Using Stable Isotopes to Identify the Geographic Origin of Food

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Consumers are increasingly interested in knowing where their food comes from and what exactly is in it. Unfortunately, food labels are not always accurate. In fact, some products are mislabeled intentionally in order to garner a higher price in the marketplace. Can anything be done to determine if a product really is what it says it is? How can you tell if that wedge of Parmesan cheese was really made in Parma, Italy?


Stable isotope analysis can tell scientists whether this wedge of cheese was made in Parma, Italy, or Hoboken, New Jersey. (Photo credit: Sue Wilson/Alamy)

What Is A Stable Isotope?

You may know that radioactive carbon isotopes are used to determine the age of objects such as fossils and other materials of organic origin. But not all isotopes are radioactive. Stable isotopes are isotopes that do not decay over time like radioactive isotopes do. Analysis of these naturally-occurring isotopes can be used for a variety of purposes, such as authenticating that a cheese labeled as Parmesan was truly produced in Parma, Italy.

Four stable isotopes commonly used to authenticate a biological product, such as a type of food, include hydrogen, oxygen, carbon, and nitrogen. Hydrogen exists as the isotopes ^{1}H and ^{2}H. Oxygen exists as ^{16}O, ^{17}O, and ^{18}O. Carbon exists as ^{12}C and ^{13}C. (^{14}C is a radioactive isotope.) Nitrogen exists as ^{14}N and ^{15}N.

Stable isotopes can be used to identify the geographic origins of water and test whether the bottled water you're drinking is actually from Fiji, a spring in France, or from the local municipal water supply. How is this possible? How is this possible? Oceans only show small variations in isotopic abundance, and thus ocean water is typically used as a standard, where both the H and O isotope rations are deemed to be 0 percent. However, as water evaporates from the ocean and condenses into clouds, the isotopic ratios differ significantly, dependent on cloud temperature and the amount of leftover moisture in the cloud mass. Bodies of water, such as lakes and rivers, reflect these isotopic ratios from the input of precipitation. These isotopic abundances can further change as evaporation occurs over these bodies of water. Through the water and oxygen cycles, plants and animals incorporate hydrogen and oxygen isotopes from local water sources into their bodies. The isotopic analysis of water samples collected from locations all across the United States, as well as from locations around the world, has allowed scientists to create a map that indicates the expected isotopic ratios in a substance from a given area. Thus, when testing a bottled water sample, scientists can determine if waters source is correctly labeled.

Stable isotopes can also be used to determine if beverages or other foods have been contaminated. For example, stable isotope analysis can be used to determine if a product marked 100 percent pure clover honey has actually been spiked with corn syrup or another form of unlabeled sugar. Carbon isotopes can be used to determine the diet of livestock. For example, stable isotope analysis can find out whether ground beef marked as grass-fed was actually made from cattle that were primarily fed a grain-based diet. Nitrogen isotopes can be used to trace nitrogen sources for plants and food sources for animals and humans, which can in turn be used to determine the origins of products derived from these sources.

Measuring Stable Isotopes

To determine the stable isotope ratio in a sample, whether it is a drop of water or a piece of meat, it is placed into a machine called a mass spectrometer. The sample is incinerated to become a gaseous form, and then bombarded with ions to scatter the sample's atoms. A strong magnet is used to pull the sample's atoms through a flight tube. Since the different isotopes vary in mass (for example, ^{18}O is heavier than ^{16}O), it takes longer for the heavier atoms to travel through the flight tube, thereby separating the different isotopes in flight. A detector at the end of the flight tube counts the number of atoms for each specific atomic mass. The counts of each isotope are added and calculated as a ratio. It is the ratios of heavy to light isotopes that convey the important information to scientists.


Stable isotope analysis can be used to determine if the water really came from a spring in France. (Photo credit: Simon Belcher/Alamy)

The downside of using a dedicated mass spectrometer is that it can take up a lot of room, is relatively high-maintenance, and can typically range in cost from $300,000 to $1,000,000. In recent years, a new family of isotope analyzers that use optical technology has been developed that solves many of these problems. These new analyzers are compact (similar in size to a briefcase), portable (meaning samples don't need to be taken, or sent, to a dedicated lab), and significantly less expensive than mass spectrometers. In addition, the use of the new analyzers does not require special training or major manipulation of the samples before testing. Though mass spectrometers will likely remain necessary for when extremely precise measurements are required, the new machines provide a more convenient and affordable way to conduct stable isotope analysis.

Other Uses of Stable Isotopes

Stable isotope analysis has a role in a number of other applications outside of food identification and authentication. For example, oxygen isotope ratios in the keratin protein found in a hair or fingernail sample can be used to determine where a person has traveled over a period of time. This information has implications for forensics, as such data could be used to retrace a persons geographic location during the duration of their hair or fingernail growth.

Stable isotopes are also used from ice cores, tree rings, or ocean sediments as a proxy for past climate conditions. We now know the temperature of the air and ocean water, as well as atmospheric CO_2 concentrations for the past 900,000 years due to information gathered from stable isotope analysis.

Scientists are now creating synthetic isotopes that are being used for medical uses as well as new sources of energy. Given these innovations, while isotopes have been a useful tool for ecological and forensic scientists, it is thought that we have only scratched the surface of using stable isotopes in scientific research.

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