



FoodPrint.

The FoodPrint of Fake Meat

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One real meat and two meat-free patties



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Foreword

Several years ago, I found myself at a food-tech investment conference in a tony San Francisco hotel ballroom. I'll never forget the first pitch deck I saw that began with a screed against the horrors of factory farming. Slide after slide shared some of the impacts: the toll on climate and biodiversity, for instance, the link to foodborne illnesses and antibiotic-resistant bacteria. The arguments echoed ones I'd been hearing my whole life, raised by a mother who had published her first book, *Diet for a Small Planet*, two years before I was born. In that book — revisited this year in a celebratory 50th anniversary edition — my mother, Frances Moore Lappé, documented the enormous inefficiencies built into industrial livestock production: Turning over vast amounts of prime agricultural land to raise crops to feed livestock was just one of the elements of waste in the design of factory farms, what she dubbed “protein factories in reverse.”

The book also included one way to be part of taking on this industry: more than 100 recipes to help center plants on your plate.

Today, fifty years on, we can see the multifaceted impacts of industrial animal production and the increasingly ultra-processed meat products that line our supermarket shelves: the environmental harm tied to feed crop production and animal waste and the human health harm, too. We also have even more evidence about how a plant-rich diet is a foundation for a healthy diet and the health implications of diets high in red meat and processed meats. In 2015, the world's leading cancer agency determined that processed meats are carcinogenic and long-term health studies have clearly shown the impact of consuming high amounts of red meat and processed meat, from increased risk of Type 2 diabetes to cardiovascular disease. We also know so much more about how the toll of this industry plays out in other ways, too: meatpacking plants are among the most exploitative and dangerous places to work and the decades-long de-unionization drive in the industry has made them only more so since the 1970s.

All this brings me back to that hotel ballroom. Many of the pitches I heard were for a new wave of products just hitting the marketplace, pitched as powerful disrupters to an industry that some value at over \$1 trillion annually: high-tech ultra-processed meat alternatives made from plants, not animals.

There is no question that there is an urgent human health, environmental, and worker well-being need to disrupt the industrial animal agriculture sector. Will these new products help us do just that?

In this timely new report, FoodPrint digs into the questions behind the spin: What are the environmental impacts of these products? What are the health properties of these foods? What are the opportunity costs of investing public and private research dollars into these products and not other paths for food system reform? These questions become even more paramount as we hear calls for massive public investment into research and development into ultra-processed meat alternatives or into purchasing these products for public institutions, like our nation's schools.

To date, many of the claims of the benefits of these products have come from the companies themselves, their investors, or non-profit organizations whose mission is to expand the markets for these products, so this report is a welcome addition to a critically important public conversation. For those of us who care deeply about transforming our food systems to ensure greater sustainability and justice along global supply chains, asking questions about these new products is vital and this report helps us begin to ask — and answer them.

- ANNA LAPPÉ

Author, "Diet for a Hot Planet: The Climate Crisis at the End of Your Fork and What You Can Do About It"
Contributor, "Diet for a Small Planet: The 50th Anniversary Edition"
by Frances Moore Lappé

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Introduction

Meat-free alternatives to burgers, bacon and sausage are now offered everywhere, from fast food chains to restaurants to grocery meat cases, with more entering the market every day.¹ For those who want to avoid eating animals, fake meat has been made and marketed in a variety of ways, for a long time. But this new wave of ultra-processed alternative meat products — like Impossible Burger, Beyond Meat and even lesser-known brands from meatpacking companies like Tyson Foods and Cargill — represent something different. They are being marketed to meat eaters, and the people who make them insist that they are better for animals, the climate and human health, too.

With the plant-based industry growing twice as fast as overall food sales, the products are appearing everywhere. Even though they make up less than 2 percent of the market for meat, investors and the media have breathlessly celebrated their continued upward sales trajectory.² ³ Many, especially the company owners, insist that these products will drastically cut into meat consumption, curtail meat production and save us from the catastrophic effects of climate change.⁴ If true, that would be something to celebrate.

Our industrial food system is wreaking havoc on our planet. Industrial meat production, especially beef, contributes 14.5 percent of global greenhouse gas emissions, making it a top contributor to climate change.⁵ The United Nations' IPCC Report on Climate Change identified that shifting diets away from meat to plant-based menus has the power to help us fight climate change by drastically cutting our greenhouse gas emissions.⁶

In this report, we ask questions about these assumptions and dig deeper into how these products deliver on promises of lower environmental impact, fewer animals in production, and improved personal health. We examine whether the adoption of these products into daily diets is health-promoting and also whether it is chipping away at industrial meat production and consumption, as the industry promises, to reduce the number of animals that suffer in factory farms.

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Fake meat burgers



We also examine what it means to compare these products with their industrial meat counterparts instead of comparing them to more sustainably produced meat, or to truly plant-based protein sources, like beans. We attempt to answer the question: are *these* food products the solution to our very real problems: a climate crisis, an animal welfare crisis and a public health crisis? Is more technology what is needed?

While the companies marketing this new generation of ultra-processed alternative meat products are eager to capitalize on the idea that any shift towards plant-based eating can deliver huge wins for animals, people and the environment, some of these promises are unproven, and some clearly untrue. With pundits going so far as to suggest that meat alternatives merit government investment,⁷ it is important to move past the hype and ask whether they can really change the food system, or if they are yet another avenue for the food industry to sell unhealthy food, make money, consolidate power and avoid regulation.

What a Healthy and Sustainable Diet Should Look Like

Our diets have many impacts on the environment, and climate change is one of the most urgent ones to address. The standard American diet is heavy in industrially produced meats and ultra-processed foods, both of which rely on industrially raised crops that make them some of the most greenhouse-gas intensive foods to produce. There are many different eating patterns that can help minimize our carbon footprints, but many experts in both health and environmental fields agree that the diets that are healthiest for both humans and the environment are rich in whole foods, especially plants.⁸

A healthy, plant-rich diet should:

- Center minimally processed, mostly whole foods
- Minimize highly processed and ultra-processed foods like packaged snacks and sweets
- Be rich in fruits, vegetables, grains and legumes produced without chemicals
- Include only moderate amounts of meat, dairy, fish and other animal products rather than making them the center of every meal
- Source ingredients from sustainable farming systems — especially those grown in diverse ecosystems with few or no chemical inputs — using USDA Organic, biodynamic, and other meaningful labels whenever possible, and prioritizing foods from local farms that use regenerative methods

The Basics of Ultra-Processed Meat Alternatives

The products we will be discussing in this report are generally called, by those who produce and market them, “plant-based meats.” We prefer the term “ultra-processed meat alternatives” because we feel it more accurately describes this group of products: they live in the arena of existing ultra-processed foods and carry with them the same health problems that public health experts have alerted us to with other highly processed foods.



Fermentor using yeast to produce the leghemoglobin

We will not be covering lab-grown meats, which are part of the market development for alternative meat products, which are outside the scope of this paper and also not widely available to consumers.

We will be confining the discussion to fake meats, even though plant-based milks, like almond, soy and oat, have come into the mainstream, and new products like plant-based tuna, eggs, shrimp and so forth are becoming more and more available.

PROCESSING PLANTS TO MAKE IMITATION MEATS

It is not a new concept to process plant-based foods that are rich in protein and to use them as the centerpiece of a meal. These foods can be made with varying degrees of processing, from minimally processed — for such products as beans and tofu — to highly processed — for such products as a faux chicken nugget. (We will delve more deeply into the problems with highly processed foods in the health section of this report).

Many plant-based foods are rich in protein, and many cultures around the world have long traditions of using plant ingredients to help supplement, stretch or imitate meat products. Vegetarians from many culinary traditions have relied on minimally processed or naturally fermented, protein-rich foods like tofu, tempeh and seitan for centuries. While these products are often eaten and enjoyed on their own terms, they have also been used to create a variety of “mock” meats, particularly in Asia, where Chinese Buddhists, for example, have eaten gluten or soy products designed to imitate everything from duck to pork to squid.⁹ There have also been, for a

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long time, even less processed protein-rich foods like lentil patties offered in India or falafel in the Middle East. The notion of obtaining protein-rich foods from real plants with minimal processing has been done for hundreds if not thousands of years.

There is also a long tradition in the West of people avoiding meat, dairy and eggs for moral, health or environmental reasons. In recent decades, people have turned to highly processed soy, vegetable, grain, fungi and legume-based patties, nuggets, sausages and the like from companies like Boca and Quorn, as well as less processed options like the black bean burgers on offer at vegetarian cafés or featured in iconic 1970s vegetarian cookbooks, like the recipe section of “Diet for a Small Planet.”

In recent decades, food scientists have developed more sophisticated, lab-based ways of changing the textures and flavors of foods. Unlike earlier plant-based foods, the latest generation of meat alternatives are ultra-processed, meaning that they are made almost entirely from isolated ingredients like protein concentrates, purified oils and extracted flavorings containing no whole-food ingredients. When these ingredients are put through high-tech, proprietary processing, food companies can produce imitations that come much closer to the tastes and textures of animal meat.

Because this more complex ultra-processing allows them to imitate meat so convincingly (Impossible Burger’s ability to “bleed” is a key selling point), these high-tech, high-investment products can access a new market: meat eaters. While companies push these products as the solution to the negative impacts of the industrial meat industry, their potential to disrupt the global meat market also makes their patented processes and ingredients potentially valuable investments for new startups and established meatpackers alike.

WHAT ARE IMITATION MEATS MADE OF?

Meat alternatives are formulated from a mix of ingredients, including protein isolates, fats, flavorings and other additives. Like older generation plant-based proteins, the proteins that make up ultra-processed meat alternatives come from crops; but unlike the ones used in tofu and other

Fake meat patties



products, these are far more processed versions of the ingredients. Most of these newer products use chemically extracted protein isolates or concentrates from soy or peas, rather than the whole beans themselves.

These chemically extracted proteins are cooked and pushed through a machine that blends and shapes them into strands resembling short muscle fibers as they cool, allowing manufacturers to imitate a range of processed meat products convincingly.¹⁰ Food scientists are also developing processes to create larger pieces of imitation muscle fiber, widening the range of available meat substitutes, from ground meat imitations to other meat products, like chicken tenders and even whole cuts of meat.¹¹

Brand Name	Parent Company	Replacement Meat Type	Protein Type				Unique Ingredients
			Soy	Wheat	Pea	Other	
Impossible	Impossible Foods	Beef, Sausage	x				Soy leghemoglobin (heme); fortified with B12, folate, zinc
Beyond	Beyond Meat	Beef, Sausage			x	Myco-protein	Beet juice for coloring
Quorn	Monde Nissin Corporation	Beef, Chicken					Carrageenan
Abbot's Butcher		Beef, Chicken			x		Non-GMO
Sweet Earth Enlightened Foods	Nestlé USA	Beef, Chicken, Deli Meat		x	x		
Tofurky	Turtle Island Foods	Beef, Chicken, Deli Meat	x	x			Carrageenan
Ozo Foods	JBS	Beef, Sausage			x		Shiitake-fermented plant protein
Pure Farmland	Smithfield Foods	Beef, Sausage			x		
Before the Butcher		Beef, Chicken, Sausage	x				Medium chain triglycerides
Lightlife	Maple Leaf Foods	Beef, Sausage, Deli Meat	x	x	x		Carrageenan
Trader Joe's		Beef, Turkey			x		Beet juice for coloring
Simulate Products		Chicken	x	x			Non-GMO
Daring		Chicken	x				Non-GMO
Raised and Rooted	Tyson Foods	Chicken		x	x		Medium chain triglycerides
No Evil		Chicken, Sausage		x			No oil or fats



Fats are also integral to bringing a convincing texture to meat alternatives. Animal meats contain a mix of saturated and unsaturated fats. It's the saturated fats — which are solid at room temperature and partially melt through the cooking process — that give meat its richness, moisture, and chew.¹² Meat alternative manufacturers use both unsaturated oils like canola and soybean and plant-derived saturated fats like coconut and palm oil. Nutritionists advise us to consume fats — especially saturated fats — in moderation, regardless of whether they are from plant or animal sources.¹³

Added flavorings are also part of many ultra-processed meat alternatives. In many products, the characteristic “meaty” flavor (which chefs and food scientists call umami) comes from yeast extracts, similar to the nutritional yeast that many vegetarians know as a seasoning. These flavorings differ from more complex products, like soy leghemoglobin, that are derived from genetically modified yeast and used in some burgers to give a “bleeding” effect. Other fungi, like mushrooms, are a rich source of vegetarian umami flavoring, so some products incorporate mushroom extracts or partially ferment their primary protein ingredients using cultures from mushrooms like shiitake.

One of the most recognizable elements in animal meats, particularly red meats, is heme, the red-colored compound in blood. Heme gives color and flavor and can be difficult to imitate as it turns from red to brown when cooked. Many products approximate the color and “bleed” of animal meat with vegetable-based ingredients like beet juice or tomato paste,¹⁴ but one manufacturer, Impossible Foods, includes a compound called soy leghemoglobin in its products, a heme-

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like, plant-derived compound. While Impossible Foods originally isolated this ingredient from the roots of soy plants, today, they use genetically modified yeast to produce large amounts of soy leghemoglobin in fermentation tanks.¹⁵ Regulation of this patented new ingredient has been controversial, as it has never been used in food before.

Beyond the umami taste, the flavor of real meat comes mainly from smell.¹⁶ In meat products, proteins and sugars react at high temperatures to create an array of aroma compounds that are responsible for rich grilled and roasted flavors. Plant proteins lack many of the chemicals needed to react this way, so they are extracted from natural sources and combined to produce aromas that closely resemble specific meats. These are added back into the plant-based products as natural flavors.¹⁷ Other vegetable-derived, natural flavors, particularly those from savory plants like onions, may be included. Products like sausages typically include spices like those found in the meats they are imitating.

The Problems Ultra-Processed Meat Alternatives are Intended to Solve

It is without question that we need to eat much less industrially produced meat. From the ecologically damaging way that livestock feed is grown, to the resulting water and air pollution, to the workplace and animal welfare horrors of the factory farm system, conventional meat production carries a hefty price tag for people, animals and the environment. Nearly 99 percent of the meat sold in the US is conventionally produced,¹⁸ which means that most of the meat products people are eating are part of the problem. There is the additional problem of our cultural attachment to cheap, factory-farmed meat and the fact — either perceived or real — that most meat eaters in this country are not willing to cut back on something that they believe to be so culturally and nutritionally essential.

These products are marketed as a solution to all of the above, so it's worth digging into each of these problems, and what is at stake.

ANIMAL WELFARE PROBLEMS WITH INDUSTRIALLY PRODUCED MEAT

It is impossible to deny that the dominant US meat production system is broken. Animals live much of their lives confined in concentrated animal feeding operations (CAFOs), also called factory farms. Here they are treated as units of production, as





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“protein,” rather than as sentient beings. Animals in confinement generally live in crowded and cruel quarters, are subject to inhumane processes like amputations (to control behavior) and are unable to engage in natural behaviors like grazing, rooting, or playing.

When animals go to slaughter — more than 32 million cows, 131 million pigs and 9 billion chickens every year in the United States alone — they are subjected to even more cruel treatment and suffering through inhumane slaughter practices.^{19 20} Slaughterhouses are cramped, loud and terrifying to animals. Even when facilities theoretically adhere to animal welfare standards, the sheer volume of animals that are slaughtered every day means that they will be treated carelessly, as pre-slaughter sedation measures often fail.²¹ This means that many animals spend the last moments of their lives under immense stress and suffer a painful death.

ENVIRONMENTAL IMPACT OF MEAT PRODUCTION

The conventional meat system carries a large environmental footprint, too. Because feeding livestock adds an entire link to the food chain, eating animal meat is less efficient than eating plants directly. Growing crops to feed livestock takes up an enormous amount of farmland, water and other resources; producing one gram of protein from beef, for example, can take 100 times more land area than producing a gram of protein from a plant source like beans, peas or soy.²² The industrial farms that grow these crops pollute water with excess fertilizers, causing dead zones in the ocean and contaminating groundwater. Insecticides and herbicides are also overused, harming pollinators, hastening the collapse of insect populations, and accelerating the evolution of herbicide-resistant “superweeds.”^{23 24}

Beyond feed, the factory farms themselves cause significant environmental problems. Manure from CAFOs can contaminate water supplies by seeping or overflowing from storage lagoons or overapplied as fertilizer, and the fumes from decomposing waste can exacerbate asthma and other health conditions. This worsens health problems for people living near CAFOs, which are often located near low-income communities and communities of color lacking the power to fight back against polluting industries.²⁵

Greenhouse gases are the most significant environmental impact of animal agriculture, with livestock being responsible for 14.5 percent of global greenhouse gas emissions globally.²⁶ Methane, which is a more potent greenhouse gas than carbon dioxide, is a particular problem; cattle are the largest single source of methane emissions in the US, outpacing even

natural gas production.²⁷ Methane, carbon dioxide and other greenhouse gases retain more of the sun's heat than other gases in the atmosphere, so extra emissions speed up global warming and climate change. Because meat production is such a large source of greenhouse gases, curbing emissions from the industry should be one of the top priorities for slowing climate change.

MEAT PRODUCTION, PUBLIC HEALTH AND OCCUPATIONAL SAFETY

The crowded, hot, and unsanitary conditions in CAFOs are the perfect spreading ground for diseases. About 70 percent of the medically important antibiotics sold in the US are used on farms, where producers use low doses of antibiotics in animal feed to prevent disease and promote growth.²⁸ This provides an ideal environment for antibiotic-resistant bacteria which also infect humans, to evolve. The World Health Organization has called on countries to aggressively curb antibiotic use in agriculture.²⁹

Viruses, like COVID-19, can also pass between people and animals. CAFOs have already been the origin of one human pandemic: the 2009 Swine Flu outbreak was ultimately traced to a packed hog farm in Mexico. Researchers warn that CAFOs are the most likely place for another pandemic to originate.³⁰ These risks are highest for workers on CAFOs, who already experience altered flu seasons due to the exchange of viruses between people and animals.³¹

Health and safety concerns don't end once animals are off the farm. Slaughterhouses and packing plants are also home to some of the worst working conditions in the food system, with high rates of employee injury, poor compensation and few protections from risks like COVID-19.³² Food safety is also a major concern. Rushed slaughter and processing speeds increase the risk of meat being contaminated with fecal bacteria and other contaminants like salmonella and E. coli. These can cause serious illness and death: the CDC reports that meat and poultry are responsible for more foodborne illness fatalities than any other kind of food.³³

MEAT INTAKE AND PERSONAL HEALTH

While producing so much meat is environmentally destructive, consuming so much meat is deleterious for personal health. While most nutritionists agree that limited amounts of meat can be part of a healthy diet, the average American eats far more meat — about 138 pounds per year — than the recommended 84 pounds.^{34 35} Excess meat intake is a major source of extra calories in the American diet, which fuel the epidemics of obesity and diabetes. Processed meats are especially problematic, with





Feedlot



Meat processing facility



Cooked real beef steak

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the International Agency for Research on Cancer declaring them to be known carcinogens, reflecting the fact that their high consumption increases risk of colorectal and other cancers.³⁶ They are also associated with elevated risk for heart disease, strokes, and other cardiovascular disease.³⁷

APPEALING TO A NEW AUDIENCE

One problem which these products position themselves as a solution to is the quandary of meat lovers' not wanting to (or being unable or unwilling to) give up meat. After all, with the rich history of vegetarian cooking and products, and so many meatless options already available, you might wonder why there is a need for "new technology" that provides even more meat-free "meat." The answer is that companies developing and promoting these new ultra-processed meat alternatives are trying to capture a new market share: the non-vegetarian meat lovers who never imagined they could give up something they love so much. As Pat Brown, founder and CEO of Impossible Foods has said, "The only consumer we care about with our products is the hardcore meat eater."³⁸ That's probably why one of the first of these products, Impossible Burger, was engineered to "bleed."

These products' potential appeal to the carnivorous market makes them exciting to investors, but also to those who feel our diets aren't changing fast enough in response to an accelerating ecological crisis. So far, the meatless options out there have not succeeded in swaying meat lovers away from meat in high enough numbers to make a difference. Creating a product that is more meat-like aims to speed up that conversion process. And repositioning the traditionally unexciting field of food science as planet-saving "tech" helps position meat alternatives as a solution to stubbornly high meat consumption rather than as another highly processed food.

In an attempt to reach a wider audience, part of the messaging for these products is that you can make them part of a "flexitarian" lifestyle.³⁹ While some of the mission-driven companies have said that their goal is to eliminate animal products completely, they have also promoted their products with the messaging that you don't entirely have to give meat up to make a difference to the planet or your health.⁴⁰ Their marketing suggests that even a few careful swaps can meaningfully chip away at your former rate of consumption and decrease your personal footprint. So far consumer data seems to suggest this is working. 98% of people buying these alternative meat products in the US are also buying conventional meat.⁴¹

Also included is a promise that these products will really deliver on the dietary protein front. To the protein-obsessed worried about meeting their nutritional needs — despite research

showing that most people are eating nearly twice as much protein as their bodies require — they promise to keep protein at the center of the plate.⁴² Essentially, these products promise that not much needs to change. You can still experience the taste and pleasure of meat, even indulge in a fast-food meal. You can still compose your plate the same way, with meat at the center, maybe on a bun.

Environmental Impacts of Ultra-Processed Meat Alternatives

It's clear that replacing industrial livestock would be a win for animals and animal welfare: the question is whether these products are the answer. There's good reason to second-guess the claim that such products are environmentally friendly. They might have a lower environmental footprint than industrial meat, but performing better than the most polluting products in the food system is a low bar to clear. Like other ultra-processed foods and conventional meat, they are still the product of industrial agriculture. It's important to look at all the issues involved in producing ultra-processed meat alternatives and compare how they stack up against a broader range of sustainably produced, whole plant and animal foods. Given that companies market meat alternatives as a way for consumers to be part of the solution to the problems of our food system, these comparisons are important for people who are trying to make the most sustainable food choices for themselves.

THE PROBLEM WITH MONOCROPPING

The legumes and grains that make up both conventional livestock feed and most meat alternatives are farmed in industrial monocultures, large areas of just one species that are simple to maintain and harvest. While monocultures take less labor than biodiverse farms, they are environmentally intensive to maintain, with a heavy reliance on chemical fertilizers and pesticides. This system has several negative impacts on the environment: producing these chemicals emits a huge amount of greenhouse gases and using them throws natural nutrient cycles out of balance. Soils under chemically intensive monocultures are low in beneficial microorganisms and invertebrates, which help recycle nutrients from dead plants.^{43 44 45} Because they are often heavily plowed, they quickly lose the organic matter that makes them naturally fertile through a mixture of erosion and decomposition.⁴⁶ This organic matter holds a huge amount of carbon dioxide, and destroying it accelerates climate change.

Iowa cornfield





Tractor spraying pesticides

Products that are made with soy often come from soybeans that have been genetically modified to resist the herbicide glyphosate or other weedkillers. This allows farmers to spray entire fields in herbicides, killing weeds and leaving the plants intact. This damages soils, harms insects, and accelerates the evolution of “superweeds” that resist multiple herbicides, pushing farmers to use more and more toxic chemicals in addition to glyphosate.^{47 48 49}

While some brands do source non-GMO ingredients, at least one brand, Impossible Foods, advertises its use of GMOs as being environmentally progressive.⁵⁰ In addition to their use of GM soybeans, the company also produces its soy leghemoglobin using GM yeast. While there are few environmental risks associated with the yeasts, which are grown indoors, some consumers seek to avoid GMOs out of concern about consuming new ingredients like soy leghemoglobin.

While meat alternatives are made from crops that can be environmentally damaging, they are still marketed as a better choice than conventional meat products. This is mainly because conventionally raised livestock eat an enormous amount of corn, soy and other industrially raised crops, making meat alternatives look relatively efficient when they are quantified in terms of emissions, water use and other measures (through techniques like life cycle assessment). But while side-by-side comparisons might point out specific differences between an industrially raised beef burger and a Beyond Burger, for instance, they aren’t a holistic assessment of sustainability, and often miss costs and benefits of foods that are more difficult to quantify.

BETTER THAN WHAT? MAKING FAIR COMPARISONS TO OTHER FOODS

There are many ways to assess the sustainability of a product numerically. One of the most common is called life cycle assessment (LCA). By carefully modeling every step of the production process, LCAs provide an estimate of the resources needed to make a food and how much waste and emissions are created in the process. Ultimately, this can be used to estimate the gallons of water or the kilograms of CO₂ produced for every four-ounce burger patty, for example. LCAs often assess two products side by side to give a clearer picture of how different choices stack up against alternatives, though they can’t measure every dimension of sustainability.

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Several meat alternative manufacturers have commissioned LCAs of their products, and they generally compare the product with the conventional version of the meat they imitate. These comparative LCAs demonstrate that — at least in terms of greenhouse gases, water use and some other measures — meat alternatives have a smaller environmental footprint per serving than a similar amount of conventionally produced beef or sausage. According to these LCAs, producing a four-ounce Beyond Burger, for example, uses only ten percent of the land it takes to produce a four-ounce beef burger. It also produces only ten percent of the greenhouse gas emissions and takes less than one percent of the water.⁵¹ Numbers for the Impossible Burger are similar, emitting only about eight percent of the greenhouse gases that would be generated by an equivalent amount of beef, and using only about twelve percent of the water (significantly more than the many other meat alternatives).⁵²

It's worth noting that LCAs are often used as a way for companies to market their products as sustainable, and this can limit their accuracy and objectivity. If they have good data and independently verified results, LCAs can be valuable comparative tools, but they still miss some of the most important dimensions of sustainability: soil health, biodiversity impacts and other parameters that are hard to gauge.

Choice of comparisons is also critical, and limiting the comparisons with conventional meat does not show the full picture. Considering that the latest generation of meat alternatives mainly imitates widely consumed fast-food products, the comparison is a logical one. But because these products are increasingly sold directly to consumers and in higher-end restaurants — where they might displace other plant-based foods as well as an array of regeneratively raised meat products — it's worth weighing how they stack up to less processed protein products. For instance, producing a kilogram of Impossible Burger meat emits 3.5 times more greenhouse gases than a kilogram of tofu.^{53 54} Considering that newer-generation, ultra-processed meat alternatives are replacing other vegetarian menu items at restaurants, these become important considerations for assessing how these meat alternatives would change the footprint of the food system overall if they were more widely adopted.

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Researchers comparing the costs, benefits and feasibility of different sustainable proteins have ranked ultra-processed meat alternatives below options like beans and even insects when it comes to sustainability.⁵⁵ Whole food sources of protein, like beans and other legumes, generally have smaller footprints than their ultra-processed counterparts, with beans ranking as one of the best protein sources in terms of land use, water consumption and greenhouse gas emissions.⁵⁶ These whole food options are also easier to source from farms that practice organic and regenerative methods, which drive their impact far lower than products made with conventionally produced crops.

WHAT SUSTAINABLY RAISED MEAT HAS TO OFFER

While most of the meat consumed in the US is conventionally produced, there is a growing market for meats coming from animals that are sustainably raised on pasture. There is also a growing movement of scientists and advocates who are researching and demonstrating that solutions to the climate crisis and calls for better animal welfare can both be answered by raising livestock in regenerative systems.

Pasture-raised livestock also offers a number of environmental benefits, especially for soil. Animals are natural nutrient cyclers, turning plant matter back into carbon and nitrogen, which helps support deeply rooted pasture environments to store more carbon and prevent soil erosion.⁵⁷ These gains are most notable on land that has been degraded by years of industrial crop production, restoring biodiversity and soil fertility. One study found that beef cattle that are carefully managed can help restore carbon to the soil, resulting in beef that was able to sequester 4.4 kg of carbon dioxide equivalents per kg of meat.⁵⁸ This means that the recovering soil absorbs more carbon dioxide from the atmosphere than the animals emit. Some researchers have suggested that replacing much of the cropland used to grow grain for livestock with managed pasture could even reverse the erosion-related loss of soil carbon on US cropland, helping to curtail agricultural emissions even further.⁵⁹

Regenerative grazing's benefits extend beyond soil carbon: Biodiversity of plants, animals, and microorganisms is also higher on well-managed pasture than it is on monocultured cropland, lightening the negative impacts of animal production on the surrounding environment and even providing habitat for some species. In addition, because animals live in uncrowded conditions where they can engage in more of their natural behaviors, animal welfare is far higher than it is on factory farms.

Considering these benefits, it is important that as people, companies and governments invest heavily in solutions to the problems of industrial livestock production, they consider that regeneratively raised meat might be a better choice than embracing ultra-processed meat alternatives.

Health Questions About Ultra-Processed Meat Alternatives

Healthy diets can come in many forms, including diets that are completely plant-based, or vegan. Whether or not diets include animal products, what makes them healthy is an abundance of whole plant foods, like grains, nuts, seeds, fruits and vegetables. But even without these ingredients, diets that exclude animal products may benefit from what nutritionists call a health halo:

the perception that foods are healthy regardless of their actual nutritional value. Many consumers associate plant-based foods with health, and companies have been eager to capitalize on this perception by advertising their products as being healthier than meat.^{60 61}

But in the case of meat alternatives and other ultra-processed foods, this isn't necessarily true. While animal products are often high in calories and saturated fats, which can contribute to health problems, ultra-processed meat alternatives — many of which aim to mimic the nutritional profile of meats as well as their taste — often have the same problems. The health benefits associated with plant-based eating come mostly from eating whole and minimally processed foods. The newest generation of meat alternatives, on the other hand, are ultra-processed, made mostly from extracts and isolated ingredients and containing few to no whole foods. New ingredients present another processing concern: some of the ingredients used to give meat alternatives realistic flavors and textures are new to the human diet, and some consumer advocates have raised concerns over whether these novel ingredients are being regulated correctly.

IS PLANT-BASED INTRINSICALLY HEALTHIER? NOT IF IT'S ULTRA-PROCESSED

From a basic nutritional standpoint, most meat alternatives aim to occupy a similar dietary role as the foods they are replacing. Almost all are high in protein, but many, particularly those that emulate burgers and sausage, are also high in saturated fats. While few people would consume beef hamburgers as health food, plant-based products are often marketed as healthier alternatives than the meats they replace.⁶²

But are the plant-based alternatives intrinsically good for you? There is ample research showing that high levels of meat consumption — especially red meat and processed meat — are linked with health conditions like cancer, diabetes and heart disease. Several large studies have demonstrated that people who consume more of their protein from plant sources tend to have lower body weight, cholesterol and mortality.⁶³ But the majority of clinical research replaces meat with (mostly) whole-food plant diets rich in legumes, nuts and seeds, leaving it unclear whether the benefits come from excluding meat or including fibrous, nutrient-dense foods. As ultra-processed foods, the meat alternatives we discuss in this report do not confer the same benefits as nuts and legumes.

Processing is a broad umbrella, covering everything from washing and canning food to isolating proteins and extruding them to make a meat alternative. Nearly all foods are processed in some form, and while processing doesn't necessarily mean a food is unhealthy, certain types of processing can make foods less nutritious. Under the NOVA classification system, which is used by the United Nations Food and Agriculture Association, foods are grouped together by how much they are refined from whole food ingredients.⁶⁴ These span from group one foods, which are made from whole ingredients to group four foods, which are made almost entirely from isolated extracts, concentrates, and high in additives like food colorings, sodium, stabilizers and preservatives. While a conventional veggie burger might be made mainly of group one, two and three foods, the newest generation of meat alternatives are all ultra-processed group four foods.⁶⁵

From the standpoint of ingredients, ultra-processed foods tend to rely on high levels of sodium and fats to be palatable, and meat alternatives are no exception, with several brands exceeding the sodium content of the meats they replace. Because they are formulated from purified ingredients, ultra-processed foods also generally need to have vital nutrients added back in as fortifying supplements. In the case of meat alternatives, many of the critical nutrients found in meat such as iron, zinc and vitamin B-12 are added as separate ingredients, though they may not be absorbed from fortified foods as well as they are from whole foods like meat, nuts and seeds.⁶⁶



Because the current generation of meat alternatives is fairly new, research comparing the health impacts of meat and meat alternatives is limited. One study, funded by Beyond Meat, examined how people’s health changed when they switched from eating meat to meat alternatives. The study had several limitations — most notably its small size and relatively short duration — but it did find a few changes when people who were eating meat switched to meat alternatives.⁶⁷ After eight weeks of eating meat alternatives, study participants also saw slight improvements in some markers of cardiovascular health, but they were small, and only appeared when subjects were transitioning off of the phase of the study where they ate two beef burgers daily. Plant-based meat consumption on its own didn’t show the same results, so the results mostly emphasize that people’s health improves when they aren’t consuming excessive amounts of meat.

The problems with ultra-processed foods go beyond the burgers themselves. Their positioning in the fast-food market highlights a broader issue with ultra-processed foods: they are rarely consumed alone. Ultra-processed products are often marketed together in meals and packaged foods, and these make up a growing part of daily food intake around the world.⁶⁸ Studies examining dietary changes in multiple countries have concluded that this replacement is associated with an overall decrease in the nutritional quality of diets around the world.⁶⁹ In turn, this decline in dietary quality is linked to an array of conditions like obesity, diabetes, depression and cancer. Some of this may be the result of changes to the gut microbiome, the blend of microorganisms that live in the digestive tract and influence a number of health factors. Researchers have pointed to high consumption of ultra-processed foods as a factor that leads to an unbalanced microbiome and conditions like obesity and diabetes.⁷⁰

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While vegetarian and vegan eating is often presented as a solution to poor diet quality, the reality is that many plant-based products are also ultra-processed foods. In fact, surveys have indicated that vegans and vegetarians consume higher levels of ultra-processed foods than non-vegans, mainly because of plant-based alternative products.⁷¹ This leads researchers to question whether the expanding market for meat alternatives — along with accessory products like burger buns — might be displacing healthier options for many vegetarians, and how this impacts dietary quality overall.

NOVEL INGREDIENTS IN MEAT ALTERNATIVES

Processing protein isolates, fats and extracts into a convincing meat alternative requires both complex physical and chemical manipulation and the introduction of new ingredients. This raises further health concerns. Although extrusion and other processes often reduce the allergenicity of foods like soy, the potential for allergic reactions to new ingredients or reshaped proteins is still a possibility, and experts have advised that people who have allergies to soy, peanuts, and other legumes and fungi avoid ultra-processed meat alternatives.⁷²

Of more concern are the new ingredients used to give products flavor and color. To avoid tighter regulation as food additives, new ingredients need to achieve “Generally Recognized as Safe” (GRAS) designation from the FDA. Application for GRAS status — and therefore, disclosing new ingredients — is voluntary. When companies do register a new ingredient as GRAS, they provide their own scientific evidence to support their claim.⁷³ Critics of the system say it leaves room for undisclosed additives and poorly performed research that might give consumers a false sense of security.⁷⁴

Impossible Foods' attempts to secure GRAS status for their characteristic ingredient, soy leghemoglobin (or heme), illustrates some of the shortcomings of the GRAS process. Although the compound was new in human food and had never been produced from bioengineered yeast before, the company initially only provided evidence that similar heme proteins from animals and plants were safe. The FDA deemed this to be inadequate evidence and denied the registration.⁷⁵ After the company performed its own toxicity testing on rats, however, the FDA accepted the GRAS designation.⁷⁶

Between the safety of other hemoglobin compounds and the additional research submitted by the company, soy leghemoglobin doesn't appear to present any acute health risks. But consumer advocacy groups have voiced concern that the evidence presented to the FDA is still inadequate, considering it doesn't cover long term exposure. While the Center for Food Safety filed a lawsuit arguing the FDA should use a more stringent standard, a federal court ruled in favor of the agency's designation.⁷⁷

The fact that the health status of many ingredients and processes is unresolved comes as a secondary concern to many of the companies producing meat alternatives. Their first priority has been securing patent protection for many of their special ingredients, arguing that they can be more transparent about health and safety once they've ensured that their intellectual property is protected. Impossible Foods, for example, has at least 139 patents, but aside from the founder's insistence that the company would "never sell food to consumers that isn't better than what it replaces," these novel processes remain trade secrets.⁷⁸

FOOD SAFETY

Meat alternatives are not exempt from other food safety concerns. For conventional meat, most illness-causing bacteria that contaminate animal meat come from the animals themselves; so, it

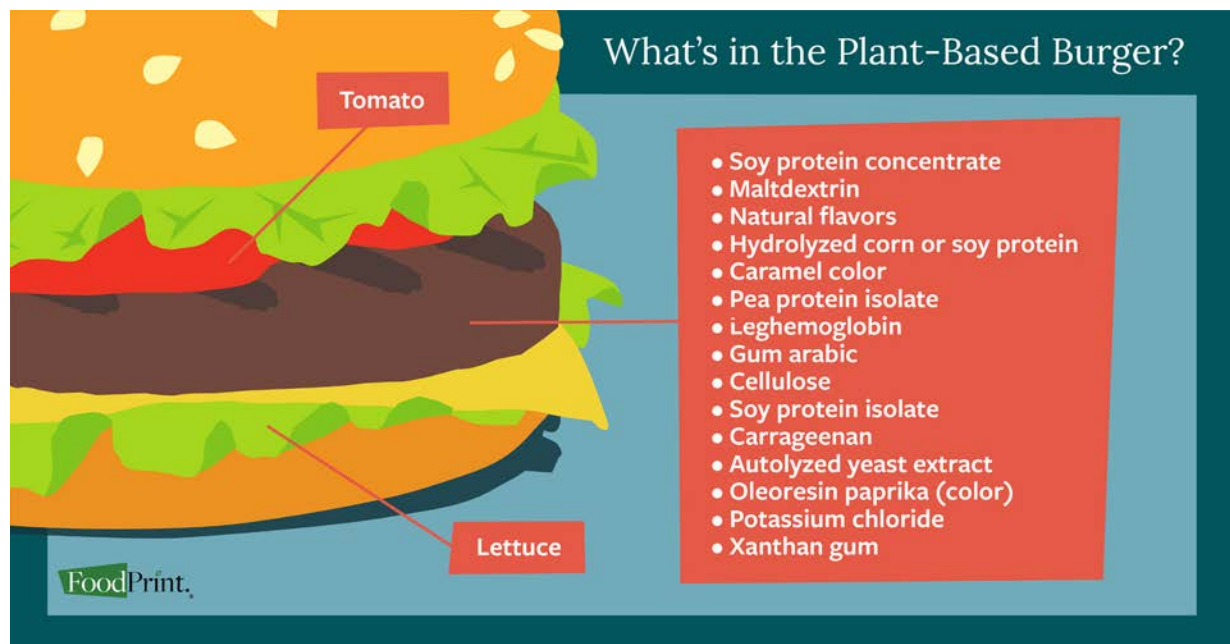
Cooked vegan sausage patties



is true that using only plant-derived ingredients negates much of the risk. But meat alternatives, just like actual meat products, are moist, nutrient-rich, and good environments for bacteria to grown in: they therefore need to be produced, stored, and fully cooked.⁷⁹

WHAT IS AND ISN'T ON THE LABELS

Food labels can be confusing on any product, and ultra-processed meat alternatives are no exception. Many of the products have labels that make claims about how products are made or what goes into them. These range in quality and consistency, and only some are third-party certified: the USDA's Certified Organic label is subject to stringent certification, for example, while other claims may not be so carefully enforced. Several of the products are labeled "No GMOs," but only some have Non-GMO Project Certification. Because many of these products are made from conventionally grown crops, most are not Certified Organic, which would ensure that the products are made with ingredients that weren't grown with synthetic fertilizers and pesticides. With a few exceptions, those that include soy are also ineligible for certification from the Non-GMO Project, because most soy in the United States is genetically modified.



Meat alternatives are almost universally produced without animal products, but because there isn't a universally used vegan certification, some of the products carry a vegan label that isn't independently certified.

Nutrition labels and their ingredient lists do carry all their primary ingredients, but there are some ingredients that might not be fully represented. This includes things like flavorings, which might be listed as "natural flavors" or colorants without more specifics about where these ingredients came from. While natural flavors derive from natural sources, they are still heavily processed ingredients differing widely from their original state. With all ultra-processed ingredients, the chemical processes used to refine, stabilize and package them don't appear on ingredient lists, even when these processes — everything from the hexane used to extract flavors to the BPA used in packaging — can leave behind trace residues.

Who Profits from Ultra-Processed Meat Alternatives?

Between the intensive farming, heavy processing, and the amount of investment in technology that meat alternatives require, they end up being an inefficient protein. Where they might have an advantage, the researchers suggested, is in social acceptability. Proponents of new meat alternatives argue that, particularly in fast food settings, people aren't that interested in the quality of the meat itself and won't mind replacements that are filling, affordable, and taste nearly the same. But can meat alternatives effectively replace meat, or are they just an additional product on the market and ultimately an additional revenue stream for the biggest and worst meat companies to continue business as usual?

The first companies to occupy this new "space" — ultra-processed burger alternatives that woo meat eaters away from meat — were self-proclaimed mission-driven companies. Pat Brown, founder of Impossible Foods, has stated that his goal in starting his company is to eradicate animal agriculture by 2035.⁸⁰ Beyond Meat's CEO, Ethan Brown, was described by a breathless *Los Angeles Times* article as "a former fuel-cell industry executive with an MBA and a sweeping business plan," a vegan looking to start a fast food revolution.⁸¹ Both sound extremely confident that the instant popularity of their products and soaring sales mean they are approaching their goals. But a closer look at who is set to profit from the growth of the meat alternative market — as well as an examination of how sales data lines up with meat production data — gives ample reason to question the narrative that these products are the magic bullet to cure the meat industry's problems.

NEW PRODUCTS, NEW INVESTMENT OPPORTUNITIES

On its face, turning people away from conventional meat products seems like a worthy cause: the meat industry is certainly destructive, and several of the brands marketing the latest generation have explicit mission statements about eliminating animal suffering, slowing global warming, and building a better food system. But considering the wide array of traditional, lower-impact meat alternatives already available, the venture capital and corporate interest (in the latest generation of ultra-processed meat alternatives) comes down to their presumed ability to capture a lucrative new market. If meat alternatives can successfully sway meat eaters, investors in the new products will be well-rewarded. The Good Food Institute reports that plant-based meat sales reached 1.4 billion dollars in 2020. Assuming that meat alternatives displace as much of the meat market as dairy alternatives have displaced cow's milk, such new ventures could mean a 14-billion-dollar business opportunity soon.^{82 83}

To that end, many of the companies developing new ultra-processed meat alternatives have attracted enormous investment. Some of the most visible names have gotten the most money, with Impossible Foods raising



Vegan bacon strips

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more than 1.5 billion dollars since 2011. Of that, more than half came in the last two years, proof of investor eagerness to cash in as the company scales up.⁸⁴ Even companies without products to market have attracted huge investor interest: Motif FoodWorks, Inc., a startup that is developing new ingredients for meat alternatives and other plant-based foods, just raised \$226 million despite having only one product, which hasn't yet entered commercial production.⁸⁵ This discrepancy stems in part from investor eagerness to capitalize on new, proprietary technology, a fact reflected by how aggressively companies pursue patents for novel processes and ingredients like soy leghemoglobin and protein texturizing processes; essentially, a technology that promises better, more convincing food in the future is more lucrative to investors than products already on the market.⁸⁶

To many of the entrepreneurs who promote meat alternatives, attracting investment and proving that plant-based foods can be a moneymaker is critical to shifting the food system away from commodity meat.⁸⁷ But critics see these goals as fundamentally at odds: building a sustainable food system isn't a get-rich-quick scheme, and overreliance on venture capital funds means that even "mission-driven" companies are likely to cut corners to ensure that investors see a return.⁸⁸ This approach could lead companies to reproduce many of the issues found in the rest of the food system, such as unsustainable or dubious sourcing of ingredients and poor labor conditions.⁸⁹

MEAT CONGLOMERATES GET IN ON THE ACTION

But while some of the pioneering companies producing meat alternatives have explicit mission statements about building a more sustainable food system, they are no longer the only companies making and selling these products: a growing number of meat alternative brands are owned and operated by major meatpackers like Tyson, JBS and Cargill. The eagerness with which major meatpackers are developing meat alternatives casts doubt on the idea that meat alternatives will solve the meat industry's problems. Are the same corporations who lobby to keep the meat industry deregulated and lucrative likely to try and cut into their own profits?



So far, meatpackers have branded their plant-based offerings in a way that distances them from their meat products. JBS has contemplated setting up a subsidiary specifically for its plant-based offerings, citing “cultural differences” between the markets for meat and meat alternatives.⁹⁰ With a business strategy of capturing as much of the plant-based sector as possible, the company is clearly treating meat alternatives as a separate, expanding market that is not intended to displace meats. The company’s simultaneous expansion of their beef processing facilities is further evidence of their confidence in the future of industrial meat.⁹¹ Executives at Tyson Foods have also indicated they intend to develop their plant-based products as a parallel product line, allowing them to become a “one-stop protein shop” rather than solely a meat processor.⁹²

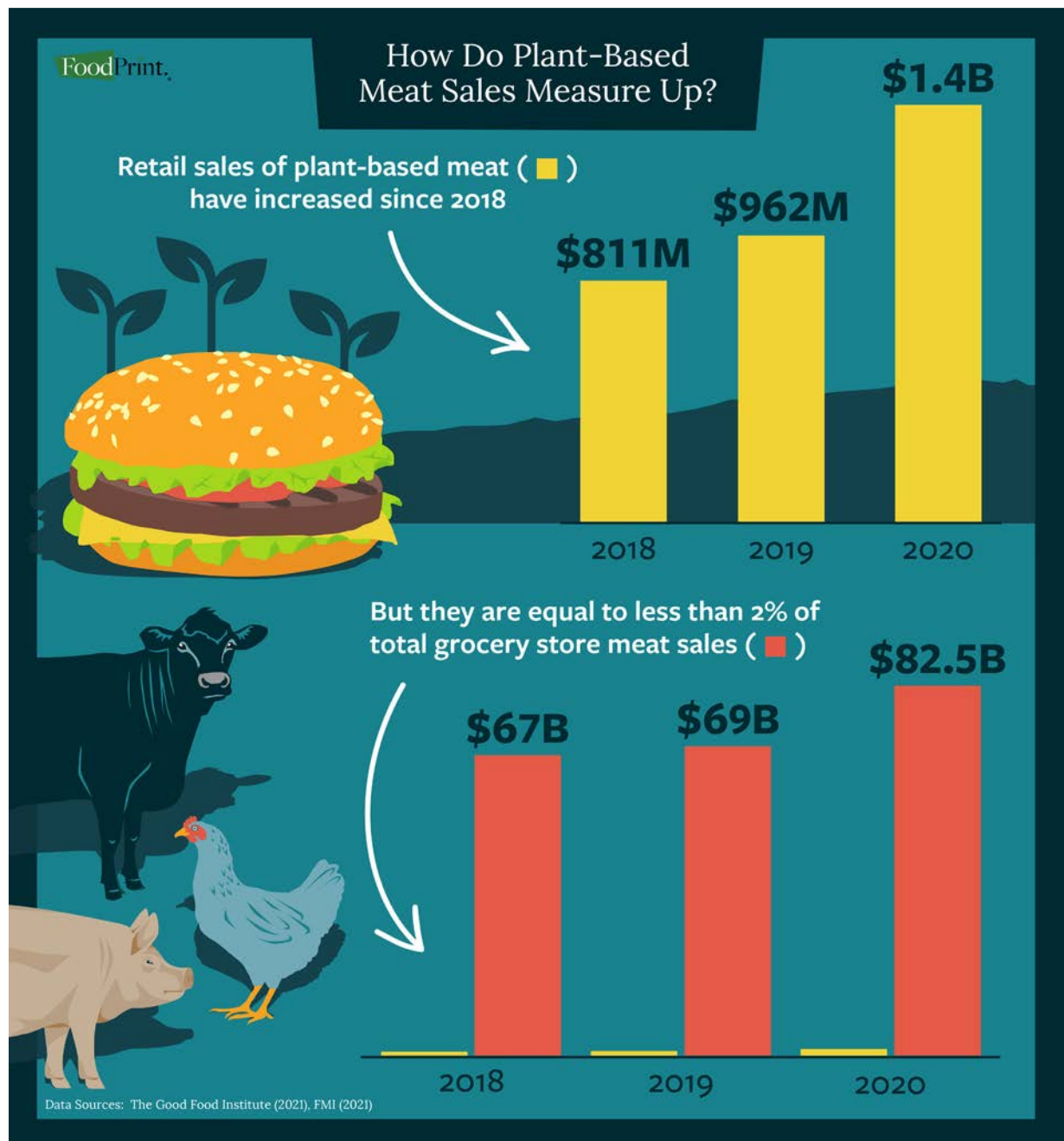
Even if growth in meat alternatives does mean some reduction in meat sales, many companies responsible for the industrial meat system are still poised to profit. Leaders at Cargill, which does much of its business processing soybeans for livestock feed in addition to processing meat, have projected that plant-based foods might cut into their own beef sales, but the company is already a major processor of pea protein for Beyond Meat.⁹³ Meanwhile, the company is cashing in on booming demand for both meat and plant-based products, expanding its soybean processing capacity to better supply both livestock feed and inputs for meat alternatives.⁹⁴

The ease with which these same companies can retool themselves to succeed at producing meat alternatives speaks to core issue of presenting meat alternatives as a solution for the problems of industrial meat: while it’s true that they have a smaller environmental footprint than industrial beef, pork and chicken, meat alternatives are made from the same inputs. Dramatically scaling up production — the only way that meat alternatives can become cheap enough to have a chance at displacing meat sales — may require fewer resources than producing more meat, but it is the opposite of divesting from the industrial food system that causes so many problems in the first place.

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IS REPLACING MEAT POSSIBLE?

Examining consumer behavior and sales data backs up the idea that while meat alternatives might be booming, they aren't on track to replace meat any time soon. As production scales up on many plant-based meat products, costs have dropped dramatically: Impossible Foods recently dropped its retail prices by 20 percent, bringing the price per pound to \$5.49. This brings it within striking range of ground beef prices, which rose during the pandemic and have yet to fall. This accompanied an expansion into 17,000 grocery stores nationwide. Beyond Meat's sales figures are also impressive, with sales revenue more than doubling in 2020.⁹⁵ Overall, more than 18 percent of US households purchased meat alternatives in 2020.⁹⁶





The CEO of Impossible Foods says he believes they are on track to fully eliminate animal agriculture by 2035.⁹⁷ Though these numbers suggest displacement, meat sales are also at record highs: even in the face of a pandemic-driven recession and high prices, grocery store meat sales grew 19.2% in 2020, with 98.4 percent of American households buying some meat.⁹⁸

Research on consumer behavior and attitudes casts further doubt on the idea that meat alternatives are going to successfully displace meat sales. Actual sales data, while limited, has shown that displaying meat alternatives next to meat in the grocery store can significantly increase the sales of the alternatives. However, there was no accompanying decrease in meat sales, which backs up the possibility that these products aren't true meat replacement for most consumers even when they're sold side-by-side in the meat department.⁹⁹

There are consumer attitude trends that could set the stage for greater acceptance of meat alternatives, particularly the growing number of people interested in reducing meat consumption: 23 percent of Americans sampled in a recent poll identified that they had cut back on their meat in the past year.¹⁰⁰ But there's still some deep-seated skepticism about meat alternatives, particularly among the target audience of meat eaters: a 2016 study found that even in a simulated environment where prices and taste of hypothetical meat alternatives are the same as the meats they would replace, 65 percent would still choose a beef burger over an alternative. This was especially true among people who said they frequently eat meat and purchase burgers often.¹⁰¹ Clearly, even if meat alternatives were to become indistinguishable from meat, many consumers would still be attached to the notion of authenticity and pick animal meat over substitutes.

This undercuts the notion that inexpensive meat alternatives are a natural swap for meat in fast food settings, since the research also showed that people who consume the most fast-food feel the strongest preference for real beef, even when it costs more. This has already borne itself out: fast food chains that initially debuted meat alternatives to great fanfare, like Dunkin and Little Caesars, have since pulled back their offerings, citing low sales and unenthusiastic customers.¹⁰²

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Cooked Beyond Burger

In contrast, the people most likely to be friendly to a meat alternative ate little to no meat to begin with and had strong attitudes toward the environment.¹⁰³ This runs counter to the Good Food Institute’s own research on consumer strategy, which states that “vegetarians and vegans should not be the target segment.”¹⁰⁴ Many fast food chains have replaced longstanding, customer-favorite vegetarian options with Beyond and Impossible products.¹⁰⁵ Rather than bringing meat-eaters towards plant-based foods, the newest generation of ultra-processed meat alternatives is mostly recontouring the existing suite of vegetarian options, displacing lower-impact options like traditional veggie burgers that vegetarians and vegans might find more appealing.

Conclusion

The problems with our industrial livestock system are critically urgent to address. The threat of climate change and the potential positive impact of reducing how much meat we eat and reforming how we raise animals and use land cannot be underestimated. Industrially produced meat is cruel to animals, terrible for land and water, hard on workers and, when eaten in excessive quantities, bad for our health. The temptation to find a silver bullet in a product that could finally break through to new audiences and shift their dietary preferences quickly is understandable.

If these products could deliver on all fronts — be better for animal welfare, better for the environment and better for our health, that *would* be something to celebrate. So far, all they have demonstrated is that they are better on GHG emissions than their industrial meat counterparts, but they have not demonstrated that they are better than regeneratively raised livestock or a diet of whole grains and legumes — and they rely on the same system of monocultured GMO crops that have proven to be bad for our soils and waterways.



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In terms of health, they are also not a win over industrially produced meat. Unlike traditional plant-based foods, these new meat alternatives are ultra-processed foods, which health professionals recommend avoiding because of their negative health impacts. Finally, they have not demonstrated that their popularity can cause a decline in real meat sales or production. Sales data does not show that these products have an ability to meaningfully shift regular meat eaters away from their traditional burgers. These products mimic conventional meat not just in taste and appearance but also with respect to the system in which they are produced — in some cases, becoming a part of it, lining the pockets of the world’s largest meat conglomerates, allowing them to continue business as usual, or even grow.

These products seem like an appealingly practical solution to America’s seemingly unbreakable obsession with industrial meat: they’re easy to market because they meet popular tastes and can be easily interchanged with industrially raised meats in restaurants, fast food chains and backyard barbecues. This might make them easy to adopt, but this is also their fundamental weakness as a solution — the food system needs more transformational change than simply reconfiguring what burgers it serves, or offering new, industrial, ultra-processed options. The task of building a more sustainable food system will hinge on more aggressive action from governments and communities. Reigning in the exploitative meat and agribusiness industries with better regulation, empowering food and farm workers, and promoting regenerative farming should all get as much attention as new products.

For consumers who want to adopt a more climate-friendly diet, or are committed to animal welfare, there are other options, from regeneratively raised meat, to minimally processed organic plants and legumes. A healthy and planet-friendly diet does not require new technology and does not have to include more industrially produced products.

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Cooked vegan beef patty



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Closeup of cooked fake burger patties





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