

Chemical Defenses in Herbs and Spices

Tracking biosynthetic pathways for human health

By Susan McGinley



David Gang

David Gang holds fresh ginger rhizomes that contain active anti-inflammatory compounds called gingerol and shogaol.

The sweet basil that tops your spaghetti sauce, the ginger blended into your pumpkin pie, and the turmeric mixed in your potato curry add more than just taste. All three of these culinary flavorings contain powerful compounds—eugenol, gingerol and curcumin, respectively—that can fight certain types of inflammation, infection and other threats to human health. People have used these and other herbs and spices for thousands of years, not only to flavor and preserve their food, but also as medicine (*see sidebar*).

Of more immediate interest to the plants that produce these substances is their own survival. They create compounds called phenylpropanoids that include not only eugenol, gingerol and curcumin, but also hundreds of others, to defend themselves against animals and microorganisms like bacteria and fungi. Scientists at the University of Arizona are studying the chemical properties of herbs and spices to find out not only how these protective compounds work, but also how and where they are synthesized in plants.

“I’m very interested in how plants interact with the environment, and how they do that chemically,” says David Gang, a professor in the University of Arizona’s College of Agriculture and Life Sciences, and a member of the UA’s BIO5 Institute. Gang has studied the formation of phenylpropanoids in plants like sweet basil, ginger and turmeric for more than a decade.

“How is it that plants are able to defend themselves without being able to get up and run away? They do that with chemical

warfare: antibacterial, antifungal, antimicrobial,” he says. “They can also deter animal and insect feeding.” Plants create defensive compounds by synthesizing them along specialized pathways that are still not fully understood. Gang wants to find out how these pathways work, and how that process is controlled in plants that have been a part of ancient cuisines and traditional medicines.

“Many of the herbs and spices used in cooking were originally used to preserve food, and were quite valuable,” Gang notes. “Columbus set sail for southeast Asia in search of cloves, cinnamon and black pepper, which were worth a lot of money. Those spices produce a lot of antimicrobial compounds, plus they preserve meat and keep you from getting sick. But in my lab we’re not medical doctors. We’re really interested in understanding how the plants actually make these compounds.”

Several federal institutions are also interested in the results. Funding for this research comes from the National Science Foundation for ginger and turmeric, and from the National Science Foundation and the USDA for basil.

Intrigued by such a vast, unexplored field, Gang began postdoctoral work in 1999 on eugenol biosynthesis in sweet basil with Eran Pichersky, a professor at the University of Michigan. Gang has continued this collaborative research at the UA not only with Pichersky, but also with other scientists from the UA, Washington State University, Purdue University, the Salk Institute for Biological Studies in California, and the Max Planck Institute in Germany. Gang has several graduate and undergraduate



Turmeric inflorescence (left). Turmeric extracts contain curcumin, a compound that has powerful antioxidant, anticarcinogenic and anti-inflammatory properties.

Active Compounds in Basil, Turmeric and Ginger

The following compounds are responsible for the characteristic flavor of the herbs and spices that contain them. Here are just a few of their healing properties:

- *Eugenol* is the active ingredient in sweet basil, cloves, cinnamon and nutmeg. It serves as an antioxidant in food, fights inflammation, and also has analgesic, antiseptic and anesthetic applications in dentistry. Tulsi, or Holy Basil, which contains eugenol, has been used as the principal herb in Ayurvedic medicine for centuries.
- *Curcumin* is the active ingredient in turmeric that gives many dishes in Indian cuisine their traditional golden orange color. Turmeric has been used in India for more than 5,000 years. Hundreds of studies show that curcumin has powerful antioxidant, anticarcinogenic, and anti-inflammatory properties. It holds promise for treating arthritis, halting tumor growth, reversing some of the effects of cystic fibrosis, and inhibiting HIV reproduction in the body, among other uses.
- *Gingerol and shogaol*, the pungent active compounds in ginger, are highly effective against nausea, including motion sickness and morning sickness in pregnancy. Ginger originated in Southeast Asia, where it has been used for more than 2,000 years as an anti-inflammatory agent to treat headaches, stomach ailments, joint pain, and other problems.

Note: The herbs and spices mentioned above also contain other active compounds.

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students, as well as post-doctoral fellows working on these projects in his lab.

Although several different plants make eugenol, the researchers needed one that could be grown easily and studied live in Tucson. Cloves, which produce the most eugenol, were eliminated because a clove tree takes 20 years to make cloves. Instead, sweet basil (*Ocimum basilicum*) was chosen because it contains a fair amount of eugenol and thrives in hot climates. It originated in the Middle East where it still grows wild. Gang and his team planted basil in a rooftop greenhouse on the UA campus and harvested leaf samples to study in the laboratory.

It turns out that microscopic “dots” on the surface of basil leaves are actually tiny factories that produce eugenol.

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“We’ve been isolating the tissue where these compounds are made, in a special structure on the leaf called a glandular trichome,” Gang says. “We’ve been able to remove the trichomes from the leaf and separate them into fractions that produce the compounds. We sequence their RNA to get an idea of the genes that are expressed in the trichomes and involved in the biosynthesis of the compounds. This is creative, translational biochemistry, with a genomics approach.” The team also determines which enzymes the trichome produces, and in turn, which compounds result.

“We’ve identified all of the genes involved in making eugenol,” Gang says. Results of this research were announced in June, 2006.

“Now we can take those glandular trichomes, isolate them from other types of cells and use them as a model to study metabolic pathway systems in living organisms. These are the best systems to work with for doing that, in my opinion. The basil system is good for understanding the basics.”

The active ingredients in ginger and turmeric, which accumulate in the

underground stem of these plants called the rhizome, are not as easy to figure out. Research results will take more time not only because the plants are more complex, but also because they just take longer to grow.

“In ginger and turmeric we’re still at the stage of figuring out how the medicinal compounds are formed,” Gang admits. “We do know that just a couple of steps are needed to produce curcumin from common building blocks in all plant cells.”

All of this research is aimed at finding ways to engineer plants metabolically to make compounds for food, health, energy and industry, according to Gang—the building blocks for interesting products.

“We have pretty good means for engineering the plant to make different oil profiles, such as in corn and soybeans,” he says. “But, how can we make plants better at making feedstocks for fuel or other industrial applications? I’m interested in being able to utilize plants to make products that we as humans think are interesting—perfumes, plastics, medicines, flavors, and so on.

“Instead of using a chemical factory that could emit pollution, we could do it in a living plant, and basil helps us understand how that could be done. We know enough now to know we still need to know more. Basil is a good model for understanding how metabolic pathways operate inside a single cell.” ❖



Sweet basil grown in a UA greenhouse yields leaves high in eugenol, a compound with analgesic, antioxidant, anti-inflammatory and anesthetic applications.