# The Science of Cooking with Wine

It is now well-known that it is not possible to remove all the alcohol from a wine-based sauce unless the sauce is cooked to dryness. This was first shown convincingly by careful experiments published in 1992 by Augustin and co-workers (J. Am. Dietetic Assoc., 92: 486-488). Following recipes from *The Pillsbury Kitchens' Cookbook* (1979) these researchers found that anywhere from 4-85% of the alcohol remained in various dishes cooked with wine or liquor. The amount of alcohol remaining was greatly influenced by the cooking temperature and time. For example, Pot Roast Milano made with burgundy retained only 4-6% of the alcohol after simmering at 185 degrees F for 2.5 hours, while Orange Chicken Burgundy retained 10-60% of the alcohol after simmering at 185 degrees for ten minutes. Cherries Jubilee made with brandy retained 77-78% of the alcohol after flaming for only 48 seconds.

So why wouldn't the alcohol, which boils at 172 degrees F (78 degrees C) evaporate from a sauce much faster than the water, which boils at 212 degrees F (100 degrees C)? The reason is because alcohol and water have a strong affinity for each other. The oxygen and hydrogen atoms in ethyl alcohol (the *alcohol* in alcohol) have an affinity for the hydrogen and oxygen atoms in water molecules due to *electrostatic attraction*. This is because the oxygen atom has a strong attraction for the two electrons in the chemical bond between oxygen and hydrogen. This results in the oxygen atom having a partially negative electrical charge. The reverse is true for the hydrogen atom chemically bonded to oxygen resulting in a partially positive electrical charge on the hydrogen atom. This creates a fairly strong attraction between the partially negative electrical charge on the oxygen atom of one molecule with the partially positive electrical charge on the hydrogen atom of the other molecule (similar to the attraction between opposite poles on two magnets). The electrostatic force between an oxygen and hydrogen atom is called a *hydrogen bond.*

Hydrogen bonds are only about 5% as strong as true chemical bonds, which involves the physical sharing of electrons between atoms rather than a weak electrostatic attraction. Nevertheless, this attraction is strong enough to produce what is known as an *azeotrope* when alcohol and water are mixed. When an azeotropic mixture of alcohol and water are heated to boiling the first vapors that are formed contain mostly alcohol (perhaps 95%) because it boils at a lower temperature than water. But because of the hydrogen bonds formed between molecules of alcohol and water, there will always be some higher boiling water molecules carried along with the molecules of alcohol even as the mixture begins to boil. After the mixture has boiled for some time, and has been reduced in volume by perhaps half or more, there will always be some alcohol molecules remaining in the mixture because of the strong attraction between alcohol and water molecules. Towards the end both the vapor and mixture in the pan will consist of mostly water and about 5% of the alcohol originally added to the mixture (for example, the amount of alcohol in the wine at the start).

So is there any way to reduce the amount of alcohol in a wine sauce? Yes! Dan Souza, a test cook at America's Test Kitchen did an experiment proving it is possible to reduce the amount of alcohol in a sauce depending on how the sauce is concentrated. The experiment is described in the new book on *The Science of Good Cooking* published by America's Test Kitchen (see Concept 37 – *Speed Evaporation When Cooking Wine*). Dan made two different sauces. In one he reduced two cups of red wine containing 14.5% alcohol to one cup, then added one cup of chicken broth and further reduced the mixture to one cup of final sauce. For the other sauce he combined two cups of the same red wine with one cup of chicken broth and reduced the mixture to one cup. Both sauces took approximately 15 minutes to reduce to final volume. The concentrated sauces were then sent to a lab for analysis. The results are shown in the table below.

| | Wine Reduced Before Broth | Wine and Broth Reduced Together |
|---|---|---|
| % Alcohol Before | 14.5% | 9.6% |
| % Alcohol After | 0.2% | 1.6% |

Both sauces were made with two cups of wine and one cup of broth, and both were reduced to the same volume. When the wine alone was reduced in half, then mixed with broth and further reduced, the amount of alcohol that remained was much less than when the same volume of wine and broth were concentrated in one step. Reducing just the wine first leaves a small amount of alcohol in the remaining one cup of concentrate. The alcohol is further reduced when one cup of broth is added, so the net result is much less alcohol remaining in the sauce reduced in two steps compared with one. Thus, it is possible to reduce the amount of alcohol remaining in a sauce depending on how the sauce is concentrated.