How do bees capture nectar with their tongue?

Bees feed on the nectar they collect by foraging on flowers with their tongue decorated with very long papillae. Researchers from the Free University of Brussels and the University of Mons have studied the mechanisms of fluid capture to show that its efficiency drops when the nectar becomes very sweet. Their study appears in the journal PNAS.

Bees are peaceful foragers that contribute to the pollination of flowering plants by collecting nectar. This sweet liquid, which provides them with the energy they need to live, is collected with their tongues dipped into the nectar five times a second. The higher the sugar content of the nectar, the more energy it provides. To increase their attractiveness to insects and thus their chances of being pollinated, plants should therefore produce the sweetest nectar. In reality, its sugar concentration rarely exceeds 60%. The reason for this limitation is to be found in the capture mechanism itself. In vivo measurements show that beyond this limit, the bees capture less nectar per lap. However, the reasons for this reduction in efficiency of the bees' tongue were not known.

Led by Fabian Brau of the Université libre de Bruxelles, ULB - Unit of Nonlinear Physical Chemistry, Faculty of Science - Pascal Damman of the University of Mons - Laboratory of Interfaces and Complex Fluids - and Denis Michez of the University of Mons - Laboratory of Zoology, a team of researchers have shown that surprisingly, the shape of the papillae decorating the bees' tongue determines the optimal sugar concentration for the energy intake rate.

Published in the journal PNAS today, this interdisciplinary study, combining in vivo experiments with a physical model of fluid capture, has provided a deep insight into the essential role of papillae in nectar capture in bees.

Of the 20,000 bee species known to date, almost half have a long tongue decorated with very slender papillae (Figure 1). To collect nectar, bees periodically dip their tongues into it. Experiments carried out under a microscope equipped with a high-speed camera show that when the tongue is immersed in nectar, the papillae open up like the hairs of a paintbrush. The presence of these out-growths therefore makes it possible to trap a greater quantity of nectar than a smooth tongue. However, these same experiments also show that this morphological advantage no longer plays a role when the sugar content of the nectar exceeds 60%.

Figure 1 : Papilles d'une langue d'abeille (Megachile rotundata). Barre d'échelle : 100 µm. (crédits : Agricultural Research Service and F. Brau).
a critical value. Indeed, when the sugar concentration increases, the viscosity of the nectar increases rapidly and prevents the papillae from opening completely before the tongue withdraws from the nectar.

Using an approach based on fluid mechanics and rod elasticity, the authors derived a physical model for the movement of papillae in a viscous liquid. By combining this theoretical model with measurements of the morphology of the tongue, they explained why the nectar ingestion rate in bees drops sharply at sugar contents larger than 60%. Their theoretical predictions were confirmed by in vivo measurements of these intake rates in several bee species.

Surprisingly, this study shows that the precise value of this limiting sugar concentration is determined by the relationship between the length and diameter of the papillae. A correlation between the morphology of the bee’s tongue and the viscosity of the nectar that would have been difficult to predict a priori and which highlights a process of co-adaptation of plants and their pollinators.

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_Essential role of papillae flexibility in nectar capture by bees_

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