food for thought

This is the first installment of the new "Food for Thought" column, written by Dr. Margot Vigeant. The column explores the relationship between food/drink and chemical engineering processes/concepts.

THE OLDEST UNIT OPERATION

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Chemical Engineering is defined by the *Encyclopedia Britannica* as "the development of processes and the design and operation of plants in which materials undergo changes in their physical of chemical state."[1] Our discipline started to be recognized as its own separate profession in the late 19th century, culminating with the founding of AIChE in 1908. But we all recognize that the practice of chemical engineering goes back much further than a mere 113 years. From the large-scale harvesting and processing of beetles into carmine pigment by the Paracas of Peru three thousand years ago to the articulation of conservation of mass by Lavoisier in 1789, people have been *performing* chemical engineering for much longer than there's been a name for it.

So if, as I claim, humanity has been doing chemical engineering for centuries, what was our first unit operation? And why, in a column that purports to be about food, have we read about nothing but history, bugs, and Frenchmen? While the latter question may be ultimately unanswerable, I'm going to bring food to the party by suggesting that the first recognizable unit operation was the fermentor.

Often when chemical engineers think about fermentation, their minds go first to pharmaceutical production as pioneered by Pfizer's scale-up of penicillin production in 1944. Much older is the use of fermentation to turn substances that are either inedible or rapidly spoiled into more nutritious, longer-lasting human-digestible foods. Pickles, cheese, yogurt, beer, wine, bread, chocolate, coffee, tea, kimchi, and more are the delicious products of fermentation processes. Let's talk for a minute about the point of fermentation, culinarily speaking. Most of the foods humans like to eat are also foods for various bacteria and fungi (I'm going to group these together as "microbes") that actively compete with humans for food. If they get to it first, the food's nutritional value decreases. We notice because such food becomes smelly and unattractive — it's spoiled. Think about milk left on the counter too long or what happened to that orange that rolled under the counter after a couple of weeks. However, it turns out that not every microbe is out to get us (or our food).

While some microbes turn previously yummy grains and milks into actively poisonous mush, other microbes are not so bad. Brewer's yeast, for example, will metabolize sugars extracted from grain and generate ethanol and carbon dioxide among a number of other flavorful and aromatic compounds. The bacterial culture added to yogurt will turn lactose, otherwise indigestible by a large fraction of humanity, into lactic acid and other compounds. These chemicals in turn denature and coagulate milk proteins, creating the pleasing gel that is yogurt.

The trick in fermentation for food and beverages is to help the desired microbes grow while keeping the numbers of undesirable microbes as low as possible. A major factor in doing this is finding a way to appropriately prevent contamination of the fermentation vessel once the proper microbes have been introduced. Sometimes, as with grapes, the microbes we want are covering the food from the get-go. All we have to do is mush up the grapes, keep the environment at the correct level of oxygen, and get out of the way. Other foods, like bread, *might* cultivate appropriate microbes if left to themselves. But as anyone who's tried to start a sourdough culture will know,

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this process isn't automatic. In this case our solution is to keep some of the microbes that worked last time around and use it to kick-start the fermentation this time — some sourdough starter, some yeast from the vat, some yogurt from last time. If we add these "starters" to our prospective fermented food, odds are good their head start in numbers will allow them to outcompete other microbes that might be present. In the case of dairy and beer, we usually ensure this is true by heat treating to kill off the original microbial inhabitants. But because that drives off volatile flavor molecules, many other processes omit that step.

OK, so sure, fermentation is the process by which microbes turn edible or inedible raw materials into different edible materials. Great. What does that have to do with food preservation? Well, here's another clever thing. A fermented food is *already* rotten — the good bits (from a microbe's point of view) have been munched up. And the chemicals produced by the fermenting microbes are even worse, again from the microbe's point of view. If you're squeamish, you may wish to look away at this point and rejoin us in the next paragraph. Still here? Remember how microbes consume certain molecules and generate others? Well, that generation isn't just helpful, carefully constructed generation, as with pharmaceutical fermentations. In general, what fermenting microbes excrete is what every living thing excretes: waste. And waste *is* waste, from the organism's point of view, because it contains compounds that are detrimental or poisonous to the organism. Just as we couldn't live in a sea of urine (ew!), yeast can't live in a sea of ethanol. It's why fermented beverages like wine and beer have an upper limit on ethanol content — the environment eventually becomes too poisonous for yeast to go on growing. A fortunate byproduct? It's too poisonous for most other microbes, too! Hence, food is preserved!

So to return to the first unit operation. We now have a list of specifications for our intellectual ancestor, the first chemical engineer, to put into practice in her fermentor. A fermentor needs to be waterproof and contamination-resistant. If it's possible for the fermentor to be held at a consistent, known temperature, that's also a plus. How do we put these specifications into play in a world without plastic, glass, or large-scale metalwork? How about an earthenware pot with a narrow neck and fitted lid that is embedded into the wall of a house or partly buried in its floor! The narrow neck cuts down on contamination and limits gas exchange, as does the lid — gas exchange can happen around the edges of the lid, but contamination will be cut down by the creation of a circuitous route for exchange (as was documented by Louis Pasteur with his swan-neck flasks in 1859). And once fermentation is done, her beer or wine will be improved by the reduced exposure to oxygen. Setting the fermentor into the large mass of the wall or the floor ensures a more constant, although uncontrolled, temperature throughout fermentation.

Earthenware pots of just this design have been discovered in the country of Georgia, where at least 8,000 years ago our first ChemE used them to make wine.[2] It's such a robust design that Georgians are still using similar pots, called a "kvevri" or "churi," partially buried in their basements, in wine-making to this day. Given that the archeological evidence is probably of a widespread practice and not the first fermentor, it's possible that our first unit operation is two orders of magnitude older than our profession. So raise a glass of your favorite fermentation product in honor of the neolithic ChemE and the first unit operation, the fermentor!

REFERENCES

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