A meaty issue

Our insatiable appetite for red meat is bad for our health and for the planet. Sustainable alternatives are in the pipeline, but will they convince us to make the switch?

BY OLIVE HEFFERNAN

As the burger hits the pan, it sizzles. A familiar smoky aroma fills the air. The first bite reveals a juicy pink centre. But this is no ordinary hamburger. It's formed entirely from plants and was made to mimic a burger in every way by scientists in California's Silicon Valley. "Meat is really delicious stuff, but it's created by a very inefficient process," says Chris Davis, the biotechnologist who leads research and development at Impossible Foods in Redwood City — the company behind the Impossible Burger. "And in the last 40–50 years it's gone from something that's eaten on special occasions to something that's eaten all the time."

By 2050, the human population is expected to increase by around 15% to more than 9 billion people, bringing unparalleled environmental and nutritional challenges¹ (see page S6). During the same period, the global demand for meat is expected to rise by 73%², and meeting this demand will require an additional 160 million tonnes of meat per year.

Our planet cannot easily keep up with the anticipated demand for meat. "We're running out of good land," says Davis. Thirty per cent of Earth's land surface is already devoted to livestock production³, a practice that accounts for nearly 15% of global greenhouse-gas emissions⁴. Cows are the worst culprits, not only because they emit a lot of methane, but also because the production of beef uses vast quantities of water — 15,415 litres for a kilogram of beef — as well as land.

What's more, eating red meat in high quantities — as is typical in developed countries — is bad for our health, and typically associated with a higher risk of diabetes, cancer and heart disease.

Switching to more sustainable protein sources would both ease health concerns and help to tackle climate change, but there's a problem: many of us are unable to wean ourselves off beef. Despite a change in tastes in Western countries over the past three decades that has seen people

swapping their steak for chicken and pork, public appetite for beef — particularly in the form of hamburgers — remains strong.

Scientists are keen to persuade the public, especially in developed countries, where choice is plentiful, to rethink their diets. This may mean embracing the unfamiliar and eating insects (see 'Tiny livestock') or satiating carnivorous cravings with burgers that have all of the taste, but a fraction of the environmental impact of conventional burgers. "The problem we have at hand is so big that we need to explore all of the possibilities and see whatever works," says Mark Post, a vascular biologist at Maastricht University in the Netherlands, who created the first lab-grown burger. There is, however, scope to influence what people consume, says Tara Garnett, who researches food systems and sustainability at the University of Oxford, UK. "What is deemed to be desirable food changes over time," she says. "We need to be imaginative." But how do the alternatives stack up against beef in terms of their environmental and health credentials?

FAKE STEAK

Conceived in 2011 by a start-up with a mission to make the food system more sustainable, the Impossible Burger is the product of five years of research into what defines meat, in terms of both taste and texture. Piece by piece, the scientists identified and recreated the components that make meat so instantly recognizable — the fattiness, juiciness and the smoky aroma.

The plant-based ingredients they settled on were wheat and potato proteins, natural flavourings and coconut oil, with the key addition of haem — the iron-containing group that is abundant in animal tissue as haemoglobin or myoglobin. Raw beef is rich in myoglobin — haem gives it a distinctive colour, and when cooked, the protein provides a caramelized, smoky flavour. "One of the first important discoveries was that it was the haem protein that drove the flavour of meat," says Davis.

Finding a stable, non-animal source of haem was the team's next

The meatless Impossible Burger and some of its ingredients: potato, haem protein, soya bean, coconut and wheat.

challenge. Initially, the researchers tried to harvest haem-containing proteins from the roots of the soya bean plant (*Glycine max*). “After a lot of work, we realized there was no environmentally sustainable way to harvest the root nodules and extract the haem protein,” says Davis. Vast quantities of soya bean plants would be needed to generate enough haem for the burgers. The team shifted its focus, and now produces a haem

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protein in the lab using genetically engineered yeast.

The Impossible Burger is available for around US\$16 in 11 US restaurants, including the Michelin-starred Public in New York City. It’s not the only faux-meat burger on the market — the main competitor is the Beyond Burger, which is sold in US stores to cook at home, but this contains beetroot-juice extract to give it a meat-like colour. Reviews of both are positive, although the Impossible Burger is generally deemed more convincing in its imitation of a conventional burger. It has been described by food bloggers as ‘juicy’ and having a ‘mineral, meaty flavour’, especially when cooked medium rare. Feedback was not always so positive, however. About a year into the project, the company tested its first prototype. “It was charitably described as rancid polenta,” says Davies. But the fact that the burger firmed up and had a smoky flavour after cooking showed the team that it was on the right track.

Impossible Foods says that an analysis of the environmental impact of

each ingredient of its burger suggests that it is much better for the planet than a conventional burger (see ‘Sustainable options’). The research is unpublished, but the company says that switching a quarter-pound beef-burger for an equivalently sized Impossible Burger saves as much water as a 10-minute shower, eliminates the greenhouse gases emitted during a 29-kilometre drive in an average car, and frees up around 7 square metres of land. Nutritionally, it contains levels of protein and iron comparable with an average hamburger.

Impossible Foods is still only able to make a limited number of burgers; it could be years before this meatless ‘meat’ is on supermarket shelves. And despite the positive reviews, some people can tell the difference between burgers made of faux and real meat, especially when served without copious dressing.

LAB FRESH

Even die-hard beef lovers could soon have the option of a more-sustainable diet. In the past few years, scientists have been working hard to grow beef — in the form of burgers or meatballs — in the lab.

Typically, making a cultured burger begins with harvesting muscle cells from a living cow, and then culturing these cells in a lab by feeding them with a nutrient-rich serum so that they can grow into muscle tissue.

The muscle cells grow as small strands; 20,000 of these strands make one regular-sized burger. Biologically, the meat is identical to that from a cow, although an ordinary burger also contains small amounts of bone, cartilage and connective tissue. It provides as much protein and iron as a conventional burger, and could be manipulated to be even more nutritious by bumping up its vitamin or mineral levels, for example.

The argument is that production of a lab-grown burger emits a fraction of the greenhouse gases (an estimated 7.5 kg CO₂-equivalent per kilogram of edible meat) and requires just 10% of the water that production of a conventional beefburger does. The energy requirements for large-scale production are unclear. These will depend on the production process, which is still in development.

In 2013, Post unveiled the first lab-grown burger, fried in a little oil and butter, to the media. The prototype burger cost \$330,000 to create and initial reviews were modest at best. “The burger was convincing in that it was recognizable as meat, but it was still dry” says Post. Since then, Post and his team have been working to make the burger juicier by adding fat tissue cultured from stem cells. And another company, Memphis Meats in San Leandro, California, has created a lab-grown meatball at a reported cost of around \$40,000 per kilogram.

Post’s hope is that in ten years, his team will be producing beefburgers at a retail price of €60 (\$64) per kilogram, and possibly even as low as €12 per kilogram (comparable to the cost of organic beef mince in UK supermarkets), depending on how efficient the team can make production.

One of the challenges of scaling up production is being able to grow large numbers of muscle cells quickly. The cells for Post’s first burger were grown using a relatively simple method, in sheets on a 2D surface, but large-scale production will require a quicker, 3D process. Post’s team are now cultivating their cells in suspension in large bioreactors. In these vessels, the cells attach to beads called microcarriers, from which they

SUSTAINABLE OPTIONS

Insects and meat alternatives provide similar amounts of protein to beef, but their global warming potential (CO₂-equivalent per kilogram) is much lower.

	Protein (% uncooked)	Kilocalories (per 100 g, uncooked)	Kilograms of CO ₂ equivalent per kg
Mealworm	14–25 (ref. 6)	206 (ref. 6)	14 (ref. 8)
Conventional beef	14–22	121–332	75–170 (ref. 9)
Faux beef	22	259	10–22

Source for conventional beef is United States Department of Agriculture and for faux beef is Impossible Foods for Impossible Burger.

INSECTS

Tiny livestock

Insects, such as locusts and cicadas, are eaten in many parts of the world.

Around the world, more than 2 billion people eat insects as part of their diet. Almost 2,000 species have been used for food; among these the most popular are beetles, caterpillars, bees, wasps, ants, crickets and locusts.

Farming insects instead of cattle has many environmental advantages. “If you want to continue eating meat, you can get ten times more efficiency by switching to insects,” says Marcel Dicke, an entomologist at Wageningen University in the Netherlands and co-author of *The Insect Cookbook: Food for a Sustainable Planet* (Columbia Univ. Press, 2014). Ten kilograms of plant protein is needed per 1 kilogram of live beef cows, but only 1.7 kg of feed is needed per kilogram of crickets⁶.

As well as being highly efficient food converters (turning most of their nutriment into body mass, rather than waste), insects can be fed organic waste (food, animal or human), breed rapidly and need comparatively little land or water. For locusts, crickets and mealworm larvae (considered the most likely to make it to the Western market) the greenhouse-gas emissions are around 100 times lower than for cattle⁶.

Insects are also highly nutritious — one reason they’ve long been eaten in the developing world. In general, they’re high in fat, protein, fibre, vitamins and minerals, although the exact figures vary between species and from one life stage to another. Compared with beef, for example, the yellow mealworm — the larval stage of the beetle *Tenebrio molitor* — has similar energy and mineral levels, slightly lower fat and marginally higher vitamin levels⁷. The beetle is endemic to temperate climates and the larvae are suited to mass rearing, making them a promising option in Western countries.

The industry faces two hurdles: scaling-up production in a way that’s cost-effective, and winning over consumers. Researchers at Wageningen University are focused on optimizing the reproduction, growth and nutrient content of mealworm species and the black soldier fly (*Hermetia illucens*), which could be used to feed fish, pigs and chickens. And insects are gradually cropping up in Western diets, often as ingredients in snacks. Energy bars made with cricket flour include Chapul, Exo and Crobar. “People who are not used to eating insects will accept something they can’t see much more quickly,” says Dicke. Most of us already eat insects without knowing it, he says. Insect parts routinely end up in processed foods made from harvested crops because otherwise producers would have to pay for the labour to remove every insect from a tomato or coffee plant.

Dicke expects that whole insects will be a common sight in European supermarkets in the next few years. “Locusts, I’d recommend as a first try — it’s basically the same as a shrimp. If you eat shrimp, there’s no reason why you wouldn’t eat locusts,” he says. **O.H.**

grow outwards, making the cell-proliferation phase much shorter.

And Post’s team have made another advance since the burger was unveiled. Apart from the cultured muscle and fat cells, the team has removed all other animal products from the process. The cells for Post’s prototype burger, for example, were fed and grown in fetal bovine serum, which is extracted from the fetuses of pregnant cows during slaughter. Now, the team grow cells in an animal-free medium. This could make their burgers acceptable to some vegetarians and animal-welfare advocates.

In March, Memphis Meats showed off two new creations: chicken strips and duck, which they served à l’orange style at the unveiling. Although the cost of production of the poultry, which is cultured from animal cells, is high, at less than \$20,000 per kilogram it is around half the initial cost of their meatballs. Israeli start-up SuperMeat also plans to make lab-grown chicken — after a crowdfunding drive to raise funds last year, it hopes to have products in the supermarket in five years.

PUBLIC PERSUASION

The success of each of these alternatives is dependent on people being prepared to eat them. Generally, Western societies have a low rate of willingness to try cultured beef, eat insects or switch to vegetarianism. But proponents argue that if the alternatives taste good, then people will eat them. “People will ultimately choose to eat what

is most delicious,” says Davis.

“People are willing to eat foods, such as a hot dog, without fully knowing what it’s made of or how it’s being made,” says Post, who thinks that the same will eventually be true of food such as the lab-grown burger.

The overwhelming feeling is that the more informed people are, the more willing they will be to change their habits. In one study, for example, when people were told about the environmental benefits of cultured beef, the number of respondents willing to try it rose from 25% to 43%⁵. “We’re always changing our consumption patterns, and our diets are constantly in flux,” says Garnett. “It’s a failure of imagination to assume that behaviour can’t change.” ■

Olive Heffernan is a freelance science writer in Dublin, Ireland.

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