

SPICE FAKES & FRAUDS

By Michele Hathaway

Food would be pretty boring without **spices**. Can you imagine pizza without Italian seasonings like oregano and thyme, or cookies, cakes and ice cream without vanilla?

The story of spices is as old as human civilization. Ancient Egyptians traded for cinnamon as early as 3,000 B.C.E., which they used for flavoring food, making perfume and embalming the dead.

But what if someone mixed olive leaves into your pepper? Worse, what if there were pesticides on the olive leaves or dangerous levels of lead in your cinnamon? Food fakes and frauds are as old as the spice industry. Adulterations not only diminish the quality of our pizza and other foods—some adulterations can be deadly.

What's in a Name?



CHILI

A spicy stew-like dish that usually contains meat, peppers, tomatoes and beans.



CHILE

A variety of fruit from the Capsicum genus, a small pod ranging in spice from mild to intense.



CHILI POWDER

A spice blend primarily composed of ground dried chile peppers with spices such as cumin, garlic powder, and oregano.



Most spice fraud is economically motivated adulteration (EMA). In 2023, the global spice and seasonings market was valued at more than \$27 billion, a number that is expected to more than double by 2032. As people discover new and diverse cuisines and the health benefits of different spices, the demand for global spice trade grows. With higher demand comes an incentive to create imitations and to bulk up spices with fake ingredients to increase profits.

According to the U.S. Food and Drug Administration, “Outside estimates by experts have found that food fraud affects 1% of the global food industry at a cost of about \$10-\$15 billion a year, although some more recent expert estimates put the cost as high as \$40 billion a year.” And because the journey of most spices from their origins in fields and forests throughout the world to our dinner plates is long and complicated, spices are vulnerable to adulteration at multiple points along the way.

Food chemists and analytical chemists are key to finding food fraud, as well as developing new food textures and tastes and enhancing food nutrition.

FOOD CHEMISTS: FRONTLINE DETECTIVES

An essential branch of food chemistry involves testing for purity, quality and safety. Cleanliness and quality control are essential in the processing of food. Monitoring food processing is one of the crucial functions of food and drug administrations around the world. Where things get dicey is when spices are bulked up to increase profits.

According to Terry McGrath, Chief Scientific Officer of Bia Analytical in Belfast, Northern Ireland, testing over the last 13 years has shifted from targeted to untargeted testing. Targeted testing looks for a specific substance in a sample. In this case, the chemist needs to

know what to look for and test specifically for each suspected contaminant.

Untargeted testing is much more efficient. “The whole concept of untargeted analysis,” said McGrath, “is really to understand what normal looks like, and does the sample differ from normal.” Spice buyers and inspectors simply want to know if the product is pure and unadulterated. With untargeted testing the chemist compares the analysis fingerprint of the pure spice with that of the spice being investigated. If the spice is adulterated, then the buyer can decide whether they want to do further testing to identify the impurity or pass on buying that batch of spice. One of the most recent and valuable developments in untargeted food testing is the use of near infrared spectroscopy (NIRS) with chemometric modeling analysis.

SPOTTING FAKES WITH SPECTROSCOPY

To detect fakes, chemists are finding new applications for technologies that have been

around for a long time, said McGrath. “With the development in artificial intelligence and machine learning, suddenly you have so many more applications, so many more ways to interpret that information. And it becomes very, very exciting because you find out so much more,” said McGrath.

Chemists use spectroscopy to study how light and other forms of electromagnetic radiation interact with matter. The absorption or emission of electromagnetic radiation can tell a chemist a lot about the materials, such as the different kinds of bonds and the elements present. NIRS and X-ray fluorescence (XRF) are two of the spectroscopic tools that food chemists use to analyze spices.

NIRS uses the near infrared region of the electromagnetic spectrum with wavelengths ranging from 780 to 2500 nanometers. Substances absorb light in this region based on the kinds of bonds present and a detector produces a spectrum. The pattern of the spectrum can be used to identify a molecule or compound. One important aspect of NIRS is that irradiation with light does not damage or break down the sample; it is considered a non-invasive technique. NIRS is very versatile: it can detect organic and inorganic material, which means that if someone has mixed red brick dust into chili powder, NIRS can help detect it.

When paired with chemometric modeling or algorithms—that is, using math and statistics to analyze chemical data by means of artificial intelligence or machine learning—NIRS spectroscopy is a powerful analytical tool. Recently, companies such as Thermo Fisher and Bia Analytical have teamed up with manufacturers to make simple handheld spectrometers for use in the field. Now, a spice buyer can check if the spice they want to buy at a shop in port or a

EVOLUTION OF NIRS IN SPICE ANALYSIS

1970s

Phil Williams pioneers use of NIRS for measuring protein and moisture contents in wheat trading.

2000s

Widening applications to authenticity, quality, and adulteration. Detection of adulterants, such as foreign seeds and contaminants.

2020s

Continued research on portable NIRS devices and real-time analysis in situ. Development of handheld NIRS devices for field-based spice analysis.

1990s

Advances in instrument technology, improving sensitivity and accuracy. Introduction of diode array detectors and improved calibrations.

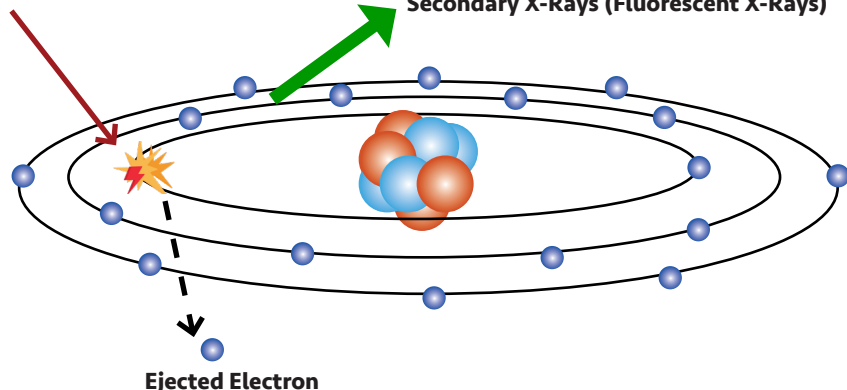
2010s

Integration of chemometrics for enhanced data analysis and model accuracy.

Primary X-Rays

Secondary X-Rays (Fluorescent X-Rays)

Ejected Electron



warehouse is pure without having to send it to a lab first.

X-ray fluorescence (XRF) is another way to use light to test a substance without causing damage. For this reason, it has been used to analyze works of art. New developments in the field of XRF have given rise to handheld instruments that can be carried into the field.

When a concentrated beam of X-rays from an XRF spectrometer blasts a substance, atoms in the sample can become ionized. This occurs when they absorb the energy from the X-rays and eject core electrons close to the nucleus. The orbitals emptied by the ejected electrons are filled with higher energy electrons from the valence or outer energy levels. When these higher energy electrons “fall” into the lower energy spaces, energy is released in the form of high energy X-rays.

Once food chemists know what a pure spice does when it interacts with X-rays, they can compare sample spectra and detect frauds—if the adulterant has a noticeably different elemental composition from the pure spice. The adulteration of turmeric with lead(II) chromate (PbCrO_4) can be detected using this method, since lead and chromium are heavy metals and have very strong interactions with X-rays.

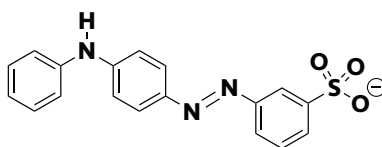
One of the other advantages of XRF is that if an anomalous element is present in a sample, it can be detected even in relatively small amounts—which isn't possible with NIRS. However, XRF is not without its own weaknesses. XRF is most reliable for detecting elements

with higher atomic numbers than potassium, so a lot of organic adulterants—which contain only carbon, hydrogen and oxygen—will not show up.

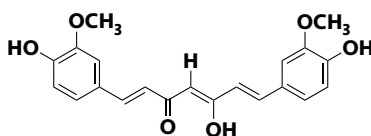
SEPARATING THE REAL FROM THE FAKE: CHROMATOGRAPHY

Chromatography has been used to separate plant pigments for over 100 years. Chromatography separates the components of a liquid or gas using a stationary phase, such as paper,

METANIL YELLOW



CURCUMIN



Metanil Yellow and curcumin are very similar in color. Food chemists can separate the two colors using chromatography. The presence of Metanil Yellow indicates that the spice sample, usually turmeric, has been adulterated.

sand or gel, and a mobile phase, such as liquid or gas that percolates through the stationary phase. Different components of the substance are absorbed with different strengths in the stationary phase, causing them to move at different rates in the mobile phase.

A common practice in spice adulteration is to dye fake ingredients the color of the true spice. Chromatography can detect the presence of dyes, such as the toxic Metanil Yellow. Metanil Yellow is often used to impersonate curcumin, the compound responsible for turmeric's yellow color.

LOW-TECH TESTING FOR IMPURITIES

We can detect a lot of spice fraud simply by using our basic senses of sight, smell and touch. For example, saffron—the stigmas of the *Crocus sativus* plant—is the most expensive spice in the world. Saffron has a lovely, rich, distinctive aroma. Depending on the quality, quantity, and source, saffron currently retails between \$1,000 to \$2,000 per pound, making it one of the most vulnerable spices to EMA.

Real saffron can be bulked up, or completely substituted, with plant material such as safflowers or cornsilk. Real saffron threads are trumpet-shaped. If the saffron threads don't bulge at one end, they are not real.

Also, if you rub a few saffron strands with your fingers after placing them in cold water, fake saffron will break apart and turn to dust. Real saffron is crimson, and the base of the



ACCEPTABLE SUBSTITUTIONS

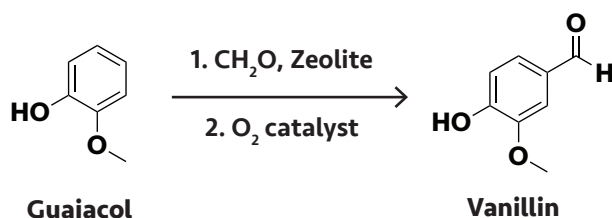


VANILLA

Some spice imitations are well known and accepted. For example, less than one percent of vanilla sold in the world today is from real vanilla. Real vanilla harvested from the plant is the second most expensive spice in the world, after saffron. Vanilla beans (or pods) are the fruit of only three species of orchids. These orchids take a long time to grow and are vulnerable to weather events and theft.

The vanilla bean has over 250 flavor components, but the main molecule is vanillin (4-hydroxy-3-methoxybenzaldehyde). Food chemists skilled in organic chemistry can make vanillin for a fraction of the cost of harvesting the same amount from the native plant. Only the most discerning palates can tell the difference between real and imitation vanilla extracts.

Vanillin can be produced from substances with a similar molecular structure, such as rice bran, corn sugar, wood pulp and petroleum products. According to Robert McGorin, ACS fellow and flavor chemistry professor at Oregon State University, “the majority of commercial vanillin is synthesized from guaiacol—a natural compound found in wood smoke and clove oil.”



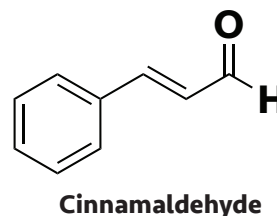
CINNAMON

Most cinnamon sold in the United States today is not “true” cinnamon. True cinnamon, *Cinnamomum verum* (*C. verum*), is known as Ceylon or Sri Lanka cinnamon. It has a light brown color and a more subdued, delicate aroma. A related species to *C. verum* is *Cinnamomum cassia* (*C. cassia*), which originated in China and is sold under many different names. *C. cassia* cinnamon is a darker brown than *C. verum* cinnamon and tends to have a more robust flavor that many people prefer.

In some countries, such as the United Kingdom, *cassia*-based cinnamon must be labeled as such. Both *C. verum* and *C. cassia* cinnamon come from the inner bark of their respective trees. Cinnamaldehyde accounts for the flavor of cinnamon. Beyond its recognizable flavor and scent, cinnamaldehyde is considered by some to have health benefits, such as antimicrobial and anti-inflammatory properties.

One reason *C. cassia* cinnamon is less well accepted is the presence of coumarin. Cinnamon trees can also draw impurities such as lead into their bark from the soil. These substances are found in higher concentrations in the bark of the *C. cassia* tree than the *C. verum* tree.

Most cinnamon is safe to eat in reasonable quantities for adults, but lead can be especially dangerous for children. In 2024, the National Institutes of Health reported finding high levels of lead in apple sauce marketed to children, which had to be recalled. Consumer Reports also found high levels of lead in some brands of cinnamon.



The take-home message is you want to be buying your herbs and spices from reputable sources who have a really good understanding of their supply chain and who have put tests in place to allow you to make sure you as a consumer are safe.

TERRY MCGRATH, CHIEF SCIENTIFIC OFFICER OF BIA ANALYTICAL IN BELFAST, NORTHERN IRELAND



Saffron is harvested from the stigmas from *Crocus sativus*. Spice counterfeiters often bulk up samples of saffron or replace it completely with safflower (*Carthamus tinctorius*).



SHUTTERSTOCK

Safflower can be used for herbal teas and is sometimes used as an inexpensive bulking agent for saffron.

stigma can be yellow. Rubbing a sample of saffron between your fingers should not leave any color on your fingers. Safflower, however, will dye your fingers yellow.

Safflower's scientific name is *Carthamus tinctorius*. The word tinctorius is Latin for "used for dyeing." Many naturally occurring dyes are found in plants such as indigo, which is used to dye blue jeans. The scientific name of the indigo plant is *Indigofera tinctoria*. These dye molecules can be dissolved in the oils or water on the skin, leaving behind a tell-tale color.

Knowing if the color compound in a spice is water soluble or not means that water may be a low-cost test. If the water becomes colored after a spice is submerged, then there is a water-soluble dye present. However, not all dye molecules dissolve in water.

Another water-based test is density. If a spice is denser than water, it should sink. If the sample of a spice that should be denser than water floats on the surface, it may contain sawdust—a common, easily dyed adulterant in powdered spices.

Beyond sawdust, commonly used bulking agent include wheat, corn, rice and potatoes. Luckily, they contain starches that are rarely present in spices. Iodine turns substances containing starch a dark blue (almost black) color and can be used to detect starch molecules.

CASE STUDY: OREGANO

In 2012, McGrath's group conducted a global survey of oregano sold in large retail stores such as Walmart and Target in the United States and Tesco in the United Kingdom. They found that 25% of the oregano was adulterated with olive leaves, sumac and other nonfood

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or lower-value foods. Pesticides were also present.

They repeated the survey in 2024 and discovered that the large retailers had solved the problem. The use of testing and quality teams stopped the adulteration for these big-chain suppliers.

When the group tested oregano samples from smaller shops and specialty markets, they found adulteration had shifted to the supply chain for these markets. McGrath said that while one sample "was being sold as oregano, there was none, absolutely none in it." Without the personnel to do extensive quality control, these vulnerable shops—along with some hotels and restaurants that are buying wholesale or online—are at higher risk of using adulterated spices.

"The take-home message," said McGrath, "is you want to be buying your herbs and spices from reputable sources who have a really good understanding of their supply chain and who have put tests in place to allow you to make sure you as a consumer are safe."

He believes it is the responsibility of the retailer to make sure our food is unadulterated. Retailers and government organizations such as the Food and Drug Administration (FDA) are there to monitor our food supply, and McGrath urges people to push the challenge of food safety back to the retailers and government organizations.

McGrath advises that highly trained analytical chemists need to be at the forefront of the food safety and supply chain. "As a food scientist, [to help keep the food supply safe,] you want to try to think outside the box. Because the criminals, those who are cheating the system, they're being creative."

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REFERENCES

- U. S. Food and Drug Administration. (N.D.) "Economically Motivated Adulteration (Food Fraud)" <https://www.fda.gov/food/compliance-enforcement-food/economically-motivated-adulteration-food-fraud>
- GlobeNewswire. (October 14, 2024) "Spices & Seasonings Market to Hit Valuation of US\$ 59.13 Billion By 2032" <https://www.globenewswire.com/news-release/2024/10/14/2962659/0/en/Spices-Seasonings-Market-to-Hit-Valuation-of-US-59-13-Billion-By-2032-Astute-Analytica.html>
- Wetzel, Will. (June 4, 2024) "Combating Spice Fraud Using Near-Infrared Spectroscopy" <https://www.spectroscopyonline.com/view/combating-spice-fraud-using-near-infrared-spectroscopy>