Shaken, Not Stirred: The Story of Mixers and Mixing

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Abstract: For once, James Bond got his science right. A martini should be shaken, not stirred, because the aim is not so much to mix the ingredients as to get them cold through contact with ice. Shaking is much more efficient because it creates a turbulent environment where more of the liquid can come into contact with the ice surface over a given time.

But what of other foods – believing, as we do, that martinis are a food? Why do we shake, stir, or otherwise manipulate them during preparation? How should we do it? What tools should we use to assist us? In this brief survey of gastronomic materials, techniques and gadgets, we examine these three questions in turn, providing a relatively detailed background for a talk which will focus on a few of the more interesting, instructive and entertaining examples.

Background: Why Do We Stir?

We stir food during preparation for two basic reasons: To mix the ingredients (including heat) more uniformly; and/or to change the physical characteristics of the mixture.

Mixing

Mixing is one of the basic processes in cookery although, as Peter Hertzmann points out in his excellent on-line video Stirring Conclusions, cookery students often do not understand just why they are doing it. When we stir the ingredients of a cake batter together, for example, our aim is to ensure that they are uniformly mixed before baking, as in the following nineteenth century recipe for an Adelaide Cake:

Beat with the hand, in an earthenware basin, one pound of butter, and the same of sifted loaf sugar; beat separately the yolks and whites of ten eggs; add the yolks first, along with one pound of flour and two ounces of rice flour, add the whites, and one pound of nicely cleaned currants; flavour with essence of nutmeg and lemon, and bake in a tin...5

By beating with the hand, the cook uses the heat of the hand to warm the butter in contact with the skin so as to help it flow more easily as it becomes mixed with the sugar. The cook can also feel how the hard butter and the gritty sugar become blended into a soft
mass; how the egg components and the flour become incorporated to produce the very different texture of the batter; and that the currants are distributed uniformly throughout the mass before cooking.

On other occasions we wish to mix, not only the physical ingredients, but also the heat that they carry. When we ‘stir-fry’, for example, the stirring process ensures that the heat of frying is distributed uniformly throughout the mixture, and that the ingredients that initially absorb the heat from the pan are not overheated while the rest remain cold. Similarly, when we add milk to our coffee, we stir to ensure that the liquids are mixed uniformly and also that the heat is distributed uniformly. If we do not stir, convection processes break the liquid up into discrete units called Bénard cells, evidence of which can be seen in the patterns that appear at the surface.⁶

The achievement of uniformity is not always as easy as it seems. To take one example, if we were to ‘stir’ a mixture of dry ingredients by shaking it in a container rather than using a spoon or other ‘paddle’ stirrer, the larger particles would rise to the top via a phenomenon called the ‘Brazil nut effect’. The name comes from the tendency of the largest nuts (usually Brazil nuts) in a shaken container of mixed nuts to rise to the top (it is also called the ‘muesli effect’ because the nuts and pieces of fruit in a packet of muesli tend to rise to the top as it is shaken). One simple explanation is that smaller particles fall into the void spaces under the larger particles after each shake, so the larger particles gradually rise. (One simple way to overcome the Brazil nut effect when stirring powders is to use a rotary stirring motion that involves moving a spoon or other implement in a vertical circle about a more-or-less horizontal axis, so that the smaller particles are lifted from the bottom and put on the top again.) This is not the only process at work, however.⁷

Changing the Character of the Mixture

A second reason for stirring is to change the physical characteristics of the mixture. This may sometimes be achieved simply by mixing, as in the Adelaide Cake recipe above. We may also stir by beating or whipping to incorporate air, as in making a soufflé.

More often, though, we achieve texture changes by breaking up droplets, particles and even molecules, forcing them to combine into new structures. When we make mayonnaise, for example, we beat an oil and water mixture vigorously to create and break up oil droplets, making them ever tinier. When we knead bread dough, we are working at an even smaller level, forcing glutenin molecules to stretch and cross-link with gliadin in a network that conveys elasticity to the dough.

Whether we stir for mixing, or stir for texture, or both, we still need to stir in the right way to achieve our goal. Here we examine more closely just what happens when we stir, and
how our stirring technique can sometimes vastly affect the outcome through generating different flow patterns in our mixtures.

_Stirring for Uniformity._ Some recipes (especially those from the nineteenth century and earlier) specify slow stirring in one direction only – usually clockwise, as in the medieval belief that one should only walk ‘widdershins’ around a church. To modern ears, it sounds like unsupported superstition, but strangely it has a scientific basis when what we are stirring consists of droplets of one liquid suspended in another.

The flow pattern that we generate by such slow stirring is called _laminar flow_. It may be visualized as being like the lazy flow of a slowly-moving river, where bits of floating debris may pass each other, moving fastest in the centre and more slowly towards the banks, but do not intermix laterally. In fact, such a flow pattern may be reversed by reversing the direction of stirring, as the video to be shown spectacularly demonstrates. So stirring slowly in the one direction appears to make sense.

But it doesn’t, because even though the liquids may _appear_ to mix, in fact they don’t. As James Bond understood instinctively, the key to effective mixing is to avoid laminar flow, and instead to create _turbulence_. We may do this, for example, by stirring in a figure-of-eight pattern, criss-crossing and mixing up the flow lines.

Better still, we can speed up the stirring, and also choose an implement that generates turbulence through its design. One such implement is the _spaddle_, described in _Miss Leslie’s New Receipt Book_ (Philadelphia, 1850) as ‘a [round wooden stick] about a foot long, and flattened at the end like that of a mush-stick, only broader’.

The spaddle is a forerunner of the modern paddle blade mixer, and works in a similar way, by producing turbulence at the _edges_ of the blade. Such turbulence has been studied extensively by engineers, who have devised a number of simple rules that can be useful in considering just how we should stir different food mixtures.

One fairly obvious rule is that, for the most effective mixing, keep the plane of the blade or spoon that you are using square-on to the direction of motion as you stir, since this forces the maximum amount of material past the edges and at the highest speeds.

Another, slightly less intuitive, observation is that the highest turbulence occurs near the wall of the container when the blade or spoon is kept close to it. Annoyingly, though, studies have shown that mixing in the rest of the liquid (away from the zone of motion of the stirring implement) is correspondingly _less_ effective when the implement is kept close to the walls of the container while stirring. The answer is to stir in a spiral or figure-of-eight motion, bringing the implement close to the pan edge for some of the time but then bringing it towards the centre and back again.

One further observation is that multiple edges are multiply effective in producing turbulence, so for thorough mixing a slotted spoon beats an ordinary spoon hands down.
Stirring for Texture. Most of the complex, multi-component food mixtures that we stir are non-Newtonian, which means that their flow properties change with the speed of stirring. A spectacular example is corn starch-based custard, which can be poured slowly as a liquid, but which becomes solid under a sudden impact, so that it is possible to walk or run across the surface of a large pool of it, as the video to be presented will show.10

A contrary example is tomato ketchup, which can be very thick and virtually un-pourable until the bottle is shaken, when it becomes much less viscous and easier to pour – hence the old rhyme:

Shake, shake the tomato sauce bottle,
First none’ll come, and then a lot’ll.

Such changes occur because stirring affects: the size, shape and distribution of the long macromolecules (e.g. proteins and polysaccharides) in the food; the size, shape and distribution of the solid particles in the food; and the size and distribution of liquid droplets such as oil droplets. The scientific complexities involved in these questions are well beyond the scope of this talk, but from the point of view of the practical cook, there are three simple questions that we can ask:

• Do we want to break up particles, lumps or droplets, or merely disperse them uniformly?
• Do we want to align large molecules such as proteins and polysaccharides, entangle them, or even break them?
• How fast should we stir, and what implement should we use, to achieve these effects?

Here we offer some answers to these questions, along with their basic rationale.

Slow Stirring

Slow stirring tends to create flow fields consisting of parallel streamlines (scientifically known as shear flow). Adjacent streamlines move at different speeds, so that molecules or particles that lie across them will be stretched and rotated, thus changing the properties of the mixture.

Tomato ketchup, for example, contains stringy, thread-like particles of cellulose and other material. These particles are normally tangled together to create a semi-solid mixture. When we shake or stir the mixture, adjacent streamlines undo the tangles, rotating and aligning the particles so that they can more easily slide past each other and allow the mixture to flow.

The stirring of porridge provides a different example.11 As cooking proceeds, the starch granules in the individual flakes absorb water, swell, and sometimes burst, releasing starch
molecules. These molecules can act like glue, sticking the swollen flakes together and making the porridge lumpy.

To nullify this process, we must stir the porridge. We do not have to go to the lengths of three-times World Porridge Making champion Duncan Hilditch, who immersed himself naked in a bath full of porridge and used his legs and hands as stirrers. As Duncan himself pointed out, it is sufficient to use the traditional spirtle – a wooden rod roughly 1 cm in diameter. The aim is to provide sufficient force to separate the sticking flakes, without breaking the swollen flakes, releasing free starch and causing the porridge to become gluey. Calculations show that optimum shear forces are achieved by stirring at around one revolution of the pan per second. As with many stirring problems, centuries of experience have produced the optimum outcome. A whisk produces much higher shear rates at its boundaries, and would be much less suitable.

A whisk, however, is a much better implement for whipping cream, because in this particular case high shear rates actually force particles to stick together, rather than tearing them apart. The 'particles' in this case are fat globules, suspended in water. The globules have small sharp crystals protruding from their surfaces (these crystals only form when the cream is sufficiently cold), which are otherwise covered with a protective protein film. When the globules are caught in a shear field, they are pushed up against each other and forced to roll around each other. At sufficiently high shear forces, the crystals can pierce the protective films of adjacent globules, causing them to clump together.

Finally, in this brief survey of the effects of relatively slow stirring, we note that slow stirring may sometimes result in the separation of the stirred material into layers in a process known as shear banding. We are unaware of particular gastronomic examples, but would be very interested in hearing of such.

**Fast Stirring**

Fast stirring creates very complex flow fields, where streamlines, vortices, eddies and a host of other flow patterns exist simultaneously. This is very good for mixing, and can have profound effects on texture, which arise in part because there are many points (called 'stagnation points') from which material is rushing away in opposite directions.

Physicists call this ‘extensional flow’. Its effect on long molecules, such as proteins and polysaccharides, is that they become untangled and stretched, like the rope in a tug of war competition. When we stir egg white in this way, for example, the albumin molecules that are normally curled up into a ball become stretched out like pieces of string, which are then able to cross-link with other molecules at specific active points (normally safely hidden within the balls), thus forming a three-dimensional network.
When we stir more complex mixtures, such as that required to produce a chocolate ganache, the effects can be equally complex. A typical (abbreviated) chocolate ganache recipe consists of: 200 g dark chocolate, 200 g butter and 1 tbsp instant coffee dissolved in 125 ml cold water, all mixed together and warmed until melted. Then a powder mixture consisting of 85 g self-raising flour, 85 g plain flour, 200 g Muscovado sugar, 200 g caster sugar and 25 g cocoa powder is stirred with 3 medium eggs and 75 ml buttermilk. The melted chocolate mixture and the egg mixture are then stirred together until smooth and runny.

So far, so apparently simple. But if we keep beating the mixture, it will first become thinner, and then thicker, eventually ending up as a fondant!

Scientists are only now beginning to understand how stirring affects such complex non-Newtonian mixtures, and there is a long way to go before definitive predictions can be made. From the point of view of the practical cook, though, there are four simple messages:

• Choose the appropriate implement for the job.
• Aim to use the implement so as to generate the desired flow pattern.
• Start stirring slowly, and gradually speed up until you achieve the desired effect.
• Don’t over-stir, or you may undo all of your good work.

Happy stirring!

Appendix: Spaddle Recipes and the Use of the Spaddle and Whisk

Spaddle

Fine Wafer Cakes. Wash and squeeze half a pound of fresh butter in a pan of cold water. Then take it out, and cut it up in another pan, into which you have sifted half a pound of powdered white sugar, and stir them together with a spaddle (a round stick flattened at one end) till they are very light and creamy. Then stir in half a grated nutmeg, a small teaspoonful of powdered mace, a glass of sherry or Madeira, and a glass of rose or lemon brandy. Put the whites of four eggs into a deep plate, beat them to a stiff froth with a whisk, and add the beaten white of eggs gradually to the mixture. Lastly, stir in as much sifted flour as will make a light soft dough or paste. Divide it into equal portions; flour your hands, and roll each portion on your palms till it becomes round like a small dumpling. Then having heated the wafer-iron, butter the inside, and put in one of the dumplings, making it fit well. Put the wafer iron into a clear hot fire, and bake each cake five minutes. When done, take them out carefully and lay them separately on an inverted sieve to cool.
This mixture is more easily baked in thin flat cakes. Roll out the dough into a thin sheet, and then cut it into round cakes with the edge of a tumbler, or with a tin cutter of that circumference. Butter large square iron pans, and lay the cakes in them, but not so close as to touch. Put them into a quick oven, and bake them brown.17

Elsewhere in the book, Leslie writes ‘For stirring butter and sugar together, nothing is equal to a wooden spaddle [or spittle]. It should be about a foot long, and flattened at the end like that of a mush-stick, only broader. Spoons are very tedious and inconvenient for beating eggs or stirring butter and sugar, and do not produce the proper lightness’.18 She also specifies a hickory spaddle in another recipe for cornmeal cake.19

In an earlier book, Leslie writes: ‘Butter and sugar cannot be stirred together conveniently without a spaddle or spittle, which is a round stick flattened at one end, and a deep earthen pan with sides nearly straight. For beating eggs you should have hickory rods or a wire whip, and broad shallow pans’.20

Beeton sees the spaddle as more of a scraper: ‘The spaddle is generally made of copper, kept bright and clean. … The use of the spaddle is to stir up and remove from the sides of the freezing-pot the cream, which in the shaking may have washed against it, and by stirring it in with the rest, to prevent waste of it occurring’.21

Apple Postilla. Bake codlins, or any other sour apples, but without burning them; pulp them through a sieve into a bowl or pan, and beat them with a wooden spaddle for four hours; then, adding as much honey as will sufficiently sweeten the quantity of fruit, beat it at least four hours longer: it is reckoned, the longer beaten the better. Pour on a cloth spread over a tray, a thin layer of the mixture; and bake it in a slow oven, with bits of wood placed beneath the tray. If found, on taking it out, to be not enough baked on one side, set it again in the oven; and when quite done, turn it, place on it a fresh layer of the mixture, and proceed with it in the like manner till the whole be properly baked. Apple postilla is also made by peeling the apples and taking out the cores after they are baked, mixing sugar to palate, and beating it up with a wooden spoon or spaddle till all is if froth; then putting it into trays, and baking it for two hours in an oven moderately hot. After which, another layer of the beaten apples is added, and powdered loaf-sugar spread over. It may be either in thick or thin pieces. Sometimes, a still finer sort is made, by beating yolks of eggs to a froth, and then mixing it with the apple juice. The grand point, in these Russian preparations, is that of long perseverance in whipping or beating up the fruits, &c.’22
Whisk

3. An instrument, now freq. a bundle of wires, for beating up eggs, cream or the like.

1666 R. Boyle The Works of the Honourable Robert Boyle [Origine Formes & Qualites]. This being settled in the first place, we may in the next consider that by beating the White of an Egge well with a Whisk, you may redice it from a somewhat Tenacious into a Fluid Body, though this production of a liquor be, as elsewhere noted, effected by a divulsion, agitation, &c. of the parts: that is, in a word, by mechanical change of the texture of the body.

1747 H. Glasse Art of Cookery xv. 140 First beat the Whites of the Eggs well with a Whisk


From Eliza Leslie: ‘In every sort of sponge-cake, Naples-biscuit, lady-fingers, and in all cakes made without butter, it is important to know that thought the egg and sugar is to be beaten very hard, the flour, which must always go in at the last, must be stirred in very slowly and lightly, holding the whisk or stirring-rods perpendicularly or upright in your hand; and moving it gently round and round on the surface of the batter without allowing it to go down deeply. If the flour is stirred in hard and fast, the cake will certainly be tough, leathery, and unwholesome. Sponge-cake when cut should look coarse-grained and rough.’24

Notes
2. See video collage of James Bond ordering martinis at http://www.youtube.com/watch?v=OUUq5mRCimo.
3. The original ingredients (Casino Royale, Ch.7) comprised three measures of Gordon’s gin, one of (unspecified) vodka, and half a measure of Kina Lillet (a vermouth-like aperitif with quinine as the bitter ingredient). Kingsley Amis describes this recipe as ‘the great Martini enormity’ (The James Bond Dossier, London: Jonathon Cape (1965) p.123) on account of the substitution of Kina Lillet for the more traditional dry vermouth. The Bond recipe, however, still appears on cocktail menus as a ‘Vesper’, with Cocchi Americano replacing the Kina Lillet (which is no longer available) (http://chanticleersociety.org/forums/p/1116/6670.aspx).
5. Mary Somerville, Cookery and Domestic Economy, 1862.

9. While on the subject of stirring in a spiral motion, we note that wine swirling involves a similar sort of motion. Recent studies by Martin Reclari, Matthieu Dreyer, Stephanie Tissot, Danail Obreschkow, Florian Wurm & Mohamed Farhat, ‘Oenodynamic: Hydrodynamic of wine swirling’ (http://arxiv.org/abs/1110.3569) have shown that the swirling process not only increases the speed of air flow over the wine surface, thus aiding the release of vapours, but also generates complex wave patterns that increase the surface area and further enhance the release process.


15. These forces can be so severe that the ‘rope’ actually breaks. J.A. Odell & A. Keller ‘Flow-induced chain fracture of isolated linear macromolecules in solution’, Journal of Polymer Science, B 24 (1986) p.1889-916. The practical outcome is that the mixture can become thinner, or less viscous, the longer it is stirred because, as these long molecules become shorter, their contribution to the viscosity becomes less. This actually happens during our lifetime with the long molecules in the synovial fluid that protects our knee joints, where the molecules gradually become broken and degraded, and are not replaced.


As noted, shaking the martini results in much more of the ice melting than with gentle stirring, ultimately diluting the drink and simultaneously making it colder, faster. The line in Casino Royale where he invents a drink of his own creation (Vesper) is often used as evidence to his preference of cold temperature. According to the researchers, who perused the James Bond novels for their data, over the 123.5 days covered in the stories they looked at, Bond consumed an astounding 9,201.2 grams of pure alcohol in the various drinks he partook in. This means he drank an average of 521.6 grams of pure alcohol each week, an amount several times that recommended by the British National Health Service.