The ‘magic mix’ of ingredients responsible for the Impossible Burger’s taste and texture

The Food and Drug Administration just gave the thumbs up for the major beef-like ingredient in the the Impossible Burger, soy leghemoglobin. Upon cooking, it reacts to generate heme, the source of the redness of beef. The science behind the Impossible Burger is fascinating, so I went straight to the source rather than relying on the media echo chamber — the patent. But I’ve also eaten quite a few.

My first encounter with the Impossible Burger was pinching a piece off my dinner companion’s plate in February. It looked and seemed to bleed like a real burger. As I chewed, I googled the product on my phone, stopping at the word “*heme*.”

Gulp.

I stopped chewing. Once I got past the image of a bovine muscle pulsating on the plate, I envisioned the iron atom within its porphyrin ring, both lying within a surrounding globular protein, a little like a tootsie roll pop.

Heme in various guises is found in all species, from bacteria to beans to buffalos. It’s at the heart of the myoglobin in our muscles and the hemoglobin in our blood, packed most densely into the muscle cells of beef cattle.

Proteins that are the same or similar among diverse species are called “highly conserved.” They’ve not changed much through evolution because they work. Natural selection weeds out mutations that stifle the

ability to bind oxygen, which is what the iron atom at the center of the action does. All hemes have iron, but the protein globin parts vary, ever so slightly, among species.

The trick in creating a meatless burger that tastes and feels meaty is in finding an organism whose heme-plus-protein imparts what's described as savory, bloody, or just beefy.

I've been trying different brands of veggie burgers since ditching beef 18 months ago in the wake of a near-simultaneous cancer diagnosis/trip to Costa Rica, against a backdrop of our daughter urging us to do so for more than a decade (see How Genetic Testing Guided my Breast Cancer Journey to Eschewing Beef). The images on veggie burger packages depict enticing chunks of sweet potato, black beans, peas, and carrots peeking from patties consisting of the ubiquitous soy protein. These products provide palatable *alternatives* to burgers, but they're not quite the real deal. The Impossible Burger comes closest, with the Beyond Burger a close second with its pea protein based recipe.

Patent number 9,700,067 B2

The 52-page patent, awarded in 2017 after many years of work to Impossible Foods of Redwood City, CA for "magic mix," opens with two-columned pages of patent and article citations.

The meat of the patent begins with a list that might ring a bell for biology or chemistry majors: the amino acid sequences of the heme proteins from 25 species, including the top candidates for the Impossible Burger vertebrate flesh equivalent. The 25 contenders include peas, bacteria, algae, soil fungi, horse, cattle, tobacco, wild boar, and a paramecium.

The winner is at the end of the first patent claim: *"A ground beef-like food product comprising 0.1%-5% by weight of a heme-containing protein comprising an amino acid sequence having at least 80% sequence identity to the polypeptide set forth in SEQ ID NO:4."*

SEQ ID No. 4 is *Glycine max*, aka soybeans.

The heme protein, leghemoglobin (legHB), reddens root nodules of soybean plants. It provides oxygen to its symbiotic bacteria, similar to hemoglobin transporting oxygen in our blood and myoglobin in our muscles. But even the millions of acres covered in soybeans in the US aren't enough to meet the projected demand for legHB in burgers.

Recombinant DNA technology to the rescue

The obvious way to scale up production of a specific protein is to use recombinant DNA technology: make the soybean protein in cells of another, easier-to-harness, species.

When recombinant DNA technology was invented in the 1970s, the tag GMO was still years away. Early on a pattern emerged of some people objecting to agricultural experiments and even destroying experimental fields and one notable strawberry patch, while people with diabetes began to use insulin made in bacteria like *E. coli*, as they still do. It's always been a fractured field, but recombinant DNA

technology is here to stay. The pharmacopeia courtesy of the technology today includes clotting factors, enzyme replacements, heart drugs, cytokines, surfactant, hormones and growth factors, and lots more.

The researchers at Impossible Foods stitched the soybean gene that encodes legHB protein into the genome of a different organism that can pump it out more efficiently (cheaply): the yeast *Picchia pastoris*. A yeast is a single-celled fungus, but it's a complex cell, unlike a bacterium.

A single sentence in the 52-page patent spells this out: *"Heme-containing proteins also can be recombinantly produced using polypeptide expression techniques"* and can be grown in the cells of bacteria, insects, fungi, plants, or mammals. "Also" refers to extraction from natural sources or synthesis in a lab.

Is it a GMO?

Does an Impossible Burger contain a GMO? Well, yes and no. Yes because a soybean gene wouldn't naturally be in a yeast cell. But no because the legHB that the yeast cells crank out is identical, amino-acid-by-amino-acid, to the protein from soybean root nodules. So the yeast is genetically modified, the product, not.

It's a distinction with a precedent, and Impossible Foods' Chief Science Officer David Lipman grabs it in this 2018 interview for *Food Dive*. He cites the 1990 FDA approval of the first recombinant DNA food product, rennin (aka chymosin), after being deemed "genetically recognized as safe," or GRAS.

Rennin, used to curdle milk in cheese-making, is part of a mixture of digestive enzymes collected from calf intestines. Making it in *E. coli* given the cow gene for the needed enzyme is much cheaper. Regulations can be confusing. In the US, recombinant chymosin need not bear the GMO label because the protein that makes it into the product is identical to the protein straight from the natural source organism.

In the interview, Lipman uses the word "fermentation" repeatedly, which conjures folksy images of vats of sweet wine and aging pungent cheeses. "Recombinant DNA" and "genetically modified" elicit different responses, such as in this post calling the Impossible Burger out on its GMO ingredient. But the FDA deemed magic mix GRAS in January 2019 and so the burger doesn't require GMO labeling.

After the heme

The heme protein is only one ingredient of magic mix.

To fashion the burger, "flavor precursor molecules" are added. These include coconut and other plant oils, potato and texturized wheat protein, sugars, amino acids (like monosodium glutamate), one vitamin, and familiar compounds like lactic acid and creatine.

Here's the patent lingo: *"a compound selected from glucose, ribose, fructose, lactose, xylose, arabinose, glucose-6-phosphate, maltose, and galactose .. and … cysteine, cystine, selenocysteine, thiamine, methionine, and mixtures of two or more thereof."* But all foods are, ultimately, chemicals. Everything is a

chemical.

Creating the Impossible Burger also analyzed the volatiles the concoction emits upon cooking. “Trained human panelists” and other humans who deployed gas chromatography–mass spectrometry, a standard analytical chemistry test, analyzed the release of the meaty aromas upon cooking, producing “olfactory maps.” The goal was to optimize the flavor, taste, smell, texture, and the all-important “mouthfeel” of the product. Like software, new versions would come out periodically.

The meaty mash is also malleable, molded into faux body parts like wings and steaks, extruded as sausages, crumbled up delicately in soup and stew bases, and easily converted into a smorgasbord of snacks, cubes, and powders. The FDA approved the key soy leghemoglobin component on July 31.

My verdict

I’d give the Impossible Burger a grade of “A” for mouthfeel and texture, which may be the same thing. But I’d give only a B-plus for flavor, taste, and smell, because it didn’t have them. But add cheese, fried onions, a pickle, and a dollop of Sweet Baby Ray’s, and it can indeed pass for a real patty of *Bos taurus* flesh. At least the one I had lacked that deep flavor of 85%-fat burger coming straight off the grill.

On a scale of 0 to 10, with 10 being a beef burger and 0 the worst veggie burger imaginable, most products I’d rate in the 4 to 6 range, with an Impossible Burger a robust 9.

A data-packed paper in PLOS One reaches a similar conclusion: “By fulfilling the same gustatory, culinary and nutritional functions as traditional beef, the PBB (“plant-based burger”) aims to lower the adoption barrier associated with the consumption of vegetal proteins in lieu of animal products.” Two of the four authors work at Impossible Foods, but still, I think they’re right. This product can replace burgers for omnivores, and perhaps win over some vegetarians.

Beyond personal preferences and tastes, the Impossible Burger achieves its stated goal: producing it doesn’t kill any animals. It also earns high marks for environmental friendliness. According to a post at *Fast Company*, the carbon footprint of an Impossible Burger is 89% smaller than that for a cowburger and uses 87% less water, 96% less land, and cuts water contamination by 92%. The *PLOS One* article analyzes the environmental impact too.

I’m looking forward to Impossible Burger, in whatever form, hitting supermarket shelves. I’m eager to try it as meatballs. When I did this with Beyond Burger, already available in some grocery stores such as Shop Rite, the crockpot produced an inedible cement-like substance, which, however, my cats loved.

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