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Nectar: The First Soft Drink

Food coloring, preservatives, and all

Susan Milius

Pressurized fizz and industrial processing aside, modern soft drink makers lag millions of years behind the curve, still catching up with the original purveyors of tasty, sugary beverages. Flowering plants have spent aeons competing with each other to coax animals to choose their formulation of something sweet. While sweetness is important, any devoted fan of a particular brand of soft drink will tell you that a truly alluring elixir has so much more.

Botanists once spoke of nectar as basically sugar water, but in the 1970s, when two researchers checked hundreds of flower nectars, plenty of other ingredients turned up, including amino acids and alkaloids. Researchers are still exploring these and other nectar ingredients. They're also determining the compounds' market appeal.

A Phelsuma *gecko with a taste for nectar checks out a* Trochetia *flower on the island of Mauritius. Colors and other additives in nectar may be some flowers' way of marketing their offerings to pollinators.*
F. Hansen

While a successful recipe brings financial profit to beverage companies, nectars attract animals that provide a service to the plant. Usually it's the transport of pollen from flower to flower, but some plants drip nectar from their leaves or stems to attract insects that protect them from pests.

Most kinds of additives dreamed up by today's drink manufacturers have, with recent research, been recognized in plant nectars. Coloring to beguile the eye? Scents to

interest the nose? Health boosters? Preservatives? Some plants have mixed each of these into nectar concoctions.

Mus
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Rainbow appeal

Even before a pollinator tastes nectar, the seduction begins. For example, although most nectars are colorless, some plants use bright colors to advertise their liquid appeal. Other nectars give off specific aromas.

The question of food coloring in nectars—all natural, that is—has gained scientific attention thanks to a gardener in the greenhouses at Århus University in Denmark. In the early 1990s, the gardener told ecologist Jens Olesen that one of the rare flowers, the blue-purple bellflower called *Nesocodon mauritianus*, had blood-red nectar. As Dennis Hansen, an Århus student at the time, summarizes events, "Jens said, 'Bollocks! You're drunk! Nectars don't have colors!' And they went to look, and the nectar was red."

NOT CLEAR. Although most flowers have clear nectar, several dozen carry colored solutions, such as the yellow liquid glinting in this Trochetia blackburniana *flower. New tests show that a gecko species prefers a colored nectar (inset).*
Hansen

Danish research teams then visited the island nation of Mauritius, east of Africa, and spent days watching the cliff-face home of the last 130-or-so known plants of the species. The observers had hoped to spot a native pollinator, especially one with a preference for red nectar, but they failed.

However, while traveling in Mauritius, they had identified two other species—of the genus *Trochetia*, in another botanical family—that produce colored nectar. The researchers believed these were the only three species in the world with colorful nectar, notes Hansen, who's now at the University of Zurich. "In scientific papers, you always have to say, 'To the best of our knowledge ...'," he says. "Since then, our knowledge has been bettered."

After reading the article, people wrote to the Danish researchers from around the globe pointing out overlooked flowers with colored nectar. When the tally reached 11 species, Hansen decided to write an update.

To make sure that his list was complete, he and several collaborators chased down obscure journals that don't show up in databases and spent hours searching on the Internet for the phrase colored nectar translated into many languages. This ploy led him to Swedish chats about a hoya species grown as a houseplant. Its dark nectar drips on furniture, and people were offering tips about coping with dribbles. "Some of my best pictures [of colored nectar] came from Swedish housewives," Hansen says.

By this March, the tally had topped 60 species making, for example, red, yellow, or black nectars. These plants are scattered in 14 families and located around the world.

There are now four known populations of the rare *Nesocodon* bellflower plus *Trochetia* patches. Some of these plants live among potential pollinators: geckos with a taste for nectar.

To see whether geckos prefer colored nectar, Hansen and his colleagues worked on a Mauritian islet inhabited by a gecko species found on the cliff faces. The researchers could test the geckos' innate preference because the colored-nectar plants typically don't grow on the islet and so the animals hadn't been exposed to them.

The researchers made artificial flowers by sticking cardboard petals on painted laboratory tubes and filling them with various sugar solutions. Within half an hour of setting out a pair of fake flowers, the researchers typically saw a gecko skitter over to check out the contraptions.

The animals usually paused to look at the baits for several minutes and then darted to drink at one. More than two-thirds of the geckos chose a flower with colored nectar, tinted red or yellow with food coloring, instead of its nearby twin with colorless nectar.

The bright liquids inside the white tubes seemed innately appealing to the lizards, Hansen and his colleagues report in an upcoming *Biology Letters*.

Like colors, nectar scents may provide another come-on to pollinators. Under some circumstances, a plant might benefit from letting its pollinators tell by just a sniff whether a flower brims with nectar or has already been emptied, Robert Raguso at the University of South Carolina in Columbia proposed in 2004.

For example, nectar of an evening primrose, *Oenothera primiveris*, smells sharp and pungent, he says. He found methyl benzoate, as well as another volatile chemical, wafting away from the nectar. Yet his tests didn't pick up either of the scents in petals or other flower parts. Since then, he and his colleagues have identified a second unique component, 1-pyrroline. "It has a most unpleasant odor reminiscent of bleach," says Raguso.

The nectar of the century plant, *Agave palmeri*, smells like an overripe melon, he says. Seven of the 17 volatile compounds he found in it didn't occur in the flower tissues around it. Some of these special nectar compounds, such as short-chain alcohols and ketones, could be fermentation products, he says. Since his 2004 report, Raguso has found signs of fermentation in the nectar of a flower in the genus *Protea*. When fresh, it smells like papaya but later develops the odor of honey beer. Plants and their microbial lodgers may have beaten humanity to the invention of brewing too.

Healthy drinks

Biologists are intrigued by the possibility that plants also invented health-and-energy drinks for pollinators, not to mention agents that keep the beverage fresh.

SIPPING TOBACCO. Ornamental tobacco flowers turn their nectar into an insect version of an energy drink, according to a new study. The flowers attract plant chemists (inset) as well as insects because the abundant nectar is easy to collect.
Thornburg

In 2002, Robert Barclay of the University of Calgary in Alberta reported the calcium content of 22 species of Australian flowers. He proposed that flowers visited by nectar-and-fruit–feeding bats tended to offer a bit of extra calcium as a potential boon for lactating females.

More recently, Robert Thornburg of Iowa State University in Ames and his colleagues have suggested that ornamental tobacco offers its insect visitors an energy drink.

From the plant's nectar, Thornburg identified 11 of the 20 amino acids that living organisms commonly hitch together to form proteins. One, proline, appeared in high concentrations, at almost triple the concentration of the next-most-abundant amino acid. Two wild plants, soybean species from Australia, likewise showed abundant proline in nectar.

Earlier studies had indicated that insects' flight muscles burn a lot of proline during the initial phases of flight. It's a better short-term energy source than glucose, Thornburg says, because it doesn't need as much of a jolt of energy to start its breakdown.

Thornburg performed experiments using bees, which pollinate many types of plants, including soy. Previous work had shown that a bee's taste receptors for salts respond to proline. When Thornburg offered honeybees sugar solutions flavored with proline, the one they preferred had a proline concentration similar to that of the tobacco and soy nectars.

Honeybees may have a taste for performance drinks, Thornburg and his colleagues propose in an upcoming *Naturwissenschaften*.

That's a preference that farmers could turn to their advantage, says Thornburg. If researchers could figure out how to boost the proline content of nectars in crop plants, he says, perhaps more insects would visit. Those additional visits could increase pollination, which would raise the number and the size of fruits.

Letting nutritious brews such as nectars sit around in unrefrigerated

blossoms could have disgusting consequences, especially with pollinators tracking who-knows-what into a flower. "They can be in the barnyard this morning and, in the afternoon, get into a plant's reproductive tract," says Thornburg.

In the early 1990s, a chance remark from a colleague started Thornburg thinking about protein in nectar. "I had never considered that nectar was anything but a simple sugar water," he recalls. "Boy, was I wrong."

That afternoon, Thornburg ran a lab test that indicates proteins as blots on a gel strip. "Lo and behold, there were proteins," he says. "I still have the gel on my desk."

He was on sabbatical at the time his lab finished identifying the first of the five proteins. As soon as he got the e-mail with the results, he says, he plunged into databases to find similar compounds. Those chemical cousins produce bursts of hydrogen peroxide in cells, and his colleagues back in the lab soon determined that the nectar protein could do that too.

The hydrogen peroxide produced in cells is the same chemical that drugstores sell to disinfect kids' skinned knees. However, working out the functions of the five nectar proteins took Thornburg and his colleagues 11 years.

In the November 2005 *Plant Physiology*, the research team described the workings of the most elusive of the five proteins that create a floral-hygiene system. The infection-fighting hydrogen peroxide spins off highly reactive free radicals that can wipe out necessary cell chemistry. Fortunately, some of the five proteins detoxify the free radicals.

Plants may have pioneered another soft drink ploy—adding stimulants. Caffeine and nicotine show up in plant nectars, and Natarajan Singaravelan of the University of Haifa at Oranim in Israel and his colleagues are testing the hypothesis that such extras might keep pollinators coming back for more.

Some citrus nectars, for example, carry a jolt of caffeine. Although science can't yet say whether caffeine gives bees a buzz, they seem to like it. When the researchers offered free-flying honeybees a variety of caffeine-containing sugar solutions plus a caffeine-free version, the bees preferred a mildly caffeinated option. They made about 20 percent more visits to this spiked solution than to the plain-sugar one, the researchers reported in the December 2005 *Journal of Chemical Ecology*.

Sugary sips with just a touch of nicotine, either 0.5 or 1 parts per million (ppm), attracted more bees than plain-sugar solution did, the researches said in the same paper. The nectar of some tobacco species as well as that of linden trees carries between 0.1 and 5 ppm nicotine. Caged bees and their broods fed sugar solutions with dashes of nicotine showed no obvious ill effects, the researchers reported in the January *Journal of Chemical Ecology*.

Production problems

There's still toxic stuff in some nectar, though. The 1970s surveys by Herbert Baker and Irene Baker, both since deceased, turned up alkaloids, a group of compounds that includes plant–chemical warfare agents, in 9 percent of the species' nectars. Another worrisome set of compounds—

amino acids that organisms don't routinely use in proteins and that can sabotage natural processes—appeared in about half of the nectars.

For years, biologists dreamed up potential advantages for nectars that are harmful to some animals, says Lynn Adler of the University of Massachusetts in Amherst. For example, theorists proposed that a nectar repellent to many creatures might result in fewer visits from sloppy, go-everywhere pollinators that would waste a plant's pollen on other species.

TOXIC NECTAR. Nectar of the Carolina jessamine flower carries gelsemine, which can poison bees and mammals exposed to substantial doses. Researchers debate whether the toxin confers some evolutionary advantage or is just an unfortunate side effect of the plant's overall chemical defenses.
R. Mohlenbrock/ USDA-NRCS PLANTS Database

Then there was the "drunken-pollinator" hypothesis. Some nectars include ethanol or other intoxicants, and bees act oddly after imbibing. So, the theory goes, pollinators that drink spiked nectar get lackadaisical about grooming and careen around in a disheveled state delivering unusually large amounts of pollen.

In the November 2005 *Ecology*, Adler and Rebecca Irwin of Dartmouth College in Hanover, N.H., published what Adler suspects is the first test of whether toxic nectars aid plant reproduction. They used Carolina jessamine (*Gelsemium sempervirens*), a vine that bursts out in yellow flowers during March and April in its southeastern–U.S. range. Its nectar carries the toxin gelsemine, a substance also found in leaves that botanists suspect keep pests from chewing there.

In experimental plots of the vine, researchers made the rounds every morning during blooming season, carefully pipetting droplets into each open flower. Some flowers got extra doses of gelsemine, while others got a sugar solution that diluted their natural nectar's gelsemine concentration. To estimate how much pollen the insects moved, the researchers dusted flowers with fluorescent dye as a proxy for pollen.

Researchers then hovered around the plot clutching tape recorders to dictate running accounts of insect visits, which exceeded 3,000 by the end of the experiment.

"Ultimately, we found that pollinators really don't like toxic nectar," says Adler. Compared with diluted gelsemine, extra gelsemine cut short insects' visits to a particular flower and reduced the number of flowers visited. At each stop, the pollinators passed along only half to two-thirds as much pollen from the high-gelsemine plant as from low-toxin plants.

No advantage of extra gelsemine showed up. Carpenter bees still drilled holes in the flowers and drained nectar without carrying pollen to other plants. "So far, we're seeing mostly costs," says Adler.

She says that she's begun questioning whether toxic nectars do any good for plants. The toxic compounds that show up in nectar also appear in plant leaves, where they seem to discourage grazing by mammals and insects. The compounds could simply be leaking out of the plant into the nectary.

If defensive chemicals turn up in nectar but provide no benefit there, then plants could win yet another distinction. They could have been the first food manufacturers to face the problem of pesticide contamination.

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