Molecular Fingerprints Promote Safety, Traceability

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In an era of rising concerns about food safety, establishing rock-solid transparency mechanisms in the food supply chain has become a critical business issue for food manufacturers, suppliers and retailers. Ongoing problems with counterfeit and adulterated food products, as well as rising incidences of lethal outbreaks of food-borne bacteria are forcing the food industry to radically recreate its supply chain with newer technologies designed to markedly enhance accountability, traceability and safety. Pending government legislation on food safety (the Food Safety Modernization Act), the USDA's recently initiated COOL (country of origin labeling) rules and, perhaps most importantly, the lightning-fast spread of food news on the internet are making near real-time access to comprehensive food testing information down to the batch level an inevitable and essential defensive tool required to run a food manufacturing enterprise.

Creating this level of transparency five years ago would have been impossibly cost prohibitive. But revolutionary technologies are available to enable a global transformation in the world of food origin and safety testing. Leading the way is a new type of laser measurement tool based on Cavity Ring-Down Spectrometry (CRDS). Small, stable and affordable laser-based CRDS devices can now analyze ratios of stable isotopes of carbon, hydrogen and oxygen in food samples in near in real-time. (Isotopes are two atoms of the same element that have different atomic masses). Using these ratios, CRDS systems can, in minutes, record easily identifiable molecular "fingerprints" of many types of foods and beverages.

These molecular fingerprints can be used to quickly verify that key components of foods and drinks—edible oils, sweeteners, etc.—are pure and unadulterated. CRDS can also measure ratios of stable isotopes present in water extracted from food samples and compare those ratios to pre-recorded databases of ratios associated with specific geographical locations. This would create precise point of origin signatures that could be used to track food products and food product components from the farm to the supermarket shelf or the restaurant. Food manufacturers could conceivably encode this information into RFID tags or bar codes. When combined with advanced GPS and RFID tracking and logistics mechanisms, CRDS-enabled information capture has the revolutionary potential to make the contents of a food supply chain far more transparent and traceable—and safer than ever before.

Researchers have long used stable isotope ratios for point of origin, content verification and adulteration testing. The concentration of an isotope in a sample is primarily measured as the ratio of the concentration of a rare isotope to the concentration of a more common isotope. Carbon, hydrogen and oxygen, present in all food, have a number of markedly different isotopes. So measuring the concentrations of rarer isotopes to more common isotopes (rare carbon-13 versus common carbon-12) can produce ratios that can be matched against ratios for food substances recorded in internationally accepted reference standards. Nearly every chemical and biological process fractionates stable isotopes, leaving a characteristic signature of ratio values for all foods.

The exact conditions under which this fractionation process occurs influences the resulting isotopic ratios. For natural products, factors that influence isotopic ratios include unique geographical parameters such as local soil characteristics, latitude, groundwater supply, plant species, salinity and average temperature. These ratios remain fixed when the product is harvested, until/unless mixing, dilution or other adulterations are carried out. Such adulteration leaves behind additional unique isotopic signatures. So, orange juice that has been concentrated and shipped from a manufacturing plant and then re-diluted with added water will have very different stable isotope ratio values than fresh or pasteurized orange juice produced and shipped from the same location.

While the techniques to perform this type of analysis have existed, devices that could perform these tests have been too expensive and too complicated for routine operations. For example, isotopic food origin and adulteration analysis required an Isotope Ratio Mass Spectrometer (IRMS). A high-precision IRMS system can cost several hundreds of thousands of dollars. Running an IRMS requires a highly-trained scientist to keep this finicky piece of machinery operational, at most, 75% of the time. The combination of intermittent operations and steep labor cost requirements has, to date, meant high-throughput operations suitable for factory or field testing was impossible with IRMS. The high upfront costs combined with high costs of manpower and limited throughput relegated IRMS to food testing laboratories. Not surprisingly, obtaining test results with IRMS usually requires days or weeks. In those laboratories, IRMS systems serve primarily in post-mortem forensic testing roles rather than pro-active defensive roles in food safety procedures.

In contrast, a Picarro CRDS system, for example, costs approximately five times less than comparable IRMS systems. A CRDS system does not require deep expertise to maintain and operate; a factory tech can easily run a CRDS unit for months on end with minimal interuption. With few moving parts, CRDS systems rarely break down. Picarro CRDS devices can operate for months without requiring maintenance or calibration. Key peripherals allow CRDS systems to run high-throughput sampling procedures with as many as 150 samples processed in a 24-hour period. Unlike an IRMS system, a Picarro CRDS can be quickly transported between locations.

How would a CRDS device work to ensure food safety and fine-grained origin tracking? Here are a few ways. A Picarro CRDS can examine a sample of honey to measure the ratio of its two naturally occurring carbon isotopes, 13C and 12C. Plant photosynthetic pathways can be C3, C4 (or a hybrid between the two) with a

distinct carbon isotope ratio signature. Corn and cane sugar are C4 pathway plants. As a results, C4 foods, such as corn syrup, show a distinct carbon isotope ratio. C3 plants are typically flowering species favored by honey bees. As a result, the C3 pathway carbon ratio signature is a characteristic of pure honey. Any significant presence of C4 plant sugars, as indicated by the carbon isotope ratios, would indicate that honey has been adulterated with corn syrup, for example. Similar procedures can not only identify corn syrup but also beet sugar and other types of adulterants. Similarly, procedures can be used to detect adulteration in olive oil and to ascertain whether a sample of meat is grass or corn fed.

Another key way that a CRDS can work is by comparing ratios of hydrogen and of oxygen isotopes in water samples extracted from foods. These water isotope ratios are geographically unique. For example, orange juice made from Florida-grown fruits has a different signature than orange juice made from California-grown fruits.This isotopic water fingerprint would allow a fresh produce processor to isolate the responsible region for salmonella tainted spinach and isolate the region instead of having authorities shutting down an entire industry. Moving quickly to identify and sequester contaminated sources clearly would have enormous economic and health benefits to the food industry and its customers respectively.

To be clear, incumbent instruments can pull these same types of information out of food samples, but not within the speed and cost constraints of the world’s $5 trillion food industry. New technology is therefore required that can handle high-throughput operations, be operated by technicians and are field or factory-deployable. Whereas a forklift is generally required to move an IRMS, modern solutions from Picarro can be mounted on a bench or a mobile cart. And finally, this combination of flexibility, speed and low cost means that food companies using CRDS can take highly detailed molecular signature records of their production on a continous basis. These records, updated every single day, will provide unheard of transparency and traceability. The result will be a safer, more credible and profitable food chain for society, brand conscious buyers and the food industry respectively. Consider that when a salmonella outbreak next rears its ugly head, pinpointing the source of the pathogen will be a matter of hours, not weeks.

Food manufacturers who do not embrace these emerging technologies will not be able to quickly and easily trace food that has entered, passed through, and left their supply chain. Those food manufacturers are putting their entire business at risk. Witness the case of Peanut Corporation of America (PCA). In January 2009, a wave of recalls hit PCA after salmonella bacteria was found in peanut butter made by the company in a plant in Blakely, Georgia. For the next month, the company, one of the largest manufacturers of peanut butter and peanut-based ingredients in the U.S., was battered by a wave of disclosures as multiple food manufacturers and brands found products from PCA contained contaminated peanut products. PCA's products were not only found in jars of peanut butter but also in Kellogg's Keebler's crackers and even PetSmart brand dog biscuits. PCA struggled to trace batches of peanut products while simultaneously recalling products.

In February 2009, PCA filed for Chapter 7 Bankruptcy, constituting perhaps the fastest destruction of a major food company due to a food borne illness outbreak. If

PCA had had an information library with molecular fingerprints of its batches, it could have very quickly corresponded the tainted peanut products back to specific days of production or raw material suppliers and targeted the highest risk elements of its production first. A speedy, effective recall might have saved the company—if they had had the right technology in place.

Michael Woelk is the CEO of Picarro *[1], a maker of food safety and traceability equipment based on stable isotope measurements. The company is based in Sunnyvale (Calif.) and also sells products for environmental, atmospheric, and water cycle research with customers including Fortune 500 food manufacturers, top research institutions such as University of California – Berkeley and NOAA, and environmental regulators such as the Irish and German national environmental protection agencies.*

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