



The Science of Flavors in Food

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The harmony of a delicious meal is often called a labor of love, but it is also the evolutionary product of history, culture and good chemistry.

Chefs and scientists have long tried to describe the underlying patterns of tasty dishes. Within the last decade, a theory of flavor pairings has emerged stating that ingredients sharing flavor compounds are more likely to taste good together than ingredients that don't, which can lead to unexpected combinations.

For example, analysis of shared compounds landed white chocolate and caviar together on upscale menus around the world – the two shared the 'fishy' chemical trimethylamine, among others.

But new research using flavor networks has shown that the food pairing principle is both true and not true, and is significantly linked to region.

Such studies expand scientific understanding about what tastes good. Harnessing patterns in how people combine foods could help develop new products that benefit health without compromising the palate.

An amateur interest in molecular gastronomy led Dr. Sebastian Ahnert, a fellow in the Theory of Condensed Matter Group of the Cavendish Laboratory at University of Cambridge in the UK, to apply the theory of complex networks to flavor compounds, one of the basic components of flavor, besides odor and freshness, to uncover the patterns behind how people combine ingredients.

Ahnert and colleagues at Harvard University and Indiana University in the US mined 56,498 recipes from the US recipe database sites *Allrecipes.com* and *Epicurious.com* and the Korea-based site *menupan.com*, to compile a list of 381 basic ingredients and 1,021 flavor compounds found in them. [*Sci Rep* 2011;1:196. Epub 2011 Dec 15]

Statistical analysis yielded a bipartite flavor network that shows the connectedness of any two ingredients based on how many flavor compounds they share.

For example, fruits are connected to each other and share many flavor compounds with wine and tea, while mushrooms inhabit a flavor island of their own.

But when the researchers grouped the ingredients by cuisine, the principle of flavor pairing proved to be untrue for Asian food.

"In North American [and Western European] recipes, the more compounds are shared by two ingredients, the more likely they appear in recipes. By contrast, in East Asian cuisine the more flavor compounds

two ingredients share, the less likely they are to be used together," they said.

The researchers found that the iconic harmony or dissonance, respectively, of the regional foodscape is dominated by ingredients including milk, butter, cocoa, vanilla, cream, eggs and peanut butter in North American cuisine, while East Asian cuisine makes frequent use of beef, ginger, pork, cayenne, chicken and onion.

They also identified a handful of 'authentic' ingredients that instantly bind a flavor to a cuisine – soy sauce, sesame oil, rice and ginger instantly skew a dish Asian. Paprika, onion and lard would, on the other hand, be a signature of Hungarian food.

Although food scientists do not cite health benefits as the primary driver of cuisine evolution, rather emphasizing the importance of history, economics, climate and regional habits, Ahnert said the flavor network approach could be used to predict novel flavor combinations to create a wider, more attractive variety of health options.

Food and medicine already intersect in some cuisines.

"Many flavor ingredients [such as curcumin in turmeric or ginseng] have antioxidant properties or a bioactive component," said Dr. Liu Sho Quan, of the Food Science and Technology Programme and the department of chemistry at the National University of Singapore, though large randomized trials investigating their effects are rare.

A central component of traditional Chinese medicine (TCM) is the use of 'heating' and 'cooling' foods to balance the body's energy that together may have a synergistic effect for health, Liu added.

Dr. Christopher Loss, director of the department of menu research and development at the Culinary Institute of America in Hyde Park, New York, US, said Ahnert and colleagues' approach could be used in reverse by beginning with ingredient combinations known to be healthful and mining the flavor network to find combinations that make them taste better.

"It does not provide a 'formula' per se, but can help catalyze the ideation process at the front end of research and development," he said. "Developing positive hedonic flavor quality is the forte of the chef."

Dr. Michael Nestrud, a food scientist and director of Client Insights and Sensory Science at the culinary consultancy In4mation Insights in Boston, Massachusetts, suggested that food networks could be used to create combinations with specific functions, such as 'weight loss' or 'sugar free/diabetic.'

Food combinations could also be modelled to fit a nutritional profile. An elderly person may need a diet that focuses on soluble fiber, calories, B vitamins, omega-3 fatty acids, iron and phytosterols.

Incorporating human behavior when building the flavor network can help identify the foods consumers will like that also fulfil the desired nutritional profile.

"These network approaches, for the first time are able to attempt to explain extremely complex patterns in how people consume food that previously we were unable to model because we didn't know how," Nestrud said.

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