Meat Alternatives - 2019

Research Support Service

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PRESCOUTER

What are examples of companies and academics engaged in creating meat alternatives?

Consumers looking for healthy, low environmental impact, ethical, cost-effective, and new food products are generating renewed interest in meat analogues. High moisture extrusion cooking enables the production of fresh, premium meat analogues that are texturally similar to muscle meat. The appearance and eating sensation is similar to cooked meat while high protein content offers a similar nutritional value.

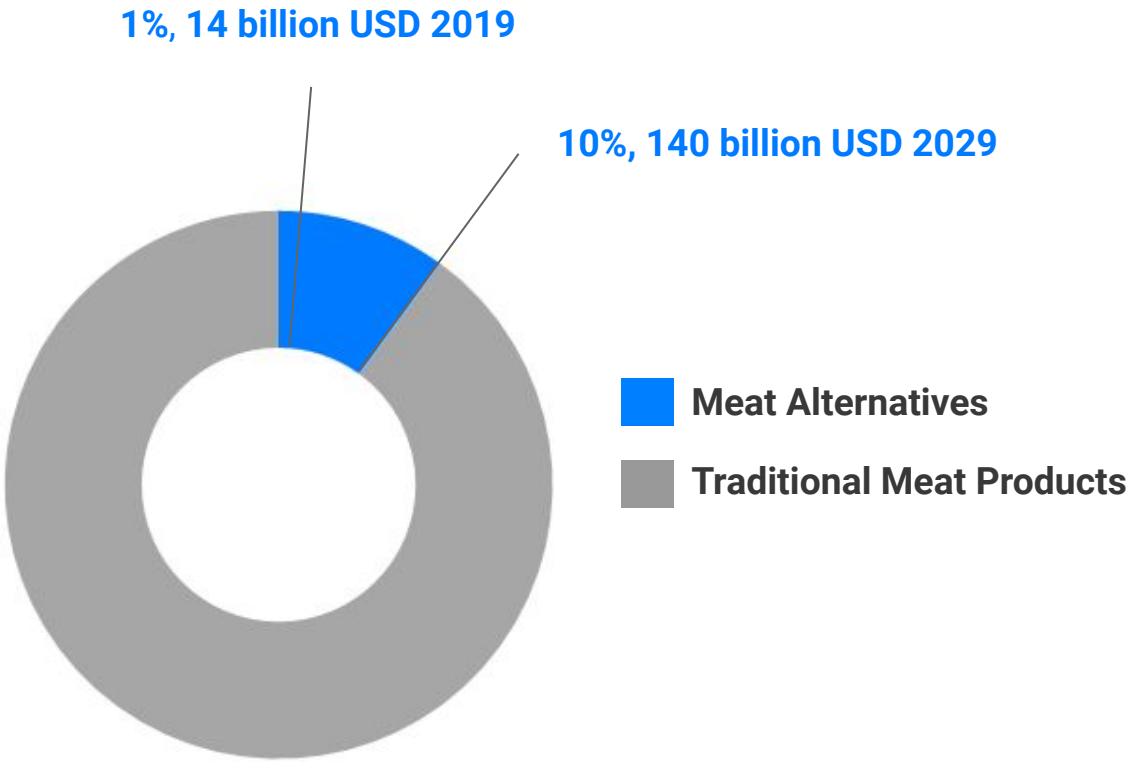
With technologies such as 3D printing, cellular agriculture, as well as high moisture extrusion cooking, it seems that the stage is set for enabling the creation of high quality meat mimetics. However, there is uncertainty in the predicted market value for plant-based and lab-made meat.

In this report, we explore the current state of meat alternatives through examples of commercially available products as well as academic developments. The focus is on plant-based meat analogues, 3D printed meat analogues, and cellular agriculture.

Executive Summary

Executive Summary

Interest is booming in plant-based meat analogues and lab-grown meat alternatives. A recent market analysis report[1] cites rising meat consumption and a growing population leading to a forecast increase in meat alternative market share from 1% today to an equivalent of 10% in 2029 of today's 1.4 trillion dollar meat market.



Meat Market Value:

$1.4 trillion

Meat alternatives to reach

$140 billion

in 2029

Figure. Market share of meat market products

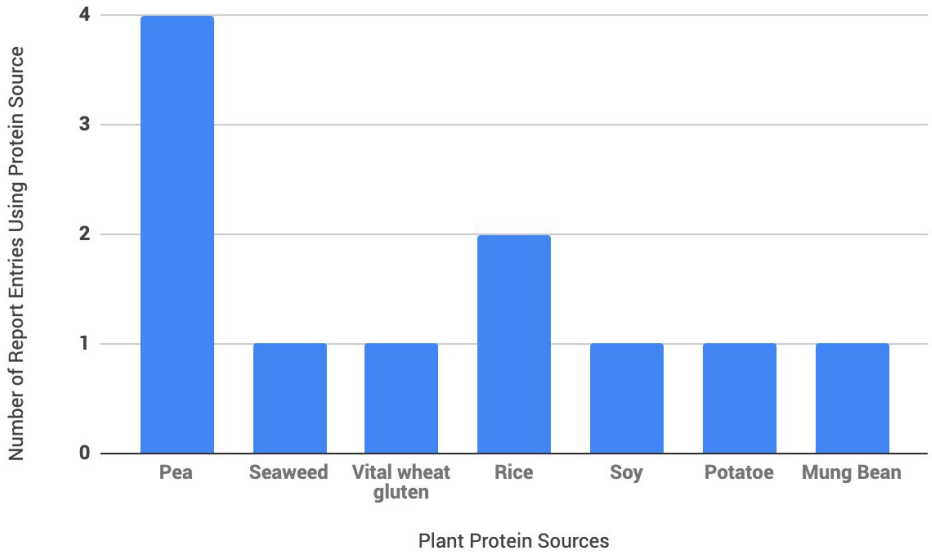
1. https://www.investmentbank.barclays.com/our-insights/carving-up-the-alternative-meat-market.html

Executive Summary

PreScouter investigated the **current state of meat alternative space** by identifying **key drivers** and **technologies** in place, in addition to examples of **commercially available products** and **academic developments**. We cover process and product-related aspects including ingredients and structure formation, nutritional value, post-extrusion processing, consumer benefits, and product-related environmental impacts.

This report focuses on three types of meat alternatives: **Plant-based meat analogues**, **3D printed meat analogues** and **cellular agriculture.**

Plant-based protein: **Redefine Meat**, **Novameat**, **Field Roast Grain Meat Co.**, **Impossible Foods**, and **Beyond Meat** are all examples of companies pushing towards creating plant-based meat analogues. Investigating the ingredients behind these meat alternatives provides insight into the landscape of protein sources being used in the industry.



Executive Summary

It is interesting to note that **none of the companies** reviewed use a single-source plant protein solution, with pea protein being present in every ingredient list except for that of Impossible Foods. For plant protein producers this may open up an additional market for certain plant proteins with more favorable textural, nutritive, and processing properties allowing the ability to achieve the desired appearance and feel.

3D Printed Plant Proteins: Within the plant-based meat alternatives arena we have seen 3D printing infiltrate and there are claims that 3D printing can greatly benefit the meat alternative industry and enable the production of a new meat category. Two companies expanding the boundaries in this arena are **Redefine Meat** and **Novameat.**

This process and technology is **still in development**, without a large-scale commercial 3D printed alternative available. 3D printing aims to combine proprietary 3D printing technology, digital modeling, and plant-based food formulations. The goal of 3D printers being able to mimic the muscle fibers found in traditional meat as well as the way that fat and water is trapped in the meat matrix **has yet to be realised**.

Executive Summary

Cellular Agriculture: Cellular agriculture presents one area with a **large potential for growth**. Using a combination of biotechnology, tissue engineering, molecular biology, and synthetic biology, cellular agriculture is paving the way to create and design new methods of producing proteins, fats, and tissues that would otherwise come from traditional agriculture.

Optimizing cellular agriculture of lab-grown real meat produced from cell cultures has potential to generate significantly less greenhouse gas emissions, while using far less land, and less water than livestock meat. If these aims can be met at scale, cellular agriculture could help protect our planet from climate change, deforestation and biodiversity loss. **The ultimate goal of cellular agriculture in this case is to produce meat that is the same as livestock meat, but does not require animals to be slaughtered.** Perhaps most appealing to those vegan and vegetarian consumers looking for ethically sourced protein is the benefit to animal welfare that cellular agriculture offers.

Subject to regulatory considerations, **JUST Meat** has set a target to make a first commercial sale by the end of 2019. Also represented in this category is **Mosa Meat**, whose CSO Mark Post unveiled the world's first hamburger made by growing cow cells, rather than slaughtering an animal in 2013. Mosa Meat is now aiming to develop their first commercial products. While Mosa Meat and JUST Inc are set to create red meat using cellular agriculture, **Finless Foods** is set to create lab grown fish. Companies are already realizing the potential to address animal welfare, for example, to create **JUST** products, healthy animal cells are first identified and isolated from a feather of a healthy chicken.

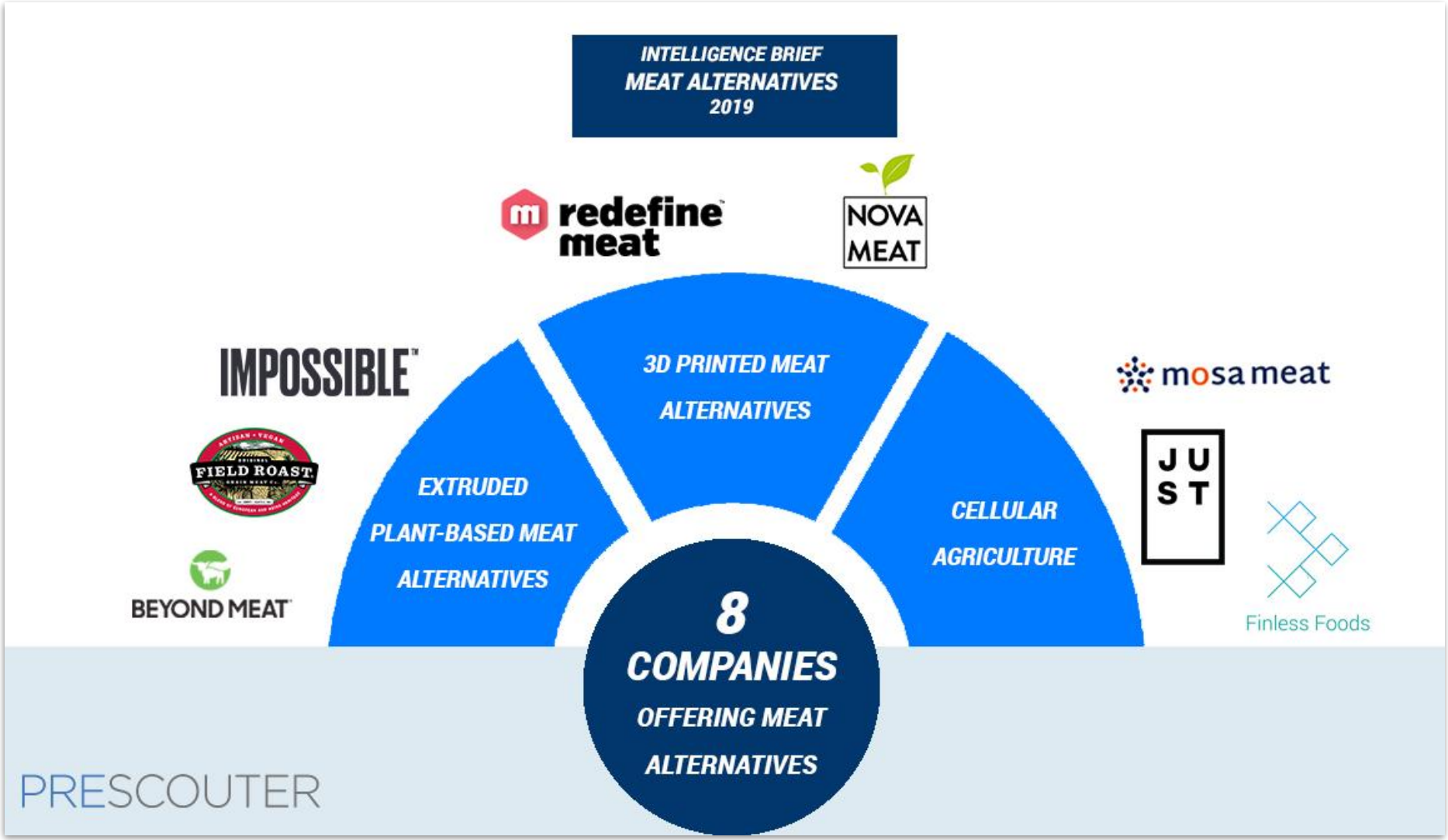
Executive Summary

Finless uses high-quality bluefin tuna fish cells about the size of a grain of rice sourced from real fish. In a recent interview at the World Ocean Summit, Michael Selden, co-founder of Finless Foods, stated that **with one tuna fish, the company can produce an infinite number of fish meat.** Further, the company is working towards no longer having to source cells from bluefin tuna by creating a type of seed bank for fish cells. This will remove the need to catch endangered species. To ensure their product is free of any animal components, Finless uses plant-based serum to nourish the cells for them to grow.

Mosa Meat cells are harvested from the muscles of a cow with a **small biopsy under anaesthesia**. One such harvest could provide enough seed material to grow enough meat to produce **80,000 hamburger patties**.

To foster the creation of more cellular agriculture startups and to propel further innovation in the space, the **New Harvest Research Institute** was founded in 2004. The Institute has funded over 20 research fellowships at institutions like Tufts University and the University of California Los Angeles (UCLA) where cellular agriculture topics such as plant-based scaffolds for marbled cultured beef and the use of insect tissue culture for food production are currently being addressed.

Summary of Companies Profiled



Introduction

Environmental Impact

Animal agriculture is responsible for approximately 18% of human-caused greenhouse gas emissions globally. With the Food and Agriculture Organization of the United Nations (FAO) estimating that the demand for meat will increase by 70% by 2050, emissions from animal agriculture will also increase.

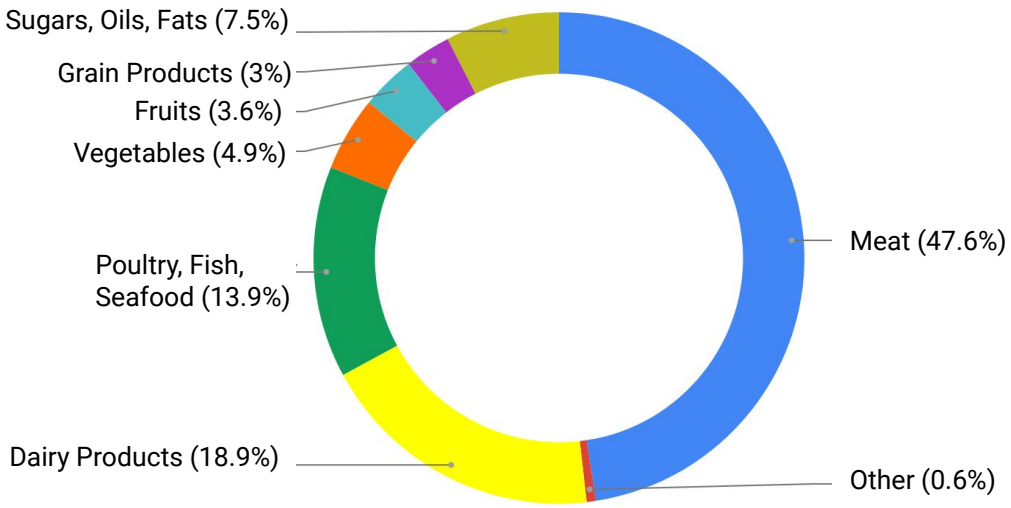


Figure: Greenhouse gas emissions from average food consumption, generated for each food type, as a percentage. (Source)

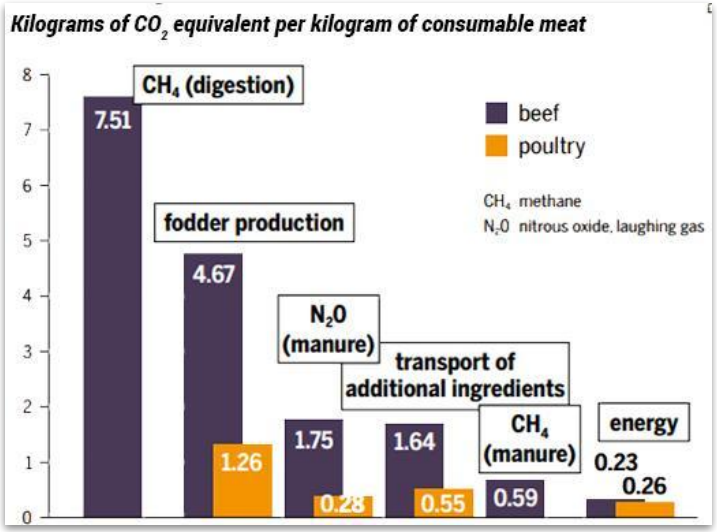


Figure: Emissions from meat production in the USA (Source)

Environmental Impact

One way to fight these environmental issues is to **stop or reduce consuming meat**. Even though we may have seen a shift in recent years, vegan and vegetarian populations only represent a minority in Western societies, anywhere between 2 - 10% in European countries, approximately 3.5% in the US and 10% in Canada. For cultural reasons, countries such as India are home to a very large vegetarian population, estimated at 40% of their total population.

Meat substitutes represent an alternative for people who wish to continue eating meat but wouldn't mind having a product that doesn't come from an animal. Given the increasing demand for meat alternatives, environmental concerns, and the need to feed the world's growing population, what can be created with the technologies that exist today?

PERCENTAGE OF VEGAN AND VEGETARIAN POPULATIONS IN WESTERN SOCIETIES

2-10%

3.5%

10%

INDIA IS HOME TO ONE OF THE LARGEST VEGETARIAN POPULATIONS

40%

Health Implications and Concerns

Consumers are increasingly analyzing their meat consumption because of the risks of high blood cholesterol, heart diseases, and other conditions *that have recently been* associated with red meat consumption in particular.

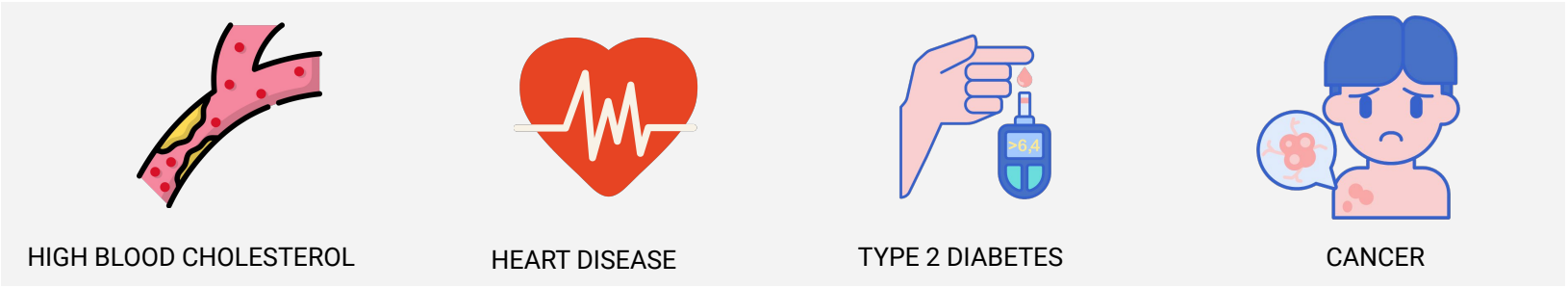


Figure: Health risks associated with red meat consumption

The health risk to consumers from the use of hormones and antibiotics in livestock management is also of concern to consumers. Interestingly, some existing meat alternative products tend to have higher salt levels than real meat and the true potential health differences or benefits remain to be identified.

Food producers have been trying to prevent bad practices, but the potential for inhumane treatment and the slaughtering of animals in industrial-scale livestock farming concerns many consumers.

Key Technologies | Extrusion

While lab-based meat is still several years away from becoming commercially available, plant-based meat alternatives are currently on the shelves of major supermarkets and on the menus of major fast-food chains.

EXTRUSION

High moisture **extrusion** cooking enables the production of meat analogues that are texturally like muscle meat from plant or animal proteins. The appearance and mouth feel are similar to cooked meat while their high protein content offers a similar nutritional value. Plant-based meat analogues are the major alternative meat product on the market today. Important process and product-related aspects include protein source, ingredients, structure formation, texture, flavor, taste and nutritional value.

Extrusion is a thermomechanical process by which moistened, proteinaceous plant materials are plasticized and pushed through a die by a combination of pressure, heat, and mechanical shear. A typical extruder set-up consists of a preconditioning system, a feeding system, a screw, a barrel, a die, and a cutting machine.

Key Technologies | Extrusion

Steps:

1. Dry or preconditioned plant protein material with adjusted moisture content is fed into the extruder through a screw feeder during processing.
2. Material is mixed and homogenized going from the feeding zone to the screw.
3. Material is transported to the compression zone where a reduction in screw depth and pitch exists, which results in an increase in shear rate, temperature and pressure.
4. This change in process conditions converts the solid material into a fluid melt which is exposed to the maximum temperature and pressure reached leading to an immediate reduction on the viscosity of the extruded material before exiting the extruder.

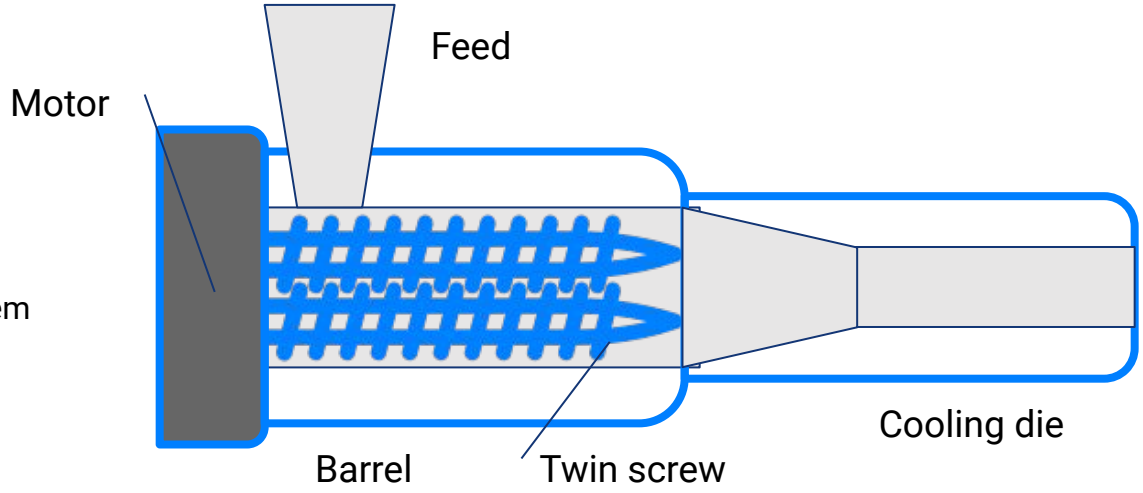


Figure: Example diagram of a typical twin screw extruder system

Key Technologies | Extrusion

Recent Research

Effects of extrusion types, screw speed and addition of wheat gluten on physicochemical characteristics and cooking stability of meat analogues (2019)

Overview: Gi-Hyung Ryu is currently working as professor in the Division of Food Science at Kongju National University in South Korea. His research focuses on food engineering including the examination of the effect of extrusion conditions and methods on food quality. Ryu has authored over 10 food engineering-based academic papers within the last 10 years.

Key Results:

- The addition of wheat gluten as well as the type of extrusion used played a significant role in determining the physicochemical characteristics that influence the texture of food products ($P < 0.001$).
- All of the tested high-moisture meat analogues (HMMAs) demonstrated more stability and a higher integrity index compared to low-moisture meat analogues (LMMAs).
- In general, the use of high-moisture extrusion cooking and the incorporation of wheat gluten into the formula at 400 g kg-1 could impart a fibrous and compact structure to extrudates similar to that of actual muscle meat, with a greater integrity index and texture stability.

DOI: 10.1002/jsfa.9722
Contact: ghryu@kongju.ac.kr

Author's Research Gate Page: https://www.researchgate.net/profile/Gi_Hyung_Ryu

Key Technologies | 3D Printing

3D PRINTING

We have seen **3D printing** infiltrate and disrupt multiple sectors, and similarly there are claims that 3D printing can greatly benefit the meat alternative industry and enable the production of a new meat category. Some claim 3D printed plant-based meat will be environmentally friendlier, customizable, more affordable and positive for animal welfare.

3D food printing isn't particularly new, but has mostly been associated with manufacturing cell-based cultured meat, rather than plant-based products. Giuseppe Scionti, founder of Novameat, adds:

> *"I was able to generate something that had the same texture as meat, I was able to create micro fibres that resembled not just a hamburger or a meatball but had the same texture as muscular tissue".*

Scionti worked for over ten years creating multiple tissues via bioprinting at the Polytechnic University of Catalonia (UPC) in Barcelona. Scionti realized during the development of a human ear prototype that the texture closely resembled the actual texture of human tissue.

In one of the most recent developments, food tech startup Aleph Farms announced that they have successfully produced lab-grown meat using a 3D bioprinter on the International Space Station, nearly 250 miles away from any natural resources. The aim is to provide meat for people living on the space station in the future.

CELLULAR AGRICULTURE

Cellular Agriculture is an emerging technology which is still years from the market that focuses on the production of agricultural products from cell cultures. Using a combination of biotechnology, tissue engineering, molecular biology, and synthetic biology, cellular agriculture is paving the way to create and design new methods of producing proteins, fats, and tissues that would otherwise come from traditional agriculture. Cellular agriculture of lab-grown real meat produced from cell cultures is primed to reach supermarket shelves in the next decade.

In the US, the Food and Drug Administration (FDA) and the Department of Agriculture (USDA) jointly regulate safety and labelling of meats, poultry and egg products. Recently, the FDA and the USDA agreed to regulate the production of cell-cultured meat alternatives derived from livestock and poultry.

References:

1. http://www.fao.org/newsroom/en/News/2006/1000448/index.html
2. http://www.foeeurope.org/sites/default/files/news/foee_hbf_meatatlas_jan2014.pdf
3. https://onlinelibrary.wiley.com/doi/abs/10.1111/jiec.12174
4. http://www.vrg.org/nutshell/Polls/2016_adults_veg.htm
5. https://www.ctvnews.ca/canada/more-than-3-million-canadians-vegetarian-or-vegan-study-1.4027606
6. https://www.worldatlas.com/articles/countries-with-the-highest-rates-of-vegetarianism.html
7. https://www.cbc.ca/news/business/beyond-meat-burger-beef-health-risks-1.5220777
8. https://www.msn.com/en-us/news/technology/first-meat-grown-in-space-lab-248-miles-from-earth
9. https://pdfs.semanticscholar.org/cf90/d287aa226b483aed430ff4f0432081bfd3d7.pdf
10. https://www.3dnatives.com/en/3d-printed-meat-040620194/

Extruded Plant-Based Meat Alternatives

IMPOSSIBLE

BEYOND MEAT®

Field Roast Grain Meat Co.

Founded: 1997 **Headquarters:** Seattle, WA, USA

Website: https://fieldroast.com **Contact:** 1-800-311-9497

Overview

Field Roast is a subsidiary of Maple Leaf Foods, Inc. They manufacture and sell vegetarian grain meat products including grain-based roast and sausage products. Interestingly, unlike many meat alternative manufacturers, the company's aim has been to produce artisanal meat and dairy alternatives that are flavorful and nutritionally satisfying without trying to mimic the taste of traditional meat and dairy goods. The company was founded in 1997 and currently has approximately 116 employees with an estimated annual revenue of $25 million.

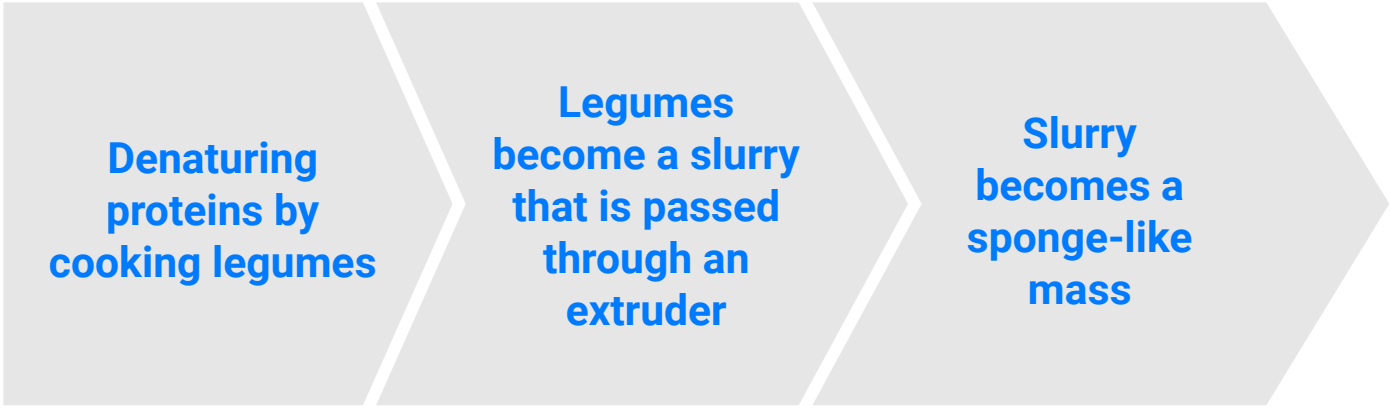
At a glance			
Protein Source:	*Various plants and grains, including vital wheat gluten and pea protein (depends on product)*	**Stage of Development:**	*Commercialized since 1997*
Scalability:	*Full commercial manufacture*	**Key Technology:**	*Extrusion*
GMO:	*No*	**Replacement Target:**	*Chicken, Beef, etc.*

Field Roast Grain Meat Co.

Technology

Via **extrusion**, Field Roast uses ingredients such as **grains**, **vegetables**, and **spices** to create plant-based meat and cheese alternatives. According to the company, they use a combination of artisanal European and Asian techniques to create the products.

Field Roast does not disclose its exact manufacturing process. However, most meat analogs are generally produced by cooking some kind of legume **to denature the proteins** that they contain. As a result, the legumes collectively become a slurry that gets passed through an extruder and becomes a sponge-like mass.



Field Roast Grain Meat Co.

Source

Grains and plants (grain and plant types vary from product to product) are the protein sources used by Field Roast to produce their products. For example, the primary protein source in sausages is vital wheat gluten. Field Roast's Field Burger is made from barley, celery, and carrots while the Celebration Roast is made with butternut squash, mushrooms, apples, wheat flour, barley malt, yeast extract, tomato paste, and various spices.

Figure: Various types of Field Roast's plant-based meat alternative products.

References:

1. https://www.owler.com/company/fieldroast
2. https://fieldroast.com/culinary-heritage/
3. https://fieldroast.com/wp-content/uploads/2013/08/Field-Roast-CR-SL-9-15.pdf
4. https://www.bloomberg.com/news/articles
5. https://fieldroast.com/wp-content/uploads/2013/08/Field-Roast-Saus-SL-7-13.pdf

Impossible Foods

IMPOSSIBLE™

Founded: 2011 **Headquarters:** Redwood City, California

Website: https://impossiblefoods.com **Contact:** +1 650 461 4380

Overview

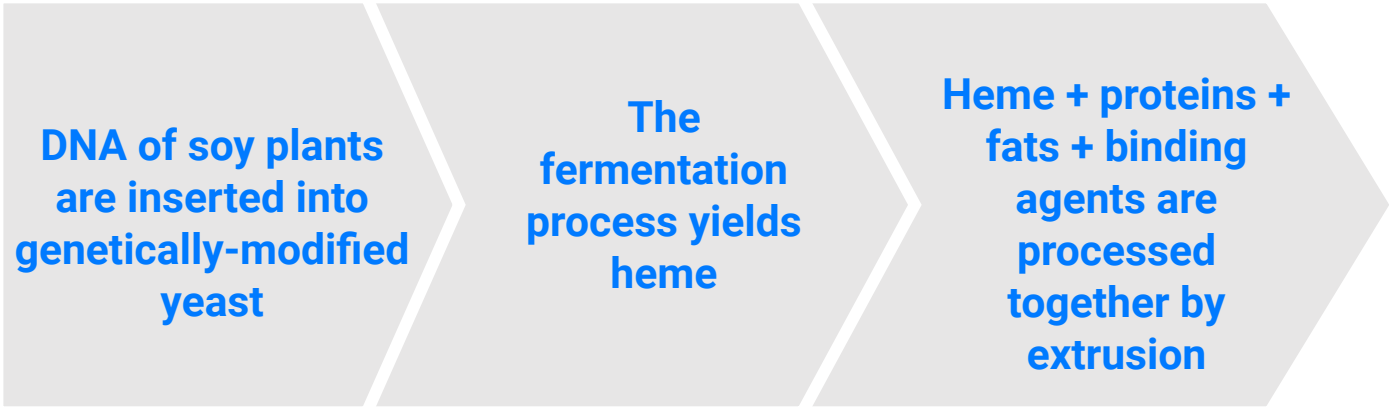
Impossible Foods was founded in 2011 by Patrick O. Brown, M.D., Ph.D. to help end the use of animals to make food, a part of the mission to ensure sustainable food production. The company makes meat, dairy and fish products solely from plant proteins. With about 200 employees, Impossible Foods produces kosher and halal certified products. The company, in 2016, launched the Impossible™ Burger and has received $687.5 million in total funding.

At a glance			
Protein Source:	*Proteins from soy and potato*	**Stage of Development:**	*Commercialized since 2017*
Scalability:	*Full commercial manufacture*	**Key Technology:**	*Extrusion*
GMO:	*Yes*	**Replacement Target:**	*Meat, dairy, and fish*

Impossible Foods

Technology

An essential part of the development of Impossible Foods' products is the use of heme, an iron-containing protein that gives meat its color. Heme is also believed to make meat taste more like meat. Impossible Foods makes **plant-based heme** via the fermentation of genetically-modified yeast. The company takes DNA of soy plants and inserts it into genetically-modified yeast. This is then fermented in a similar way as Belgian beer. Instead of producing alcohol, this fermentation process yields substantial quantities of heme which is used in the production of Impossible Foods products to give them a similar sensory appeal as real meat. The proteins, heme, fats and binding agents are processed together by extrusion to obtain the final product.



Impossible Foods

Source

Impossible Foods selects specific proteins and nutrients from greens, seeds, and grains to develop meat and dairy products. The company uses soy and potato as their source of protein, heme for the flavor, coconut oil and sunflower oil as the source of fat and methylcellulose as the binding agent.

Figure: (Left) Impossible Foods' raw meat alternative. (Right) Impossible Food burger

Impossible Foods

IMPOSSIBLE™

Recent News

Impossible Foods now has a contract with **Burger King** to supply the franchise with plant-based Whoppers. The Burger King Whopper® is one of the company's flagship products, made of real beef. The Impossible Whopper® contains about 15% less fat and 90% less cholesterol than the standard Burger King Whopper®. Yet, Burger King claims customers cannot determine the difference mainly because the plant-based Whopper® is designed to "bleed" just like a patty made from real beef. The Impossible Whopper® costs only $1 more than the standard Whopper®.

Further, Impossible Foods has been supplying **White Castle**, America's first fast-food burger chain, since September 2018. White Castle announced the Impossible Slider as a permanent feature on their menu in September 2019. Impossible Foods has also launched a co-manufacturing collaboration with **OSI Group**, McDonald's biggest supplier.

Figure: Impossible Burger King Whopper

References:

1. https://impossiblefoods.com/heme/
2. https://www.crunchbase.com/organization/impossible-foods#section-overview
3. https://www.foodnavigator-usa.com/Article/2019/01/08/Impossible-Foods-replaces-wheat-with-soy-protein
4. https://www.theverge.com/2019/8/1/20750704/burger-king-nationwide-rollout-impossible-whopper-august-8
5. https://faq.impossiblefoods.com/hc/en-us/articles/360018937494-What-are-the-ingredients-
6. https://www.prnewswire.com/news-releases/white-castle-celebrates-first-anniversary
7. https://www.businesswire.com/news/home/20190731005278/en/Impossible-Foods-Launches-Co-manufacturing-Collaboration-OSI

Beyond Meat

Founded: 2009 **Headquarters:** El Segundo, California

Website: https://www.beyondmeat.com/ **Contact:** +1 866-756-4112

Overview

Founded in 2009, Beyond Meat's mission is to create plant-based meat products such as a burgers, sausages, crumbles, etc. The company is inspired by the need to create more sustainable sources of meat to address the challenges associated with livestock agriculture such the effects on human health, climate change and animal welfare as well as constraints on natural resources. With a total funding of $122 million, the company now has products selling across the United States and other countries. With an employee count of about 200, the company has about 16 high profile ambassadors who are promoting the consumption of the plant-based meat alternatives.

At a glance			
Protein Source:	*Pea proteins, rice proteins, mung bean proteins*	**Stage of Development:**	*Commercialized in USA and other countries*
Scalability:	*Full commercial manufacture*	**Key Technology:**	*Extrusion*
GMO:	*No*	**Replacement Target:**	*Beef, Pork, Chicken*

Beyond Meat

Technology

By extrusion, they produce burgers, sausages and crumbles (ground meat) using pea proteins, rice proteins and mung bean proteins. Also, coconut oil is used as source of fat to give the product juiciness similar to real meat. Beet juice is also added to the ingredient mix to add color and also provide vitamins for the product. Beyond Meat products are engineered to have the versatility, texture and juiciness comparable to that of real meat products.



Figure: Recipes made from Beyond Meat. (Left) Beyond Beef Empanadas; (Middle) Beyond Elote Burger; (Right) Beyond Beef Mediterranean Skewers

Source

Beyond Meat creates meat alternative products using pea protein Isolate, rice protein and mung bean protein, coconut oil along with other plant extracts such as beet juice extract (for the color), lemon juice concentrate and apple extract.

Beyond Meat

Recent News

Whole Foods first sold Beyond Meat products in 2013 and according to the CEO of Whole Foods, John Mackey, this served as a launchpad for the plant-based meat company. Further, the grocer has recently included all Beyond Meat products in its aisles. In a statement by John Mackey, one of the motivating factors for this move by Whole Foods is the fact that plant-based meat alternatives are more ethical to make and have better impact on the environment.

Also, starting from September, 2019, **HelloFresh** began offering Beyond Meat's Beyond Burger in its US meal kits. In Canada, Beyond Burger has been on HelloFresh's menu since July, 2019. This partnership follows the partnership between Beyond Meat and **Blue Apron**, who have been serving Beyond Meat products in the US since July of 2019.

Beyond Meat has also partnered with **McDonald's** on a plant-based burger to be sold in Canada. Sales launched on September 30, 2019. Beyond Meat stock prices rose more than 10% after the announcement.

Beyond Meat has launched partnerships with other companies such as **Subway**, **Tim Hortons** and **Dunkin Donuts**.

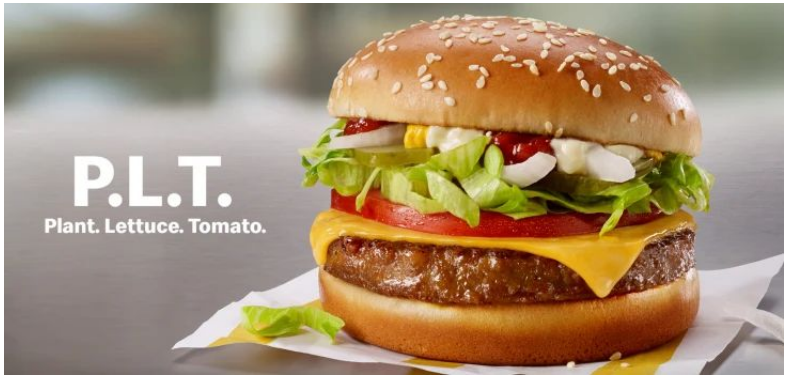


Figure: McDonald's "PLT" plant-based burger.
Credits: McDonald's

Beyond Meat

Recent News

Beyond Meat recently launched a partnership with **KFC**. The partnership has seen the production of Beyond Fried Chicken, which was tested in an Atlanta KFC outlet on the 27th of August, 2019. Customers were given samples of the new plant-based product to taste test and provide feedback the company will use to improve their product.

Figure: (Left) The KFC Beyond Fried Chicken which was tested at an Atlanta KFC outlet in August 2019

References:

1. https://www.beyondmeat.com/products/beyond-beef/
2. https://www.beyondmeat.com/about/
3. https://www.crunchbase.com/organization/beyond-meat#section-overview
4. https://www.linkedin.com/company/beyond-meat/about/
5. https://web.aw.ca/en/our-values/our-food/beyondmeat
6. https://finance.yahoo.com/news/whole-foods-ceo-says-grocer-145436160.html
7. https://www.bloomberg.com/news/articles/2019-08-26/beyond-fried-chicken-to-get-taste-tested-in-an-atlanta-kfc
8. https://edition.cnn.com/2019/09/26/investing/beyond-meat-stock-mcdonalds-canada
9. https://www.beyondmeat.com/whats-new/subway-and-beyond-meat-team-up/
10. https://www.timhortons.com/ca/en/menu/beyond-meat.php
11. https://news.dunkindonuts.com/news/beyond-meat-dunkin

3D Printed Meat Alternatives

Redefine Meat - Redefine Steak

Founded: 2018 **Headquarters:** Tel Aviv, Israel

Website: https://redefinemeat.com **Contact:** Contact Form

Overview

Redefine Meat (also referred to as Jet-Eat) was founded in 2018. It is the first company to develop novel food printing technology that combines innovations in both digital and 3D printing with innovative food science. The company has an estimated 30 employees and an estimated revenue of $10.3 million.

At a glance			
Protein Source:	*Plant-based protein source (mixture of plant-based protein, including pea protein)*	**Stage of Development:**	*Full technology commercialization expected in 2021*
Scalability:	*Only produce 1 product (steak/beef), plan to expand to other types of meat*	**Key Technology:**	*Extrusion and 3D printing*
GMO:	*Not specified*	**Replacement Target:**	*Beef*

Redefine Meat - Redefine Steak

Technology

Their production methods combine proprietary **3D printing technology**, **digital modeling**, and **plant-based food formulations**. This process and technology is still in development. However, Redefine Meat's 3D printer is able to mimic the muscle fibers found in traditional meat as well as the way that fat and water is trapped in the meat matrix.

Currently, the company only has one small 3D printing machine that makes approximately two pounds of meat per hour (seen in the adjacent figure). They plan to develop a bigger machine/printer that would help increase their production rate 10 times over. The company believes that this technology will **decrease the negative impact of traditional animal husbandry by 95%**.

Figure: Redefine Meat's Alternative Meat 3D Printer (PRNewsfoto/Redefine Meat)

Redefine Meat - Redefine Steak

Source

Redefine Meat uses **3 plant-based protein sources from a mixture of plant-based protein, including pea protein**. They do not specify the exact plant(s) that are used as the protein source, or whether or not they are GMO. In addition to the 3 plant-based protein sources, **fat** and **water** are also included in their product.

Figure: Representative image of Redefine Meat's 3D-printed steaks that have been cooked.

Figure: Redefine 3D-printed beef being prepared for patrons at a restaurant in Israel.

Figure: Redefine Meat's animal-free burgers (PRNewsfoto/Redefine Meat).

References:

1. https://www.3dnatives.com/en/3d-printed-meat-040620194/
2. https://redefinemeat.com/
3. https://www.owler.com/company/redefinestudio
4. https://www.timesofisrael.com/3d-printed-/
5. https://www.prnewswire.com/il/news-releases/redefine-meat-raises-6m-round-led-by-cpt-capital-for-its-3d-alt-meat-printer-300915357.html

Novameat

Founded: 2018 **Headquarters:** Barcelona, Spain

Website: https://www.novameat.com/ **Contact:** hi@novameat.com

Overview

Novameat is a food tech startup founded by Giuseppi Scionti that works with plant-based foods, including plant-based meat substitutes. The company was responsible in 2018 for creating a meat substitute through 3D printing, whereby a plant-based paste was used with syringes placed in a 3D printer using AutoCAD software to create a 3D printed meat alternative.

In 2019, Scionti was selected in the list of "*Nine Innovators to Watch in 2019*" by Smithsonian (magazine), and his project at Novameat was included in Peter Diamandis' article "The 5 Big Breakthroughs to Anticipate in 3D Printing".

At a glance			
Protein Source:	*Plant-based protein source (protein powder from rice, peas and seaweed)*	**Stage of Development:**	*Prototype 3D printed in 2018*
Scalability:	*Scalable, but currently only produce 1 product (steak/beef) at 2£ per 100g*	**Key Technology:**	*3D printing*
GMO:	*No*	**Replacement Target:**	*Beef*

Novameat

Technology

Novameat's production methods combine 3D printing technology, digital modeling, and plant-based food formulations. This process and technology is still in development. However, Novameat 3D printing approach is able mimic the muscle fibers found in traditional meat. Techniques that are normally used for cultured meat, and techniques borrowed from bioprinting are adapted for use with materials for plant-based meat.

Scionti believes the appearance can be improved with an investment of time and new prototypes, since this aspect is very important from the consumer's point of view. Scionti notes:

"We need to adapt the three-dimensional models to make them more complex, to differentiate the part that imitates fat from the part that imitates muscles or other tissues."

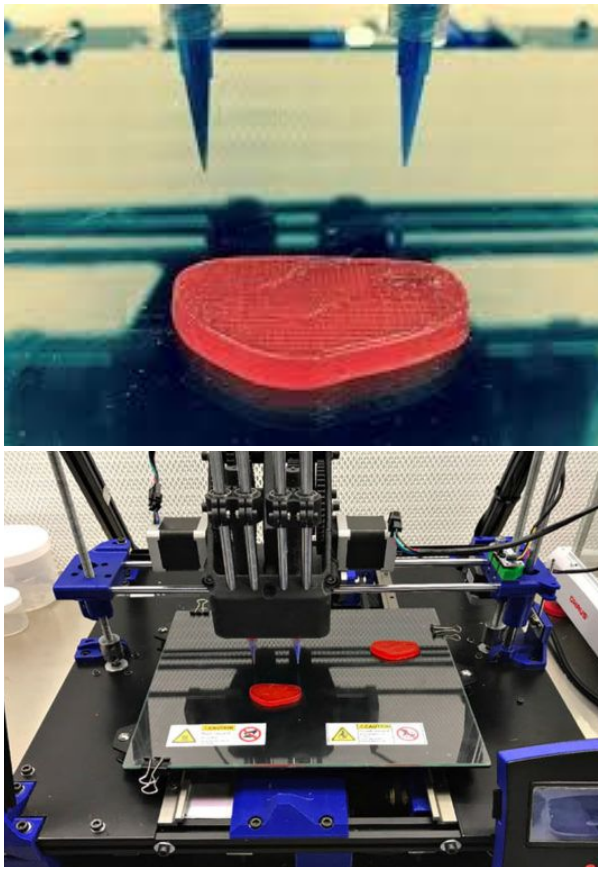


Figure: (Left) Representative image of Novameat's 3D-printed steak; (Right) Novameat 3D-printed plant-based steak being printed.

Novameat

Technology

With regards to **scalability**, Scionti claims the current technology allows for scalability that will not required multiple printers in operations simultaneously. With a continuous supply of material and several extruders working at the same time, he believes it will be possible to create much more product in a lot less time.

In **October 2018**, Scionti authored and submitted an international patent in the field of food technology, describing a unique technology that allowed for the production of fibrous plant-based food using a 3D-printer, mimicking meat texture and its nutritional value.

Source

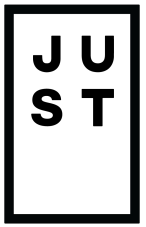
The ingredients that go into a steak are protein powder (from rice or peas) and seaweed components – food that is normally consumed by vegetarians and vegans as dietary supplements.

References:

1. https://www.3dnatives.com/en/3d-printed-meat-040620194/
2. https://elpais.com/elpais/2018/09/27/inenglish/1538061240_449222.html
3. https://mikeshouts.com/nova-meat-3d-printed-beefsteak/
4. https://www.smithsonianmag.com/innovation/nine-innovators-watch-2019-180971194/
5. https://singularityhub.com/2019/04/08/5-big-breakthroughs-to-anticipate-in-3d-printing/

Cellular Agriculture

Finless Foods



Mosa Meat

Founded: 2016 **Headquarters:** Maastricht, The Netherlands

Website: https://www.mosameat.com/ **Contact:** info@mosameat.com

Overview

Mosa Meat is a cultured meat company that was founded in 2016 following the unveiling of the first slaughter-free hamburger in London, in 2013 by Professor Mark Post. The company's aim is to find a novel method for making real meat to feed the growing human population in a way that is healthy, sustainable and animal-friendly.

The company is a spin-off of a research lab led by Professor Mark Post at Maastricht University. Their research was funded (at the cost of €250,000) by the co-founder of Google, Sergey Brin. The company currently has about 30 employees.

At a glance			
Protein Source:	*Cow muscle cells (myosatellite cells)*	**Stage of Development:**	*Lab testing stage*
Scalability:	*Scaling up process, first meat products will be available on the market in the next 3-4 years.*	**Key Technology:**	*Cellular agriculture*
GMO:	*No*	**Replacement Target:**	*Beef*

Mosa Meat

Technology

Cells are harvested from the muscles of a cow with a small biopsy under anaesthesia. The cells are placed in a growth medium containing all the needed nutrients and naturally-occurring growth factors and allowed to grow just as they would in the animal. The growth of the cells is allowed to continue in a bioreactor until there are trillions of cells. In order to have the cells differentiate into muscle cells, they stop feeding the cells the growth factors. Consequently, the cells then differentiate on their own.

The muscles come together to form myotubes (muscle fibre) which are then placed in a gel that contains approximately 99% water to help the cells take the shape of muscle fibres. When all the muscle fibre layers come together, the meat is then processed into the desired products. From one cell harvesting sample, they are able to make enough meat to produce 80,000 quarter pounders (hamburger patties).

Figure: Thousands of individual muscle fibres combine to form a hamburger.

Mosa Meat

Source

Mosa Meat uses harvested cow muscle cells to produce muscle fibres which are then processed into meat products.

Recent News

In addition to the funding the company received from Sergey Brin, the company has raised €7.5 million to further its cause in scaling up their production. The company hopes to achieve mass production by 2021. Further, Mosa Meat's investment round was led by M Ventures, the corporate venture capital arm of Merck, and Bell Food Group, the Swiss meat company.

Mosa Meat, with this funding and in order to be able to meet their mass production target, is looking to expand its facility from a 10,000 to 25,000 liter bioreactor with the capacity to produce over 100 tons of meat each year.

Figure: A burger made from Mosa Meat's cultured meat

References:

1. https://www.mosameat.com/technology
2. https://www.mosameat.com/about-us
3. https://www.forbes.com/sites/michaelpellmanrowland/2018/07/30/mosa-meat-merck/#1ae4358026f7
4. https://www.foodnavigator.com/Article/2018/07/19/Mosa-Meat-CEO-on-the-huge-challenge-of-scaling-production

Finless Foods

Founded: 2017 **Headquarters:** San Francisco, California

Website: https://finlessfoods.com **Contact:** +1 908 448 4426

Overview

Finless Foods is a biotechnology company that aims to produce seafood in a sustainable manner. The company creates bluefin tuna, a fish that has been threatened by predatory fishing practices. In 2017, Finless Foods produced their first pound of bluefin tuna meat at a cost of $19,000 and within 4 months were able to reduce the cost of production by half. By June 2018, the company had raised seed capital of $3,500,000 to further their objective of producing bluefin tuna meat at the same cost of traditional bluefin tuna sold on the market by the end of 2019. The company has 11 employees and its investors include Softmatter VC, Blue Horizon and Babel Ventures.

At a glance			
Protein Source:	*Fish cells*	**Stage of Development:**	*Lab testing stage*
Scalability:	*The company is scaling up production*	**Key Technology:**	*Cellular agriculture*
GMO:	*No*	**Replacement Target:**	*Fish*

Finless Foods

Finless Foods

Technology

Finless Foods uses four steps to produce their fish products. First, high-quality bluefin tuna fish cells about the size of a grain of rice are sourced from real fish. The cells are fed nutrient-rich ingredients, such as salts, sugars and proteins, that allow them to grow and multiply in a food-certified facility. To ensure their product is free of any animal components, the company uses plant-based serum to nourish the cells for them to grow. The result is a paste-type fish meat. The cells (the fish meat paste) are then structured into real fish fillets and steaks.

These steps enable the company to produce healthy fish meat which is fresh and free of mercury, one of the major concerns with natural fish products. Also, the method by which they obtain the cell samples does not harm the donor fish, hence, People for the Ethical Treatment of Animals (PETA) bioethicists and animal welfare activists can agree with the company when they say their product is cruelty-free.

Figure: Mike Selden and Brian Wyrwas at the Finless Foods facility in California. © Finless Foods

Finless Foods

Finless Foods

Source

Finless Foods produces fresh fish meat using high quality fish cells harvested from real fish.

Recent News

In a recent interview at the World Ocean Summit, Michael Selden, co-founder of Finless Foods, stated that with one tuna fish, the company can produce an infinite number of fish meat. The company has worked with chefs to make fish cakes that use about 30% of the fish meat paste, that is formed in their process of fish meat production. They are also looking to developing fish rolls with their product.

Further, the company is working towards no longer having to source cells from bluefin tuna by creating a type of seed bank for fish cells. This will remove the need to catch endangered species.

According to Michael Selden, the company is currently focused on penetrating the US, Canada, China, Japan and UAE markets with their products.

Figure: Finless Foods created bluefin tuna fish croquettes in September 2017 © Finless Foods

References:

1. https://finlessfoods.com/about/
2. https://golden.com/wiki/Finless_Foods
3. https://thefishsite.com/articles/cell-based-seafood-and-the-future-of-food-part-i
4. https://www.thenational.ae/uae/environment/lab-grown-fish-could-be-coming-to-a-plate-near-you-soon-1.833477

JUST Inc

Founded: 2011 **Headquarters:** San Francisco, California

Website: https://ju.st/ **Contact:** +1 (844) 423-6637

Overview

JUST Inc works with rural farmers to produce cultured beef and eggs. Also, the company is investigating other plants aside those currently on their ingredients lists aiming to make a healthier and more flavorful diet. The company's objective is to provide alternatives to conventionally produced meat in an effort to help reduce the impact of the process on the environment thereby reducing the water, fuel, pesticides, and fertilizer that is used in industrialized animal production. The company was established in 2011 and currently has 120 employees.

At a glance			
Protein Source:	*Cells isolated from a chicken feather*	**Stage of Development:**	*Commercialized eggs in the USA; the company also aims to make a first commercial sale of their meat by the end of 2019.*
Scalability:	*The company is scaling up production*	**Key Technology:**	*Cellular agriculture for meat, extrusion for egg alternative*
GMO:	*Not specified for the meat, the Just Eggs are non-GMO*	**Replacement Target:**	*Chicken, egg*

JUST Inc

Technology

To create JUST products, healthy animal cells are first identified and isolated from a feather of a healthy chicken. Plants are used as sources of nutrients for the cells to grow under conditions conducive to growth. Using **biocompatible scaffolding** and a **bioreactor**, JUST produces JUST meat and JUST eggs which have similar properties as meat and eggs respectively. Their method is free of the use of antibiotics and according to the company, the meat and eggs present "lower susceptibility to foodborne illnesses." The company believes that with its method of production, it can produce meat that is over 10 times more efficient than the world's highest volume slaughterhouse.

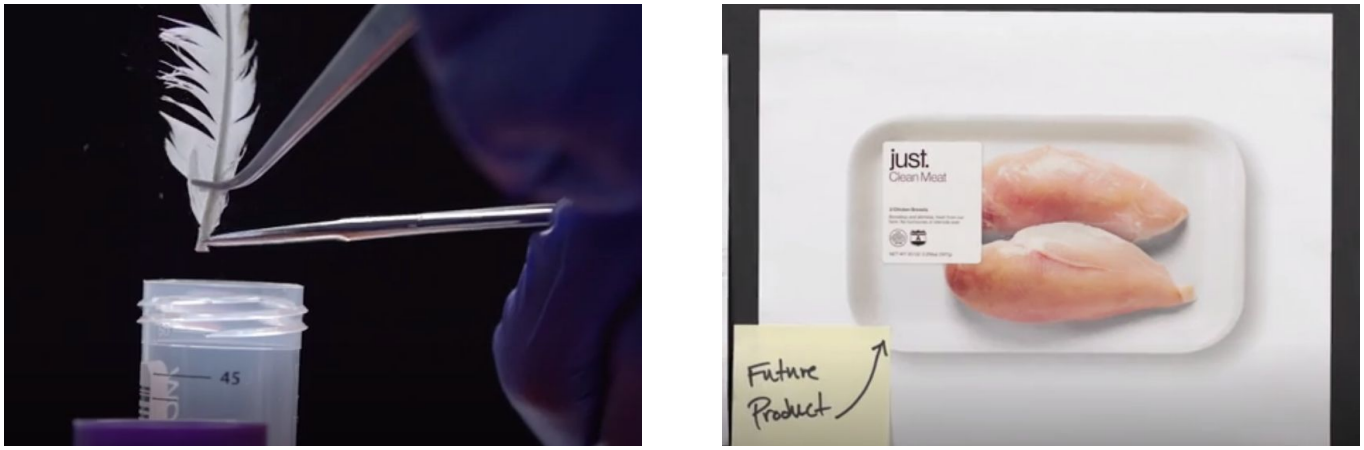


Figure: (Left) JUST Inc. scientist taking a sample of a chicken feather from which chicken cells will be isolated, fed and grown to develop the meat. (Right) The final product from the culturing of the cells isolated from the feather.

JUST Inc

Source

Animal cells are isolated from healthy animals and fed nutrients from plants to produce JUST Meat.

Technology #2 - JUST Egg

By extrusion, plant ingredients are used to produce eggs with the same texture and consistency as real chicken eggs. The company uses mung bean as the main source of protein since it gels and cooks like real eggs. In addition to the protein from mung beans, turmeric and natural carrot extracts are used to give the product its color. The end product scrambles and has the same taste as eggs and can be used as egg replacement in meals. Other ingredients include expeller-pressed canola oil, dehydrated onion, soy lecithin and tapioca syrup.

Source #2 - JUST Egg

JUST Inc isolates protein from mung beans to create the plant-based eggs.

JUST Inc

Recent News

According to a report by Food Navigator, JUST Egg is selling more than other established liquid egg brands. The plant-based egg product has been on the shelves of **Safeway** and **Albertsons** stores across the United States following JUST Inc's deal with other grocers like **Shoprite**, **Hyvee**, **Savemart** and others.

Josh Tetrick, CEO of JUST Inc, has acknowledged that they have not reached the point where they are able to bring the production cost of the JUST Eggs below that of conventional eggs. In order for the company to achieve this, he added that they will have more primary processing facilities in other parts of the world (potentially in Africa and Asia) close to sources of mung beans.

Figure: Products made from JUST Egg

References:

1. https://www.ju.st/en-us/stories/clean-meat
2. https://www.ju.st/en-us/products/consumer/egg
3. https://www.linkedin.com/company/just-inc/about/
4. https://www.theatlantic.com/health/archive/2019/04/just-finless-foods-lab-grown-meat/587227/
5. https://www.foodnavigator-usa.com/Article/2019/02/12/Plant-based-JUST-Egg-is-already-outselling-established-liquid-egg-brands-at-retail-claims-Just-CEO

Research Institutes and Research Groups

The New Harvest Research Institute: Cell Cultured Meat Research Funding

Website: https://www.new-harvest.org/

Headquarters: Brooklyn, NY, USA **Contact:** info@new-harvest.org

Overview

The New Harvest Research Institute was founded in 2004. The institute's goal is to build and establish the cellular agriculture field. To achieve their goal, the institute funds cellular agriculture research at various institutions across the United States, performs outreach and advocacy as well as organizes a self-titled annual cellular agriculture conference.

At a glance			
Protein Source:	*Cultured cells (cell types vary across fellows and research groups)*	**Stage of Development:**	*Lab scale testing*
Scalability:	*Varies*	**Key Technology:**	*Cell culturing technology, etc.*
GMO:	*GMO status varies*	**Replacement Target:**	*Varies, depends on research. Examples include beef, eggs, etc.*

Cell Cultured Meat Research Funding

Research Funding Programs

New Harvest has various funding opportunities for cellular agriculture including post-doctoral, and graduate funding programs as well as seed grant funding for short-term projects and a dissertation award.

Funded projects range from projects that investigate the development of vascular tissue in lab-cultured pork to the development of serum-free cell culture media that is specifically optimized for the culture of certain types of lab-cultured meat.

References:

1. https://www.new-harvest.org/current_research_projects

University of California: Plant-based Scaffolds for Marbled Cultured Beef

Website: https://www.ibp.ucla.edu

Headquarters: Los Angeles, CA, USA **Contact:** +1 310-825-4076 / rowat@ucla.edu

Overview

Amy Rowat is an associate professor of Biology and Integrative Physiology at the University of California, Los Angeles. The Rowat Lab focuses on understanding the processes involved in the physical phenotypes of cells and their roles in cellular physiology as it relates to human health as well as food quality. One of the lab members, Stephanie Kawecki, is a fellow of the New Harvest Research Institute. Her research focuses on engineering plant-based scaffolds for creating more realistic textured and palatable lab-cultured beef.

At a glance			
Protein Source:	*Beef cell culture (adipocytes and myocytes) with plant-based (unspecified plant type) marbling scaffold*	**Stage of Development:**	*Lab scale testing*
Scalability:	*Still in early development, not specified*	**Key Technology:**	*Cell culture*
GMO:	*Not specified*	**Replacement Target:**	*Ranch-raised beef*

Plant-Based Scaffolds for Marbled Cultured Beef

Technology

Researchers believe that the production of lab-cultured beef would reduce deleterious environmental damage caused by cattle ranching. One issue with lab-cultured meat is that it often does not taste and/or feel like ranch-raised beef. Therefore, Kawecki is in the process of developing a tunable plant-based scaffold (the specific plant type used is not specified) that allows the co-culturing of muscle and fat cells that will grow into muscle and fat tissues to make lab-cultured beef that resembles, tastes, and feels like traditionally grown beef.

Source

The muscle and fat cells used to start the beef cultures are initially harvested from live cows.

References:

1. https://www.ibp.ucla.edu/research/rowat/RowatLab.html

Tufts University: Insect Tissue Culture for Food Production

Website: http://researchers.uq.edu.au/researcher/22855

Headquarters: Medford, MA, USA **Contact:** +1 617-627-3251 / david.kaplan@tufts.edu

Overview

Dr. David Kaplan is a professor and director of the Tissue Engineering Research Center (TERC) at Tufts University. The Kaplan lab focuses on non-medical tissue engineering. One of the lab members, Natalie Rubio, was the first fellow of the New Harvest Research Institute. Natalie's research focuses on developing a culturing system that facilitates the lab-culturing of insect tissue that can be used as meat in food production.

At a glance			
Protein Source:	*Insect muscle tissue*	**Stage of Development:**	*Lab scale testing*
Scalability:	*Not specified*	**Key Technology:**	*Cell culture*
GMO:	*No*	**Replacement Target:**	*Various meat products*

Insect Tissue Culture for Food Production

Tufts UNIVERSITY

Technology

Researchers believe that the production of lab-cultured insect meat would mitigate injurious stress caused by livestock husbandry as well as offer a more cost-effective meat alternative. In order to develop a complete cell culture system for insect meat, researchers have worked on developing a suitable serum-free culture medium and an appropriate culture scaffold upon which the insect muscular tissue grows. Various biologically-derived materials such as chitosan and cellulose will also be incorporated into the meat to evaluate how they affect the texture and taste of the resultant insect meat.

Source

Cells from different insect species (a genetically immortalized GFP-expressing *D. melanogaster* adult muscle precursor cell line and primary cells isolated from *M. sexta* and *A. domesticus*) are used to culture meat.

References:

1. https://www.new-harvest.org/current_research_projects
2. https://engineering.tufts.edu/bme/kaplan/people/gradStudents.htm

University of Queensland - Maggots and Whole Locusts

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Website: http://researchers.uq.edu.au/researcher/22855

Headquarters: Brisbane, Australia **Contact:** +61 7 344 32602 / louwrens.hoffman@uq.edu.au

Overview

Professor Lowrens Hoffman is a professor of meat science at the University of Queensland, Australia. His lab is currently focused on making sausages using meat alternatives, specifically, maggots and whole locusts. He has published over 40 peer reviewed articles and book chapters. Some of his projects have focused on producing ice cream from insects, using maggots as protein sources for chicken being raised for meat and others.

At a glance			
Protein Source:	*Insect larvae (maggots) and whole locusts*	**Stage of Development:**	*Lab scale testing*
Scalability:	*Not specified*	**Key Technology:**	*Extrusion*
GMO:	*No*	**Replacement Target:**	*Beef*

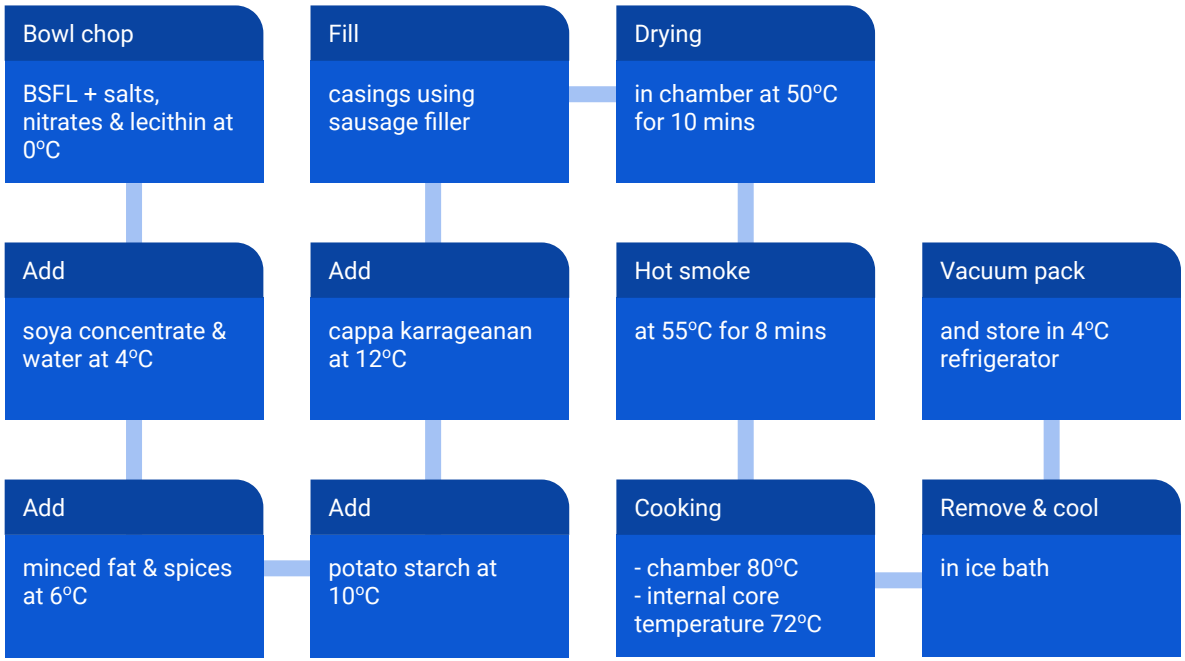
Maggots and Whole Locusts

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Technology

Professor Hoffman and his team are investigating the use of maggots as replacement for meat sausages. They believe that with time, the livestock industry will not be able to meet the global demand for meat. The team has found that broiler chicken containing about 15% maggot meal does not reduce chicken production performance, nutrient-use efficiency, breast meat aroma, flavor, juiciness and tenderness, or long-chain fatty acid composition.

The adjacent flow diagram shows how the team made sausages from insect larvae in their recent study in which they developed Vienna-style sausages using black soldier fly larvae (BSFL).



Maggots and Whole Locusts

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Technology

They found that the sausages that contained 28% BSFL were comparable to pork sausages in protein content, ash content, perceived hardness, cohesion, and gumminess. Further, it was observed that there were noticeable changes in the texture of the BSFL sausage during a 14-day period of storage, hence, the BSFL sausage may not have a long shelf life.

Source

Professor Hoffman's lab is using mainly insect larvae (maggots) to replace beef in the production of sausages. They are also looking into using whole insects like locusts.

References:

1. https://phys.org/news/2019-05-humans-maggots-scientists-insist.html
2. https://montrealgazette.com/news/world/aussie-scientist-maggot-sausage-is
3. http://researchers.uq.edu.au/researcher/22855
4. https://dl.sciencesocieties.org/publications/mmb/abstracts/3/1/289

Next Steps

Next Steps

THESE ARE SOME POSSIBILITIES THAT PRESCOUTER CAN OFFER FOR CONTINUATION OF OUR RELATIONSHIP:

PERIODIC TRACKING OF NEW DEVELOPMENTS: quarterly/biyearly scouting on any novel technologies related to the topic of interest.

OUTREACH to companies or research groups for detailed anonymous interviews.

Engagement with **SUBJECT MATTER EXPERTS** to receive an expert opinion.

Engaging with a **CONTRACT RESEARCH ORGANIZATION** for building a prototype, testing an equipment or any other related research service.

CONFERENCE SUPPORT: PreScouter can attend conferences of interest on your behalf.

WRITING ARTICLE: PreScouter can write technical or more public facing articles on your behalf.

For any requests, we welcome your additional questions and custom building a solution for you.

About the Authors

Gareth Armanious

PreScouter

Professional Summary:

Gareth Armanious is one of PreScouter's Project Architects. He specializes in the Food & Beverage and Life Sciences industries. As an academic, he specialized in membrane protein biochemistry, working with an international research group assembled to study structural and functional aspects of these challenging targets in health and disease. Gareth graduated with a BSc in biochemistry, medical specialization, from the University of British Columbia, and is completing his PhD in Biochemistry at the University of Alberta.

About the Authors

Gloria Wada

PreScouter

Professional Summary:

Gloria is a microbiologist and science writer with 6+ years of collaborative-interdisciplinary drug discovery research experience designing and modifying assays to determine the antifungal effects of plant extracts on fungal physiology. She has developed and optimized various microbiological assays and analytical chemistry lab protocols for the separation of plant products via HPLC and flash chromatography. She also has previous environmental toxicology and molecular biology research experience.

Research Background:

Mycology, microbiology, drug discovery, analytical chemistry

About the Authors

Bezalel Adainoo

University of Ghana, Ghana

Professional Summary:

Bezalel is a food scientist with experience in food analysis, food chemistry, food microbiology and food processing. He completed his BSc (Hons) in Nutrition and Food Science at the University of Ghana. He writes a blog (staywellnow.com), interpreting research findings in simple language to educate readers on the effects of food on health.

Research Background:

Bezalel has worked on projects aimed at assessing the quality and safety of dairy products and other food products. His research also focused on developing shelf-stable food products. He has also worked on some nutrition projects in Ghana as well as some climate change and food security projects in Zambia and Kenya.

Scientific Interests:

Food Chemistry, Food Processing, Food Quality and Safety, Bioactive Molecules, Nutrition

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