

The Science of Onion Flavor

Onions are one of the most widely used foods in cooking because of the luscious flavor they add to cooked vegetable and meat dishes. But pick up a fresh onion and what do you smell? Nothing! That's because, like many vegetables, onions do not develop their characteristic flavor until their cells are damaged by cutting, slicing, chopping, or cooking. Now the strong pungent smell of raw onion is noticed almost immediately.

When onion cells are damaged an enzyme called *alliinase* is released from compartments within each cell. The enzyme then comes in contact with an odorless compound called *isoalliin*. The enzyme converts isoalliin into a very unstable volatile compound called *1-propenylsulfenic acid*, which is rapidly converted to compounds called *thiosulfinates* and *thiosulfonates* that are responsible for the characteristic pungent odor and flavor of raw onions (McGorin, R. J., "The Significance of Volatile Sulfur Compounds in Food Flavors", Chapter 1 in "Volatile Sulfur Compounds in Food", Qiam, M., et al, eds., American Chemical Society, 2011). The complete conversion of isoalliin to these flavor compounds takes less than 30 seconds at room temperature. Onions also contain another enzyme called *LF synthase* that just as quickly converts 1-propenylsulfenic acid to the compound that produces tears when the onion is chopped. A compound that produces tearing is called a *lachrymator*. The name of this compound is *propanethial-S-oxide* (PSO for short), which is responsible for the heat and burning sensation when onions are eaten raw (HortScience 2002; 37(3): 567-570).

Of course, things are not quite as simple as they seem. There are a number of structurally similar (called isomers) thiosulfinates and thiosulfonates produced from isoalliin. In the developing onion bulb isoalliin is formed from a single amino acid called *cysteine*. Amino acids are the building blocks of proteins. Cysteine is one of just a few amino acids that contain the element sulfur. Methionine is another one. Thus all of the compounds responsible for the aroma, flavor, and tearing effect of onions contain the element sulfur incorporated into their chemical structure.

The flavor intensity of onions is determined by two factors: The variety of the onion (called a cultivar), and the sulfur content of the soil. Although there are hundreds of different varieties of onions, they are broadly grouped into two categories: Mild spring onions, and pungent storage onions. Mild spring onions are planted in the fall and harvested in the early spring. They tend to be fairly sweet and much less pungent than storage onions, which are planted in the spring and harvested in late summer or early fall. As the name implies, storage onions can be stored for many months in cool dry places, while mild spring onions have a shorter shelf life, and are best stored in the refrigerator.

So the flavor intensity of a single variety of onion is partly dependent on the sulfur content of the soil in which it is grown (J. Amer. Hort. Sci. 1995; 120(6): 1075-1081, and HortScience 2002; 37(1): 118-121). This is a clear example of *terroir*, or the impact of environment on the taste of a food. Sulfur exists in soil as sulfate salts. Once taken up by the roots of the onion plant the sulfate is converted to sulfur-containing amino acids such as cysteine, which in turn is converted in the onion bulb to thiosulfinates and thiosulfonates. There is a direct linear relationship between the sulfur content of the soil and the flavor intensity of the onions grown in that soil. More sulfur equals more intense pungent flavor. Soils with lower sulfur content produce sweeter, less harsh onions such as the Vidalia onion, which may be grown only in southeastern counties of Georgia according to the Vidalia Onion Act of 1986. But mild sweet onions like the Vidalia onion are also genetically predisposed to produce less pungent tasting sulfur compounds even when grown in sulfur-rich soils. And, they also contain about 18% more sugars than storage onions, which makes them a little sweeter. The sweet-tasting sugars are composed of glucose, fructose, and sucrose (common table sugar). Interestingly, sweet onions contain much more fructose than sucrose, while the reverse is true for storage onions. Fructose is 1.5 times sweeter than sucrose, so it's not surprising that spring onions are sweeter than storage onions (J Agric. Food Chem. 2004; 52: 5383-5390).

This explains the formation of the pungent flavor of raw onion. But we all know when onions are cooked their flavor turns into a mellow, sweet, even savory, meaty sensation. Fairly recent research (J Agric. Food Chem. 2004; 52: 2797-2802) has shown that heating the tear-producing compound PSO converts it to a new sulfur-containing compound called 3-mercapto-2-methylpentan-1-ol, or MMP for short. MMP tastes like meat broth. Chopping onions in a food processor, rather than simply slicing them, does extensive damage to the cell structure, forming lots of PSO, which is converted to MMP when the onions are cooked. As the conversion of PSO to MMP is not nearly as fast as the formation of PSO (because MMP is formed by simple chemical reactions rather than by an enzyme), cooking the onions for a sufficient length of time helps to increase the meaty flavor. Plus, MMP is fairly water soluble, so cooking onions with a little water after sautéing them helps to release even more MMP. In summary, finely chopping onions, sautéing them in hot oil, and then cooking with a little water enhances their savory meaty flavor. Is it any wonder slowly-cooked onions add such luscious flavor to meat dishes.