Return to Wisdom World

3.5 Theory and Practice of the Stir Fry

The stir fry is versatile because there is almost an infinite number of dishes you can cook with easily available ingredients, can be made to cater to practically any taste preference, can taste great, is easy, and can be healthy. We consider mainly the vegetable based stir fries here.

You can use any vegetable such as beans, beats, bitter mellon, bok choy, broccoli, broccoli rabi, brussels sprouts, cabbage or the more tender and tasty Taiwan cabbage, carrots, cauliflower, celery, chayote squash, chinese broccoli (Kai-Lan), chinese leeks and flowers, collard greens, egg plant, green or colored bell peppers (and other pepper varieties), green/red tomatoes, kohlrabi, leeks, mushrooms (fresh), napa cabbage, okra, peas, potatoes, pumpkins, sea weeds (kelp), snow pea tips, spinach, swiss chard, taro, tofu, tree ears, turnip greens, water spinach (Kon Shin Tsai – which means “hollow stem vegetable” in Chinese, and is a member of the morning glory family), zucchini, etc. (over 40 in all!).

Generally, they are combined with “spices” such as salt, pepper, garlic, ginger, scallions, onions, shallots, chives, mushrooms (dried), almond slivers, dried scallops or shrimp, etc., as well as “sauces” such as hot sauces (tabasco, jalapeno, etc), Hoisin, XO, oyster, shrimp, soy sauces, vinegars, wines, chicken/beef broths, ketchup, etc., and various oils such as canola, peanut, and olive.

Other ingredients are the “enhancers”, such as beef, pork, chicken, squid or cuttlefish, shrimp, scallops, Chinese sausage, deep fried tofu, pickled tofu, pickled cucumbers, dried turnips, hams, sausages, conch, bacon, crab meat, egg, fish/cuttlefish cakes, etc.

Since many of the above can be mixed in different combinations, you can see that the number of possible dishes is huge, a number much larger than 10,000. If you made a different dish every day, it would take about 100 years to go through them all!

The generic stir fry procedure goes as follows:

First, **add oil** to the skillet or wok and heat until anything thrown into it will sizzle. Peanut oil is the best, as discussed below, but Canola oil is a useful general oil to use, and in some cases, olive oil can be used, as discussed below. The amount of oil to use is further detailed below.

Then **add a “spice”** type ingredient. There are two approaches to this: the traditional approach is to fry the “spice” until the flavor is enhanced by the frying and is transferred to the oil. For those who enjoy actually eating the spice (such as garlic), it can be added later so that they don't get fried to a crisp.

Then **add the enhancers**. Since enhancers cook at different rates compared to the vegetables to be added later, they should be cooked to just the right level, and then removed, to be added later when the vegetables are almost done. Some enhancers such as salt, pepper, and sauces are sometimes added at a fairly late stage in the cooking so that they stay on the surfaces of the food to enhance their taste. If added too early, they will diffuse into the food and lose their effectiveness.

Finally, **add the vegetables**; the slower cooking parts, such as thick stem parts, should be added first. Cook until they are fully heated and then add the thin leaf sections. The biggest dilemma here is how much liquid to add. Generally, no liquid addition is necessary even if there seems to be no liquid at all in the beginning. This is an important subject that will be discussed in more detail below.

Transfer the food to a serving dish about 1 minute before its ideal cooked state, as it will cook for about a minute after removing from the cooking pot because of the residual heat.

Mathematical Theory of the Stir Fry

Stir fry cooks know many rules that must be followed for best results. But the basis for these rules is often not understood, which can cause confusion and the use of wrong procedures, especially by amateurs. Therefore, one of the important reasons for trying to understand the scientific basis for the stir fry is to learn what you should not do and the consequences of those wrong methods.

The mathematical basis of any cooking procedure is the process of applying heat to cook the food. Such thermal processes are governed by what are called “thermally activated processes”. So we must understand what is meant by thermal activation. Thermal processes include a surprisingly large number of everyday processes, such as plant growth and aging, attack by insects, bacteria, molds, etc., and, of course, cooking. These are all temperature dependent processes; that is why we put almost all foods in refrigerators or freezers to preserve them, because thermal processes generally are slowed down at lower temperatures.

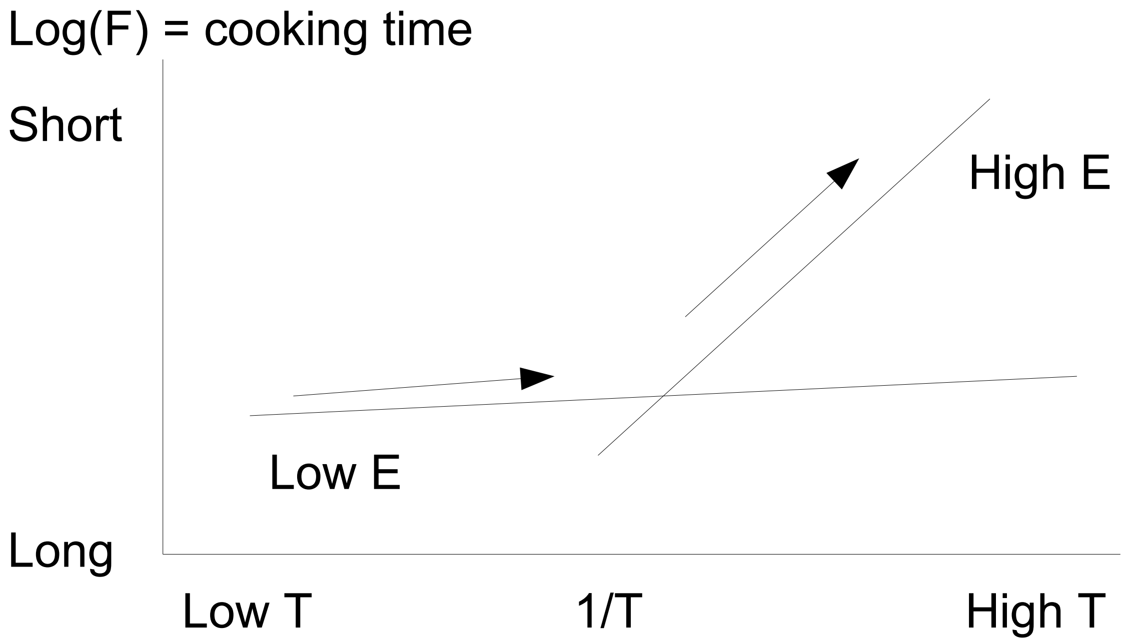
Activated processes have an activation energy which needs to be supplied in order for the process to proceed. The activation energy is like a dam; water wants to flow below the dam (to lower its energy state) but is held back by it. The water can flow down the river only if you supply the activation energy by raising a bucket of water above the dam and pouring it downriver. In cooking, you need to supply the activation energy for breaking chemical bonds so that the living vegetable is killed, the tough cellular fibers are broken, etc., so that the food ends up in its cooked state. Thermally activated processes follow an exponential equation:

F = Ce(exp.E[a]/kT), or
log(F)=Constant + E[a]/kT Eq. 1

where “e” is the natural logarithm (and “exp.” stands for exponent), F is the process under consideration (such as cooking time), C is a constant that depends on the exact details of the process, E[a] is the activation energy, “k” is a thermodynamic constant, and T is the temperature. As T increases, E/kT decreases, so that e(exp.E/kT) decreases very rapidly, causing F to decrease (shorter cooking time). Thus raising the temperature accelerates the cooking process.

A plot of log(F) vs 1/kT is a straight line with slope E; that is, at low temperature, low E processes dominate and at high temperature, the higher E processes dominate, as shown in the graph below. As you raise the temperature, the process follows the lines indicated by the arrows because other parts of the lines represent slower processes that are overtaken by the faster ones. Processes such as normal growth and aging of a vegetable, or attack by molds and bacteria, are low E processes because vegetables grow and bacteria can infect them (vegetables can rot) at room temperature . These processes are temperature dependent because you can slow them down by keeping the vegetables in the refrigerator, and vegetables will rot faster in a warmer place. Cooking, OTOH, requires much more energy because you need to break strong chemical bonds in fibers and cell walls that give cellulose, etc., their strength. Therefore, E is large for cooking and you need a high T for this process to become faster than the low E processes as shown in the figure.

We can therefore mathematically describe cooking by a two-activation energy process; a low E(L) process and a high E(H) process.* Note in the figure below that at low T, the low E process is much faster, and at high T, the high E process is faster, according to Eq. 1. So what do these equations predict as you raise the T from room T up? At first, the aging process E(L)dominates and speeds up with T. Thus the vegetable starts to turn yellow and gets tough rapidly, not what you want. Bacteria will also multiply more quickly in this warmer environment. At an intermediate T, the two lines cross and both processes occur simultaneously. At sufficiently high T, the cooking process is much faster than the decay process, so the vegetable cooks before it rots.



Two Activation Anergy Process

Just about everything you do in a stir fry is governed by Eq. 1:

(1) You want to go from low T to cooking T as quickly as possible so that there is no time for decay. This is why the wok is at smoking T when a Chinese cook starts his stir fry. But that is not enough, because the vegetables are solids and they make poor contact with the hot wok.

(2) This is why a lot of oil is used – the hot oil wets the vegetable, effectively increasing its contact area with the wok by about a factor of ten to a hundred. Oil is better than water because it can get a lot hotter without evaporating. Adding water instead of oil initially does not work because it will vaporize immediately and bring the wok T down to the boiling point of water. In some instances, adding a small amount of water to quickly "steam" the vegetable is a viable alternative because steam effectively makes 100% contact with ALL the food in the wok and steam temperature can be much higher than the boiling point of water.

(3) You must stir constantly to prevent material in contact with the wok from charring before the rest of the food is cooked – the name "stir fry" is a consequence of Eq. 1!

Eventually, cooking destroys the cell walls of the vegetables and releases water in large quantities (most vegetables are 90% water) and the wok temperature falls to below the boiling point of water. Adding salt greatly accelerates this process of water extraction because of the added osmotic pressure. Thus in most stir fry you will end up with more water than necessary without adding any liquids. For vegetables that can soak up a lot of liquid, such as cauliflower and broccoli, you can add some cooking wine or chicken broth to produce a juicier vegetable.

It is surprising how quickly vegetables will decay by E(L) when the T is raised slowly (because it is an exponential function). This is why it is so important to start with fresh vegetables, to give you enough time to raise the T before they lose their nutrition and taste. Because the food is quickly raised to high temperatures in stir frying, the vegetables you eat in a stir fry are generally fresher than those cooked using any other method, which is one reason why the stir fry tastes so good. Thus Eq. 1 not only explains everything we do in a stir fry, but also tells us what NOT to do in order to produce the best stir fry.

*Of course, there are numerous activation energies (not only two, as in the figure), one for every thermal process such as vegetable growth, decay by any number of bacteria, fungi, etc., breaking of chemical bonds at many different energies, etc., so the two activation energy model is an approximation to reality. The plot above will contain many lines, one for every activation energy in the process. This can make the stir fry process so complex that it becomes unmanageable if too many ingredients are cooked at once. For example, the activation energies for cooking shrimp, scallops, or vegetables are very different; for this reason, many cooks will stir fry them separately and then mix them at the end.