grasshoppers. This is the probable reason why honey bees restrict the collection of plant resin to some exudates, e. g. from poplar apical buds, *Clusia* stigmata and stems of *Dalbergia ecastophyllum*,[1] as well as tender plant parts, such as leaf primordia and apical buds of *Baccharis dracunculifolia*[4] and *Mimosa tenuifolia*.[10] In this regard, it is curious and suggestive the epithet *tenuifolia*, which means "delicate leaf". All these material, conventionally called "resin" in propolis research, are sufficiently soft to be either cut (apical buds and leaf primordia) or scraped from the plant surface (exudates). Okinawa and Taiwan propolis are produced from material scraped from the surface of fruits of *Macaranga*.[20]

Because they evolved as pollinators feeding on nectar and pollen, honeybees have mouthparts that enable them to act both as lapping and chewing insects. Although they are efficient at eating pollen, manipulating beeswax and sometimes helping in the defense of the colony, the chewing mandibles of honeybees are not strong enough to cut and chew plant material from many species. If that was possible, probably the spectrum of plant sources exploited by honeybees to produce propolis would be considerably wider.

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Conflicts of interest

The author declares no conflict of interests.

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