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# Editorial: Pollen as food for bees: Diversity, nutrition, and contamination

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Editorial on the Research Topic
Pollen as food for bees: Diversity, nutrition, and contamination

With the rising recognition of the importance of supporting both managed and wild bee populations for their critical role in agricultural production (Klein et al., 2007; Aizen et al., 2019) and plant sexual reproduction in natural systems (Ollerton et al., 2011), there has been an increased focus on bee nutrition (Vaudo et al., 2015).

Pollen has long been understood to be the essential primary source of protein, lipids, vitamins and minerals to support bee development and reproduction (Brodschneider and Crailsheim, 2010), but this broad generalization hides a multitude of complex questions as we examine how bees nourish themselves by foraging for pollen across landscapes (Stoner et al., 2022), and how the pollen they collect provides the nutrients they need (Avni et al., 2014; Hendriksma et al., 2019), and how nutrition drives bee health in their wide network of environmental interactions (Tosi et al., 2017). The articles in this Research Topic delve into these complexities.

Crone et al. provide a framework with three approaches to wild bee nutritional ecology: (1) identification of the bees visiting focal plant species, (2) evaluation of foraging preferences of adults in focal bee species, and (3) experimental laboratory study of nutritional requirements of larval or adult focal bee species. Their first approach has the greatest opportunity to address wild bee diversity and how bees fit into the reproductive strategy of the focal plant species, but none of the other papers contributed to this Research Topic used this approach.

Two of the papers in this Research Topic adopted the second approach, evaluating the foraging preferences of honey bees as the focal bee species over differences in landscape composition in time and space. Malagnini et al. and McMinn-Sauder et al. found interestingly similar results for spring honey bee foraging in different continents (Northern Italy and central Ohio, respectively) and across urban and rural landscapes. In both studies, the bees were using similar spring pollen sources across urban and rural locations: tree pollen (*Malus/Pyrus*, *Salix*) and spring Asteraceae (e.g., *Taraxacum*),

supplemented by *Trifolium* as the spring progressed. In late summer, however, Malagnini et al. found that semi-natural areas increased the diversity of pollen collected compared to more urban and agricultural sites.

St. Clair et al. focused on honey bee pollen resources in this late summer period in Iowa, comparing pollen collection in an agroecosystem dominated by corn and soybean with restored prairies, and then measuring the effect of pollen from these landscapes on queen fecundity in the field and laboratory. While the field results were variable both in queen fecundity and pollen composition over the 3 years, controlled testing in the laboratory showed that queen fecundity increased in colonies with a mix of polyfloral prairie pollen compared to the pollen from agricultural areas.

Beekeepers often supplement the pollen sources available to their colonies with the goal of improving colony health and productivity, but as Noordyke and Ellis explore in their review, testing of pollen substitutes for various parameters of colony productivity and health—and even consumption of the pollen substitute itself—can have mixed results depending on the availability of natural pollen, time of year of feeding, and how tests are conducted. Overall, pollen substitutes are inferior to natural pollen, and some diets have even been found to increase pest and pathogen loads or decrease bee longevity.

Clearly, we need more understanding of the feeding behavior and nutritional requirements of honey bees to be able to formulate adequate artificial diets. Elsayeh et al. measured consumption of essential amino acids and carbohydrates by young honey bee workers in relation to concentration of B vitamins and found that bees actively regulate their vitamin intake and prefer vitamin concentrations comparable to those found in natural food (pollen, beebread, and royal jelly).

Brown et al. found that treatment with tetracycline had a negative effect on longevity of honey bee workers when combined with polyfloral pollen, in contrast with other studies of antibiotic treatment. This could be due to the need for a fully functional microbiome for pollen digestion or for resistance to food-borne pathogens and raises questions about the use of tetracycline in beekeeping against bacterial pathogens.

Barraud et al. extended the experimental approach to bee nutrition beyond honey bees. They compared the effects of different pollen blends, varying in their macronutrient composition, on key life-history traits of four managed bee species, including the bumble bee *Bombus terrestris* and the mason bees *Osmia bicornis* and *O. cornuta* in addition to honey bees. They showed that the pollen blend that was worst for honey bees was good to average for the other three species, and vice versa. Thus, honey bees are not a good model species for understanding the nutritional needs of the vast diversity of other bee species.

The studies in this Research Topic have shown that our knowledge of bee nutrition is not sufficient, even for honey bees, for us to make a pollen substitute that will work as well as the natural diet of mixed pollen, collected by foraging workers and processed using the natural gut microbiome. The similarity of spring pollen collected across urban and rural landscapes from Italy and Ohio raises questions about the extent to which the same spring pollen resources are favored by honey bees across the continents, and points to specific spring floral resources to conserve for beekeepers in intensive agricultural environments. We also note that in late summer and fall honey bees need more diverse semi-natural landscapes to meet their pollen needs, with queen fecundity being particularly sensitive to diverse, high quality pollen resources.

Research and extension on pollen nutrition is imperative to enable both wild and managed bees to thrive. Even among the small number of bee species studied here, pollen mixes that favor reproduction and longevity in bumble bees and mason bees were radically different from those supporting honey bee health. There is so much more to learn about the nutritional needs of these managed bees and how their nutritional needs relate to the thousands of wild bee species on which our agriculture and biodiversity also depend.

## Author contributions

KS drafted the first version of the manuscript. All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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