



food for thought

“Food for Thought” explores the relationship between food/drink and chemical engineering processes/concepts.

LET THEM EAT CAKE

MARGOT VIGEANT

Bucknell University • Lewisburg, PA 17837

Here is a profound question for our times: Why do we frost cakes?

If you grab any handy small child and ask them this question (for example, let’s ask Freddie, 4), you will probably get a variation on “It is the best part!” and “It tastes good!” Which is accurate, but *cake* tastes good all on its own, so why do we go out of our way to make it taste even better? The answer is partly in history, partly in structural engineering, and partly in chemical thermodynamics!

One day, finding myself with a pressing deadline, I did what any sensible person would do and procrastinated by attempting to quantitatively map the border between “cake” and “bread.” This is, by the way, quite sensitive to culture. I readily admit that there are “cakes” that strike me as breads, while I’m sure there are places in the world where folks would take one sniff of my banana bread and call it cake. So, I will declare my positionality on this and say I’m basing my informal study on the names given in recipes found in several US cookbooks published between 1990 – 2020, as well as recipe cards written by my mom over the same period. After some trial and error, I decided that the simplest characterization that would apply to both cakes and breads would be to map out the fraction of each, by pre-cooked mass, that was flour, sugar, and fat. What resulted was a rather chaotic graph revealing that, by and large, things labeled “cake” are 1/3 or more sugar by mass, while things that are “bread” have fractions between zero and 1/3, with banana bread and banana cake sitting squarely on the dividing line. There were no discernible trends for either flour or fat.

This relatively high proportion of sugar is not only responsible for making cake taste good; it also has an impact on its shelf-life. But before we can discuss that, a quick refresher on my all-time favorite thermodynamic and food concept: water activity.

Water activity (a_w) is a thermodynamic value recognized as one of the best measures for how long we can expect to keep a food prior to spoilage. Activity is the ratio of component fugacity to standard state fugacity. I like to think of it as kind of a mole fraction, but corrected to account for the ways some molecules behave as more or less concentrated than they really are. Applied to water in foods, it is a handy, one-value approach for predicting if harmful or otherwise unpleasant microbes will find a given food hospitable for their growth. Above an a_w of about 0.85, many microbes can flourish, while under that level, we can expect a food to stay fresh.^[1] This means that a food with a properly adjusted a_w can be kept without refrigeration safely – a significant benefit given the expense of refrigerated shipping and storage.

The popular Twinkie™ snack cake clocks in at an a_w of 0.795,^[2] which is primarily responsible for its legendary longevity. In fact, I have a still-sealed Twinkie in my lab from 2013, and it’s quite attractive and apparently mold-free. It is, however, hard enough to drive nails, so I wouldn’t recommend eating it. But in terms of safety, it seems okay. The cakes made by home cooks might more reasonably be expected to start with a_w in the 0.90 – 0.92 range.^[2] The sugar



Margot Vigeant is Rooke Professor of Chemical Engineering at Bucknell University. She teaches chemical engineering thermodynamics, applied food science and engineering, and capstone design. Margot’s broad research area is effective pedagogy in engineering, including approaches to conceptual learning and inquiry-based activities for thermodynamics and heat transfer. She is also interested in “making” in engineering and using technology to broaden engagement and access. Margot completed her doctorate at the University of Virginia. She is an ASEE Fellow, Apple Distinguished Educator, and chair of the 2022 ASEE Chemical Engineering Summer School.

is a preservative that lowers water's activity by dissolving into the "cake" solution. But it's also hygroscopic, helping cakes to hold on to some of the water that gives cakes their characteristic moist crumb.

Nature has figured out how to keep high water activity foods fresh without refrigeration – wrap the food up in a peel or similarly waxy outer layer. A banana on its own has an a_w of about 0.98,^[2] but its peel's a_w is lower. Thus, a food that starts clean of microbes and is extremely well wrapped can keep a longer time than one would expect, given the water activity level of the original food. This provides a key hint as to the function of frosting!

But first – I don't want to elide the rich history of cake decoration. In medieval Europe sugar was an expensive import from as far away as India.^[3] If you were rich enough to have some, you wouldn't waste it inside a food – you'd put it on top where everyone could see! Descriptions of medieval and early-modern European feasts will often call out the "subtleties" – sugar sculptures that adorned tables and, yes, cakes. Food historians point to this as a start to frosting cakes, and I don't disagree. However, we then need an explanation for why it makes sense to keep doing this when the goal of a cake is celebrating Grandma's birthday and not conspicuous consumption. Certainly, part of this is from the fact that sugar can be used to make decorations much more readily than cake itself. Try to make a rose out of cake and compare the process with making a rose out of frosting, and you'll see what I mean.

While history and sugar's structural properties are important, frosting also has caught on because it helps preserve the cake. Most frostings are primarily composed of sugar and fat (think buttercream). Royal icing, made with egg whites, is more of a combination of protein and sugar. While it is possible to make a delicious frosting that has a high a_w (cream

cheese icing comes to mind, with its a_w of 0.91),^[4] there is published commercial guidance for commercial and "cottage industry" bakers to prefer formulations of buttercream and similar frostings with a_w of 0.85 and below for reasons of food safety. Aha! We have found a way to skip the single-use-plastics and wrap our cake for safekeeping. While frosting drives the calories up, it also helps preserve the cake and keep it yummy longer.

As a case in point: when my British friend Ewan and my American friend Jenny got married, Ewan's mother insisted on bringing a traditional English wedding cake – a fruitcake started nine months in advance and subsequently frosted with a royal icing of such low water content that Ewan's mum literally used sandpaper to roughen up each layer of dried frosting before laying down the next. This cake quite happily survived the time before the wedding, the transatlantic voyage, and at last count, at least one slice was still going strong.* This was in 1998!

You may not be looking to store cake for a quarter century, but with all these advantages – taste, attractiveness, preservation – you can see why frosting is more than just the icing on the cake!

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*In addition to a very dry frosting, the cake was also soaked in brandy – for an extra measure of food safety, I'm sure.