The Essential Technology of the Kitchen

The thin edge of the wedge

If, like me, you are a fan of gadgets, you have probably accumulated a number of peculiar devices in your kitchen drawers and cupboards. I have one drawer in particular that resists being opened because of all the kitchen technology crammed into it. Some choice items contained in this recalcitrant drawer include the milk foaming whizzy thing that has only been used twice and the wine bottle vacuum pump for half-finished bottles, which never gets used at all. A quick survey of all my kitchen gadgets at home reveals that they generally fall into one of two catagories: tools for preparing food and machines for cooking it.

The food-cooking machines tend to be bigger and in my house, due to a lack of cupboard space, they have migrated out of the kitchen and into the garage. These bigger machines do things that are, on the whole, only possible with said machine. So, the slow cooker contains a thermostat without which such prolonged cookery would be impossible, and the bread machine turns the production of a loaf into a ninetysecond prep-and-ignore activity. The hot-air popcorn maker is mostly retained for the amusement value of seeing the kids trying to catch puffed corn as it flies violently out of the open mouth of the machine.

However, when it comes to the food preparation devices – the mandolins, peelers, crushers, dicers and chip cutters – I have a sneaking suspicion that every single one of these is redundant. With a bit of practice, all of these gadgets can surely be replaced by a really good knife – the ultimate in kitchen gadgetry. But why does a knife cut in the first place?

If you consider how a knife is used, it has two basic modes of operation. First there is the classic chop, which involves a vertically straight down movement of the blade through the food. Secondly, you have the slice, where the blade of the knife is drawn across and down at the same time as it cuts. But how can it be that the same knife cuts some items better when slicing than chopping? The difference between these two ways of cutting was wonderfully tested by a bunch of researchers at Harvard University back in 2012. They carefully measured the forces and stresses applied to a series of small blocks of agar jelly as they were cut with a tautly stretched, very thin wire. The force needed to create the critical level of stress in the jelly block when they tried chopping was more than twice needed for the slicing action. On a microscopic level, as the cutting edge slides across the object to be cut, it catches on it, effectively sticks to it and creates friction. This friction pulls the surface sideways, creating a shear force as well as the downward force. Combined, these are enough to initiate a fracture and the cut can then propagate.

This relative lack of force required to slice helps explain why paper, which cannot chop skin because it is flimsy, can however give you a nasty cut. If you slide your finger along the edge of a sheet of paper, the paper itself is pulled taught and acts as a knife blade, slicing your skin. The very edge of the paper is rough and creates lots of friction and enough stress in your skin to start a fracture. Once initiated, the paper can then elongate this fracture, creating a cut. Interestingly, the reason paper cuts are so painful is due to the relative roughness of the edge of a sheet of paper when compared to a sharp knife. The paper edge creates a ragged tear in the skin, causing more tissue damage and more pain than a sharpened metal edge would.

Creating that initial fracture is the hardest part but, once made, the split can be pushed forwards through the material much more easily. All material, be it an apple, a chicken breast, a block of cheese or a lump of wood, has an inherent resistance to fractures. The molecules that make up the object are hanging onto each other and resisting the intrusion of the knife. Until, that is, the stress applied by the knife between the molecules gets to be greater than the force holding the molecules together. At which point they snap apart and a fracture appears. So, the key to cutting is creating the initial fracture by increasing the stress between molecules.

Based on this science it is now possible to see why the recommended way to use a knife is with a gentle forward motion along with the downwards push. This way you are creating a slicing motion rather than a chop and the effort needed is much reduced. Why, then, do we still chop a carrot and a block of cheese? In the case of the cheese, the material is sufficiently soft that the blade easily pushes into the block and starts the fracture going. And carrots are so brittle and their cells large enough that the blade of the knife can get the fracture started with little effort.

Once you have initiated a fracture you then want a thin wedge of a blade to split that fracture and propagate it through the material, creating a cut. So, the knife actually needs to do two jobs. Conveniently for us, the best way to do this is to have a devilishly sharp edge on your blade. When looked at under a microscope, a sharp blade is not as smooth as it may seem. Instead it consists of a series of ridges and furrows running up to the blade edge, creating what is to all intents and purposes, a microscopically serrated edge. As this edge slides across food it catches, creating the friction needed to produce the shear force that increases the stress and initiates a fracture. A blunted blade, on the other hand, has a rounded and smooth edge that slides, without catching, across food and does not start a cut so easily. Consequently, since you have no shear force to help, you have to rely solely on the chopping action and need to apply much more force. Which is why blunt knives are more dangerous that sharp ones; all that extra force means you are much more likely to slip.

Given the complexity of the task a blade is performing, with all the shear forces and friction needed, it should come as no surprise that the manufacture of a knife is also complicated. To create a blade that can hold a sharp edge you need to use

really hard steel. But on top of this, the edge of the blade needs to be resistant to being worn down, so the steel also needs to be tough. Hardness and toughness are not the same thing. Hardness is the ability of a material to resist being scratched or deformed by compression. Toughness is a measure of how well a material can absorb energy and deform without breaking or, to put it another way, how well it copes with being bent. This is the tricky bit, as an increase in hardness usually reduces the toughness, and tough steel tends to be not so hard. So knife manufacturers add carbon to the iron metal to create hard steel, tungsten and cobalt for toughness and a spot of chromium to make it stainless and prevent rusting.

The final part of knife science I need to mention is the angle of your wedge. A standard Western or Germanic style knife blade will be sharpened so that the angle between the two sides of the blade is about 35°. But the Japanese Santoku style blades are much finer with a total angle of only about 25°. The fineness of the blade makes a big difference; it gives a sharper edge and will therefore cut more easily. So, why not make all blades as fine as possible? Well, this comes down to practicality and what the knife is being used for. Santoku blades, while being sharper, are more prone to being dented and bent in use and in storage. If you are using a 25°-angle blade and accidentally come across something hard in what you are cutting, like a bone for example, there is a good chance you will damage the blade. Similarly, if you want to keep your Santoku blade in good condition, don't slip it in the kitchen drawer crammed with gadgets. Broader 40° blades don't suffer these problems, but will never take an edge quite like a Santoku.

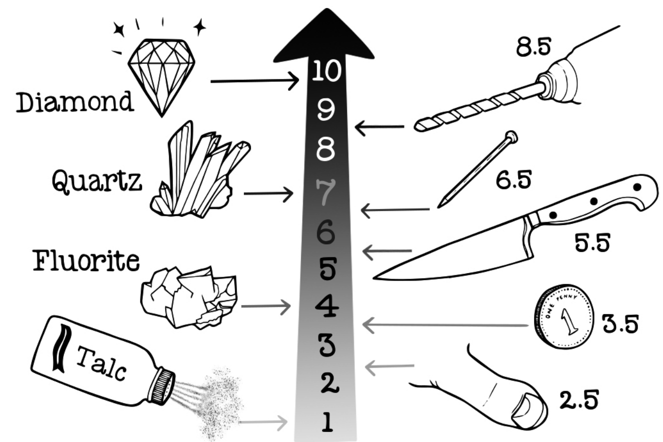
Chop, chop, chop

What use is a wonderfully sharp and sleek kitchen knife without a chopping board? The board is the less glamorous but equally important part of this ubiquitous duo, yet even here there is a hidden science.

The key issue when it comes to the design of a chopping board is the hardness of the board material – its ability to resist being deformed by compression, or specifically resistance to being cut. The material of the board must not be too soft or too hard, but just right. Too soft would be something like cardboard, as the fibres in the card are too easily cut by a sharp steel knife. After just a few uses the surface would be sliced to shreds. Similarly, the board must not be too hard, or to be exact it should not be harder than the steel of the knife's blade. If it is, the blade will quickly become blunted.

To get a sense of how hard is too hard and how soft is too soft, we need to quantify hardness. There are several ways to do this, but the simplest is to use the Mohs scale of hardness, created in 1812 by German geologist and mineralogist Friedrich Mohs. The Mohs scale goes from 1 to 10 and was really created to quantify the hardness of minerals. In particular any mineral

with a higher rating on the scale was able to scratch those lower down. Diamonds are at the top of the scale with a 10 and they can scratch anything below them, like quartz at 7, for example. Similarly quartz will scratch gypsum since this is only a 2 on the Mohs scale.



The steel used to make the blades of knives is in the order of a 5 or 6 on the Mohs hardness scale. Which means you should never use a chopping board harder than this. If you do, the fine edge of the blade will be deformed and blunted by the harder material of the chopping board. Note that both glass and granite kitchen countertops – primarily made of quartz – have a hardness of 6 and 7 on the Mohs scale respectively. So don't chop onto glass or granite surfaces with your favourite knife, unless you also enjoy regular blade sharpening. Instead the wise chef will use either wooden or plastic chopping boards. But which is the best?

There is a long running debate between professional chefs, food technologists and microbiologists as to what sort of board is the most practical, the longest lived or the most hygienic. It quickly becomes complicated by a multitude of confounding factors. For example, I have been reliably informed by a professional chef that cutting for long periods of time on anything other than wood leads to a sore arm. Conversely, many domestic users of chopping boards prefer plastic because they don't have dedicated cleaning staff and the board can be chucked in the dishwasher. Then again, some people claim that the natural phenolic compounds in wooden boards actively kill off bacteria lingering on the surface. Which leads me nicely onto one of the most crucial aspects of chopping board science; hygiene.

Since you are invariably placing raw food on the board, the potential for bacteria to remain behind and contaminate the next thing on the board is a real risk. Clearly the most obvious thing to do is follow the lead of most professional kitchens, which use a separate chopping board for foods like raw meat that contain the highest potential for harbouring nasty bacteria, like salmonella.

In an effort to go beyond anecdotal arguments, several scientific studies have been carried out, including one I was involved in for a TV series. An accredited laboratory of UK government scientists based in Glasgow carried out the tests. We started out with a big pile of new and used chopping boards, some made of wood and some from plastic. First up, to give us a uniform hygienic baseline, the boards were all

identically sterilized. We then contaminated sections of each board with solutions containing a known number of bacteria. The boards were air dried and then sampled over the course of twenty-four hours. The number of bacteria in each sample was then worked out by laboriously smearing each sample on Petri dishes, leaving them to mature and then manually counting the bacterial colonies.

The aim of this part of the test was to simulate putting something like raw chicken onto a chopping board, then failing to clean it properly, or even give it a perfunctory wipe, and using the board again some time later. We were deliberately seeing if we could test the idea that wooden boards were in some way antibacterial. Would the wood kill off more bacteria than the plastic? To the disappointment of the director on the day, the answer was no. In fact it made no difference at all what the board was made of or how old the board was. Boards that hadn't been cleaned retained a disturbingly large number of bacteria.

So, what about if you actually do what you are supposed to do and clean your board after you have used it? Once more we set to work with our chopping boards, but this time, after they had been inoculated with bacteria, we gave them a thorough scrubbing with hot soapy water. Finally the boards were tested for bacteria one last time and once again there was a resounding failure to find any significant difference. What this indicates is that if there is a difference between wood and plastic chopping boards, it is marginal and probably more influenced by the exact protocol used to clean them