

COVER STORY

NOW EAT YOUR CHICKEN AND HAVE IT TOO

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Factory farming of animals for meat causes major climate changes and environmental degradation, yet global meat consumption continues to rise with each passing year. Lab-grown meat technology has the potential to rescue both animals and the planet without punishing the palates of human meat lovers.



LITTLE does chicken Ian, pecking at food and relaxing in its Californian coop, realise that people are gorging on its meat in Singapore. The restaurant 1880, located in the riverside fashionable entertainment centre Robertson Quay of Singapore, now serves nuggets prepared from Ian’s meat grown in its bioreactors.

In December 2020, Singapore became the first country to permit the sale of lab-grown meat, also called *in vitro* meat, clean meat, cultivated meat, cell-cultured meat or cell-based meat, for human consumption. The California-based company *Eat Just* is instrumental in providing the unique treat to customers for the first time. *The Chicken*, another restaurant in Israel, is bracing to serve chicken burgers, pending final approval from the government.

A number of companies are currently engaged in producing lab-grown meat in various countries including the Netherlands, US, Israel, Japan, Singapore and India. The world’s first lab-grown meat company, *Memphis Meats*, has been co-founded by Uma Valeti, a Mayo Clinic-trained cardiologist from India. The companies are able to raise impressive funds in view of their potential in providing meat without animal slaughter and little damage to the environment. Visionaries such as Bill Gates and Richard Branson have invested in *Memphis Meats* while other companies engaged in producing lab-grown meat (Table 1), whose total number now exceeds 60, too are attracting impressive funds.

Consumption of meat by more than 90 per cent of the global population necessitates the slaughter of billions of animals (Figure 1) annually and causes serious harm to the ecology and environment of the planet. According to the 2009 study of the Washington-based World Watch Institute, livestock and their byproducts currently account for 51 per



A view of a modern chicken slaughterhouse (credit: fwi.co.uk)

cent of annual worldwide greenhouse gas emissions, as measured in CO₂ equivalence.

Centuries of Meat Eating

Ancestors of humans have been eating the meat of animals long before the transformation to *Homo sapiens* occurred. The evolution of the early hominids to the large-brained humans, believed to have taken place about 3.5 million years ago, has been linked to meat-eating and in the words of the anthropologists Henry T Bunn: “Meat made us human.”

At the same time, the pain and suffering of animals slaughtered for meat evoked empathy among animal lovers from very early times and among the earliest proponents of meat abstinence were Indians. Mahavira championed the concept of *Ahimsa* and the spread of Jainism. Jainism together and its contemporary religion Buddhism are credited with the

Table 1. Some companies engaged in the development of lab-grown meat

Company	Major interests in Lab-grown	Location
Mosa Meat	Beef	Maastricht, The Netherlands
Memphis Meats	Beef, Poultry	Berkeley, California, USA
Super Meat	Chicken	Tel Aviv, Israel
Finless Foods	Fish	Berkeley, California, USA
Meatable	Pork	Zuid-Holland, The Netherlands
Peace of Meat	Cultured cell mass, animal fat	Antwerp, Belgium
Aleph Farm	Beef 3-D tissue engineering platform	Rehovot, Israel
Eat Just	Chicken	San Francisco, California, USA
Vow	Kangaroo, other non-conventional meats	Sydney, Australia
IntegriCulture	Animal cell cocultures	Tokyo, Japan
Mission Barns	Bacon & other Pork products	Berkeley, California, USA
Future Meat Technologies	Serum-free chicken & other meats	Jerusalem, Israel
Clear Meat	Chicken	Delhi, India

popularization of vegetarianism in the sub-continent. The Greek mathematician and thinker Pythagoras laid the foundation of vegetarianism in Europe and till the term vegetarian was coined in the mid-nineteenth century, people who shunned meat were referred to as Pythagoreans.

While initial efforts to curb consumption of meat were based more on empathy towards animals, the potential harm of meat consumption on human health was also recognized early. In spite of centuries of efforts of curbing the consumption of meat by philosophers, animal lovers and religious preachers, the practice continued and over 90 per cent of the current global population consumes meat.

India is the country with the largest vegetarian population, yet over 70 per cent Indians are meat-eaters. According to the 2017 study of India's National Academy of Agricultural Research Management, 98 per cent of people from Telangana State are non-vegetarian (against 95 per cent of the USA). Overall meat consumption in India is however far lower than that of the US. Between 1960 and 2010 global meat consumption doubled and it is likely to increase by further 50 per cent by 2050.

Proliferation of the meat-eating human population all over the world resulted in proportionate rearing of animals for meat and in turn to enormous increase in greenhouse gas emission, mainly in the form of carbon dioxide and methane, cutting down of forests to create land for animal grazing, and spread of zoonotic diseases.

“Majority of meat in next years doesn't require killing of a single animal and tearing down of a single tree.” – Josh Tetrick of Eat Just

Desirable for the Human Palate

Humans are meat-loving omnivores. Evolution of the human palate to desire meat may be related to the latter's nutritional richness. According to Richard Wrangham, the Harvard anthropologist, “Meat-eating is innate and it is natural for humans to crave for meat.”

Meat is rich in all essential nutrients: essential amino acids, essential fatty acids, vitamins and minerals (possible exception vitamin C) as well as calories. There is available lot of research on the components of meat responsible for the meaty flavour. Meat has over 400 peptides and aromatics and many more are created during cooking. It has not been possible thus far to make a good correlation between the composition and the specific taste of meat.

Fats are energy-dense and play a key role in adding to meat's delicious flavours. According to Gary Beauchamp, professor of biopsychology and an expert on taste perception at the Monell Chemical Senses Center in Philadelphia, “Meat is a unique mixture of umami and fat that gets spiced when meat gets browned during cooking.” Umami is one of the five basic tastes detectable by human taste buds described as meaty taste or savoury, which is elicited by the presence

of glutamate and to some extent Inosine Monophosphate (IMP) and Guanosine mono Phosphate (GMP).

Cooking of meat enhances its desirability. The ancestors of humans learned to cook food at least two million years ago. Cooking leads to reaction of proteins with sugars in a process called Maillard's reaction, in which a variety of products with desirable flavours and aromas are formed. Cooking also causes fatty acid oxidation, resulting in the formation and release of additional inviting scents. Creaminess, juiciness and crunchiness of the meats, contributed by fats, activate the fat-sensitive neurons in the brain and cause a pleasure experience. Cooking also enhances the umami of meat, which is due to the release of the amino acid glutamate and peptides containing the amino acid.

Growing Meat Outside Body of Animals

Like most major breakthroughs, the idea of growing meat outside the body of animals originated as a figment of imagination. In 1930, Frederick Edwin Smith, a British writer and politician envisaged: “It will no longer be necessary to go the extravagant length of rearing a bullock in order to eat its steak and from one parent steak of choice tenderness it will be possible to grow as large and juicy steaks as can be desired.”

This was followed by several other predictions, science fiction and some real science.

The most notable contributions came from two Dutch men, Willem van Eelen and Mark Post. Eelen (b 1923), as a young medical student, was fascinated by experiments in which scientists were trying to grow cells in tissue culture with the target of obtaining organs for human transplantation. The technique however fascinated him for another reason; he saw in it the potential of growing muscle tissue for food. While he lacked resources and expertise, his persistence and enthusiasm helped him succeed in raising modest funds for undertaking some experiments.

Eelen obtained a patent for culturing meat *in vitro* in 1999, formed a consortium of scientists that included the now well-known Mark Post to further the work of growing *in vitro* meat. In 2013, Mark Post, now professor at Maastricht University, presented to the world the first hamburger made out of cultured meat (Figure 2). His work inspired people to create meat-based on ‘cellular agriculture’ and triggered the establishment of several of startups all over the world.

“One-day growing meat may seem as natural as making cheese or beer.” – Isha Datar, Executive Director, New Harvest



Mark Post with lab-grown meat
(Credit: speakersconnect.com)

How is Meat Lab-grown?

A tiny sample of tissue from the muscle or other parts of the animal is taken out as biopsy and stem cell are isolated therefrom. Pluripotent stem cells that can mature into all different cell types are ideal. Induced pluripotent stem cells are those that have been reprogrammed back to a pluripotent stage from which they can differentiate into a far greater range of cells. Sometimes, multipotent stem cells that are destined to give rise to muscle cells or unipotent progenitors which directly differentiate into muscle cells are also used.

Initially, the stem cells are grown in Petri dishes with nutrients including amino acids, carbohydrates, vitamins and minerals. Culture media are supplemented with additives like serum, which supply the required growth factors, and are allowed to grow. Fetal Calf Serum (FCS), isolated from the blood of unborn cow is the favourite of all types of animal tissue cultures as it supplies many of the essential growth factors. FCS is very expensive.

Differentiation of the proliferating cells in the culture results in the formation of muscle cells. Bioreactors are employed to scale up the process of growth and conversion to primitive muscle fibres followed by bulking up to form muscle tissue (Figure 3).

In order to obtain a preparation that mimics meat in taste and texture, some companies grow fat cells, cells from blood vessels and muscle cells together with the muscle cells to obtain the cell mass. To obtain structured material resembling the steaks, etc., cells are seeded on to scaffolds which are essentially moulds that help the cells organize into larger three-dimensional structures. One such material is collagen but several plant-based materials like cellulose and chitin are

also being evaluated as scaffolds. Very large number of muscle tissue can be obtained from a single tissue sample and according to *Mosa Meats*, the company launched by Mark Post, a single tissue sample from a cow can yield enough muscle tissue to make 80,000 quarter pounders (burgers that contain quarter pound of beef).

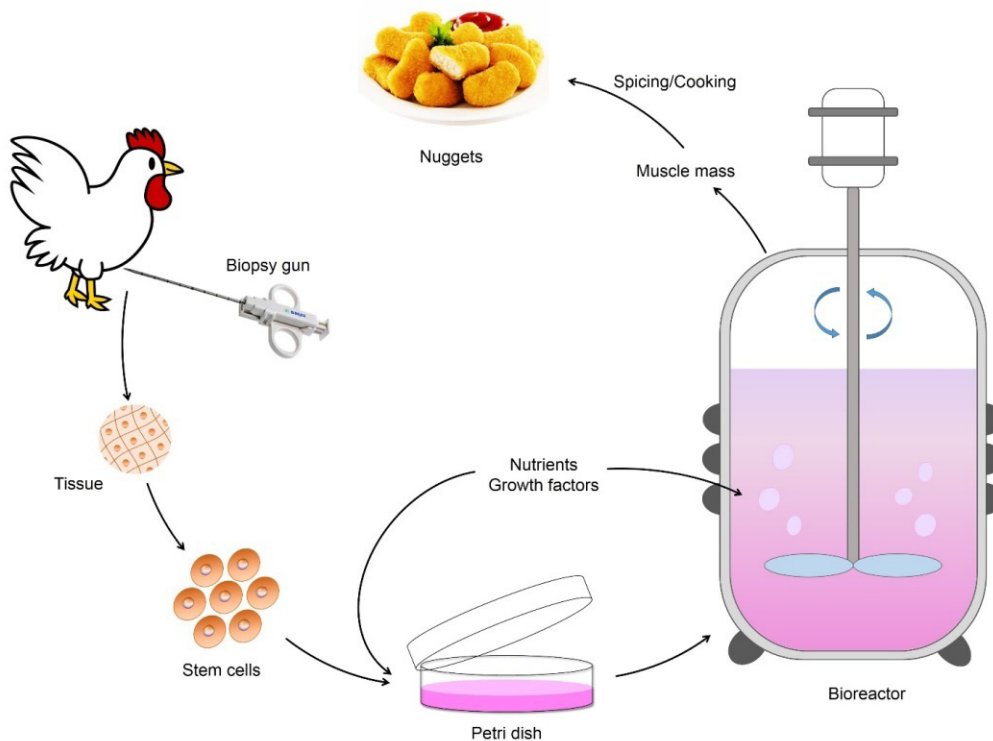
Lab-grown meat comprising of muscle cells of the animal that contributed the starter, especially when grown in presence of fat cells and other cells that co-exist with muscle cells in animals, are likely to taste similar to the meat. Reports on the lab grown meats tasted are encouraging – from Mark Post’s burger to the chicken burgers being served in Tel Aviv in the restaurant *Chicken* and the chicken nuggets in Singapore’s restaurant *1880*. Young environment protection enthusiasts who tasted the nuggets on December 19 at Singapore, felt that nuggets tasted like real chicken.

We are however a long way from obtaining preparations that resemble the popular meat delicacies like the rib eye or the gourmet steaks served in high-end restaurants.

“Cultured meat is the key to feeding a world population that will reach around 9.5 billion by 2050 while respecting animals and preserving the environment.” – Paul Shapiro

Hurdles

Culture of cells in the laboratory continues to be an expensive endeavour. Exacting conditions including appropriate



Schematic representation of the production of lab-grown chicken meat (Credit: Dr Mehboob Hoque)

Chronology of Development of Lab-grown Meat

1885: Wilhelm Roux creates the first cell culture that survives for several days.

1894: Pierre-Eugene-Marcellin Berthelot predicts lab-grown meat.

1907: Ross Harrison Establishes cell culture using the hanging-drop method.

1912: Alexis Carrel established aseptic techniques for cell culture.

1930: Frederick Edwin Smith, a writer and politician, predicted the possibility of growing beef steak outside the body of bullock.

1932: Winston Churchill in his essay 'Fifty Years Hence' published in 1932 in the book *Thoughts and Adventures* envisaged the possibility of growing chicken parts separately in suitable medium.

1943: Rene Barjavel, Science-fiction writer, described *in vitro* production of meat in restaurants in his novel, *Ravage* (translated as *Ashes, Ashes*, 1967)

1950: Willem van Eelen dreamt of using tissue culture for growing food *in vitro*, inspired by scientists trying to grow cells for the treatment of burn injuries.

1999: Willem van Eelen obtains the first patent on *in vitro* meat production for food.

2002: Catts and Zurr culture muscle biopsies from frogs and keep them alive in fungal medium.

2002: Benjaminson and coworkers cultivate gold fish muscle tissue in petridishes with the objective of use in long-term space flights and habituation in space stations. The cultivated muscle preparation tasted like meat after frying.

2013: A sensory panel at the Riverside Studio in London tastes burger with cooked meat patty prepared from meat grown in culture in Prof. Mark Post's laboratory.

2015: Fictitious restaurant "Bistro In Vitro" established by the Dutch artist and philosopher Koert Mensvoort. Menu of the restaurant includes dishes that may become reality in future including those prepared using the meat of extinct animals.

2020: *The Chicken*, a restaurant in the Tel Aviv suburb of Ness Ziona, braces to serve "Hero Chicken Burgers" prepared from meat grown in a bioreactor awaiting approval of the government.

2020: The restaurant, *1880* in Singapore, serves chicken nuggets prepared from lab-grown meat to young environmentalists.

temperature, pH and nutrient concentration, aeration, etc. are needed to be maintained.

The most expensive among the components of the media is FCS. Currently, the cost of FCS is about US\$ 500 for half a litre. Companies engaged in the production of meat in the laboratory have characterized conditions that require minimum FCS and some companies claim that they are close to developing FCS-free media with the appropriate mixture of growth factors.

The cost of production of lab-grown meat is rapidly coming down. In the year 2013 when Mark Post showcased the burger prepared with cell-grown beef for the first time, its cost was claimed to be €250,000. In December 2020, chicken nuggets were retailed for about US\$ 23 at Singapore's restaurant 1880. An Israeli company claims that it is ready to sell cells grown *in vitro* in the form of steak-like strips for the US \$50 and hopes to cut down the cost further. It is expected that extensive researches being undertaken and scaling up the process of growing lab meat will also bring the cost far further down.

Growing meat outside the body of an animal is a revolutionary concept and it is not surprising that a large number of people expressed inhibitions in trying the lab-grown meat. Many feel it is creepy, mysterious and something akin to 'soylent green,' the dreaded food described in the 1966 novel *Make Room! Make Room!* by Harry Harrison. It is however anticipated that the 'yuck' factor will vanish once the lab-grown meat becomes more readily available and people realize that lab-grown meat can be far more hygienic than that obtained from factory animal farms.

Critics of lab-grown meat argue that the elimination of animals globally will hinder the recycling of huge quantities of plant waste. Some recent studies also suggest higher use of growth factors and hormones to facilitate rapid growth of cells in culture may adversely affect the environment in the long term.

Because lab-grown meat is not a genetically modified food in which genetic material of the muscle cells is not modified and 'nothing is inserted or deleted,' obtaining clearance is likely to be easy from the Food and Drug Administration, USA and similar agencies elsewhere. Lab-grown meat however cannot be considered a vegan preparation because of its origin from animal cells. It will be interesting to see if it will be acceptable to vegans.

So will be the reaction of consumers who insist on their meat being *kosher* or *halal*. The giant meat industry currently valued at 1.4 trillion US\$ will surely fight back. But in an interesting development, some of the largest meat companies like *Tyson Foods* are taking interest in the development of lab-grown meat and are partnering with companies developing lab-grown meat.

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