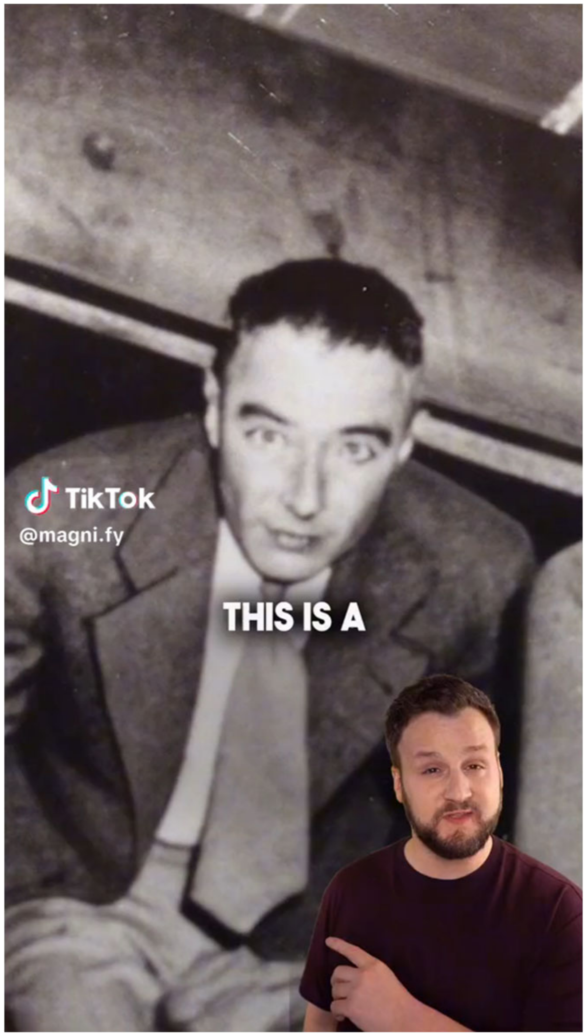
# Polymers in Food and Agriculture

# Capturing the Essence



# The United Nations: Sustainable Development Goals

















# The United Nations: Sustainable Development Goals

Goal 1: No Poverty: Economic growth must be inclusive to provide sustainable jobs and promote equality.

**Goal 2: Zero Hunger: The food and agriculture sector offers key solutions for development, and is central for hunger and poverty eradication.**

Goal 3: Good Health and Well-Being: Ensuring healthy lives and promoting the well-being for all at all ages is essential to sustainable development.

Goal 4: Quality Education: Obtaining a quality education is the foundation to improving people's lives and sustainable development.

Goal 5: Gender Equality: Gender equality is not only a fundamental human right, but a necessary foundation for a peaceful, prosperous and sustainable world.

Goal 6: Clean Water and Sanitation: Clean, accessible water for all is an essential part of the world we want to live in.

Goal 7: Affordable and Clean Energy: Energy is central to nearly every major challenge and opportunity.

Goal 8: Decent Work and Economic Growth: Sustainable economic growth will require societies to create the conditions that allow people to have quality jobs.

Goal 9: Industry, Innovation, and Infrastructure: Investments in infrastructure are crucial to achieving sustainable development.

Goal 10: Reduced Inequalities: To reduce inequalities, policies should be universal in principle, paying attention to the needs of disadvantaged and marginalized populations.

Goal 11: Sustainable Cities and Communities: There needs to be a future in which cities provide opportunities for all, with access to basic services, energy, housing, transportation and more.

Goal 12: Responsible Consumption and Production: Responsible Production and Consumption

Goal 13: Climate Action: Climate change is a global challenge that affects everyone, everywhere.

Goal 14: Life Below Water: Careful management of this essential global resource is a key feature of a sustainable future.

Goal 15: Life on Land: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss

Goal 16: Peace, Justice and Strong Institutions: Access to justice for all, and building effective, accountable institutions at all levels.

Goal 17: Partnerships: Revitalize the global partnership for sustainable development.

https://www.un.org/sustainabledevelopment/sustainable-development-goals/

# Human Population

On November 15, 2022, the human population reached 8 billion.

## HUMAN POPULATION

**Why it took just 200 years for the world's population to increase eightfold to 8 billion**

WORDS **AILSA HARVEY**

### The Origin of Humans

Modern humans originated 200,000 years ago and began to spread across continents.

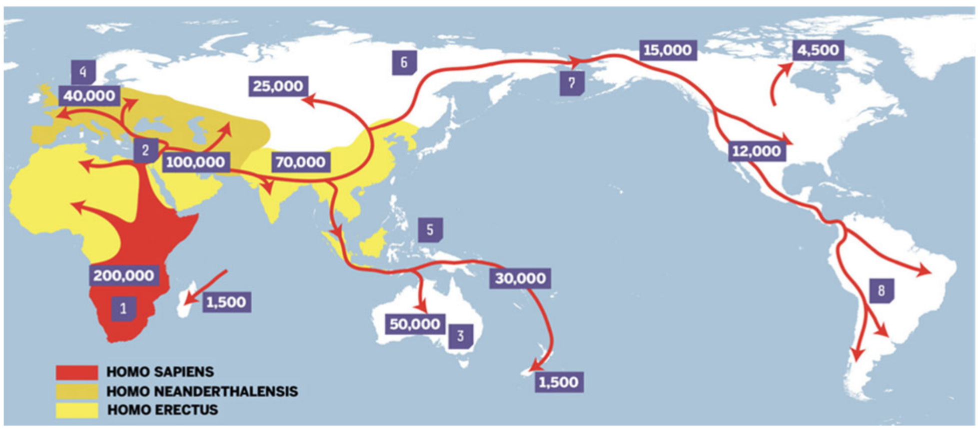
**7 BRIDGE TO THE REST OF THE WORLD**
Today's global population is around 2,000 times what it was 12,000 years ago. Due to increased volumes of water becoming trapped in glaciers, sea levels decreased and a bridge of land called the Bering land bridge formed. Around 16,000 years ago, humans migrated across this, allowing them to populate the Americas.

**4 NEANDERTHAL RIVALS**
Homo sapiens entered Europe around 40,000 years ago. There, modern humans had to compete with Neanderthals, who had occupied the continent for at least 100,000 years.

**6 END OF THE ICE AGE**
15,000 years ago, the ice age ended, and glaciers stopped their advances over northern continents. The human population began to increase and migrate again.

**2 GREAT MIGRATION**
Humans began to migrate across the globe 100,000 years ago. The population remained under 1 million.

**1 HUMAN EVOLUTION**
Around 200,000 years ago, modern humans evolved in Sub-Saharan Africa.




**3 REACHING AUSTRALIA**
Around 1,000 humans sailed to Australia 50,000 years ago. After an ice age, which drastically reduced the population, numbers increased to around 1.2 million by the time European settlers arrived in 1788. Violence against Aboriginals and new diseases introduced by colonists reduced the Indigenous Australian population by up to 90 per cent.

**8 POPULATING SOUTH AMERICA**
Human populations reached South America around 10,000 years ago. By this time, there were around 5 million people on Earth.z

**5 CLIMATE IMPACT**
By 35,000 years ago, the increase in human population slowed with the arrival of an ice age. Humans migrated farther south to avoid emerging glaciers, seeking more temperate climates.

How It Works. Issue 173

**FARMING BOOST**

Agricultural practices emerged in human societies around 12,000 years ago. Before this, people mostly adopted the hunter-gatherer lifestyle. This meant following their food and using their mobility to benefit their survival. When people began to construct farms, making more permanent homes became necessary. This lifestyle change caused an increase in settlements, which grew in size to form the beginning of some of today's large cities.

Farming allowed communities to produce their own food and have more control over the numbers that were fed. As farms grew in size, farm owners accumulated more food than their immediate families needed, leading to the trade of fresh goods. As more food and jobs became available, it became possible for populations to grow. Today, farmland makes up around 38 per cent of the planet's total land surface area in order to accommodate 8 billion people.

**5 POPULATION-BUSTING EVENTS**

**1. WORLD WARS**
During times of war, death rates are high and fertility rates are low. In World War 11, around 50 million people died in combat, while 20 to 30 million were lost to war-related famine and disease.

**2. THE BLACK DEATH**
The Black Death was a bubonic plague pandemic that first emerged in the 1300s. In Europe, it took 80 years for the population to recover. Worldwide, the Black Death reduced the population from 475 million to between 350 and 375 million. (Renaissance is a French word meaning "rebirth." It refers to a period in European civilization that was marked by a revival of Classical learning and wisdom)

**3. SMALLPOX**
Since 1900, this contagious disease has claimed more than 300 million lives. Today, however, vaccination has eradicated the disease so that it no longer poses a threat.

**4. GUNPOWDER INVENTION**
Gunpowder was accidentally invented when scientists were experimenting with making a life-lengthening medical drink. However, the explosive chemistry of gunpowder now makes up most of the world's deadly weapons.

**5. POPULATION CONTROL**
Many countries have national population control laws in place that dictate how many children each family can have. In 50 years, it's helped the average number of children per family to halve from 5.0 to 2.5.

# Food for People in the World

Thomas Malthus: An Essay on the Principle of Population (1978).
Human populations grow exponentially, while food production grows at an arithmetic rate.

| Current World Population | Current World Population |
|---|---|
| 7,924,803,105<br>February 3, 2022 | 8,089,661,741<br>February 5, 2024 |
| | 8,090,778,057<br>February 11, 2024 |

https://www.worldometers.info/world-population/

## 2016 World Hunger and Poverty Facts and Statistics

This fact sheet is divided into the following sections:

- Hunger concepts and definitions
- Number of hungry people in the world
- Progress in reducing the number of hungry people
- Children and hunger
- Micronutrients
- Does the world produce enough food to feed everyone?
- Causes of hunger

http://www.worldhunger.org/2015-world-hunger-and-poverty-facts-and-statistics/

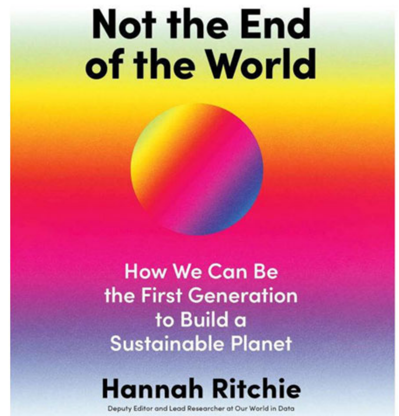
**We Already Grow Enough Food For 10 Billion People — and Still Can't End Hunger**

The world already produces more than 1.5 times enough food to feed everyone on the planet. That's enough to feed 10 billion people, the population peak we expect by 2050. But the people making less than $2 a day — most of whom are resource-poor farmers cultivating unviably small plots of land — can't afford to buy this food.

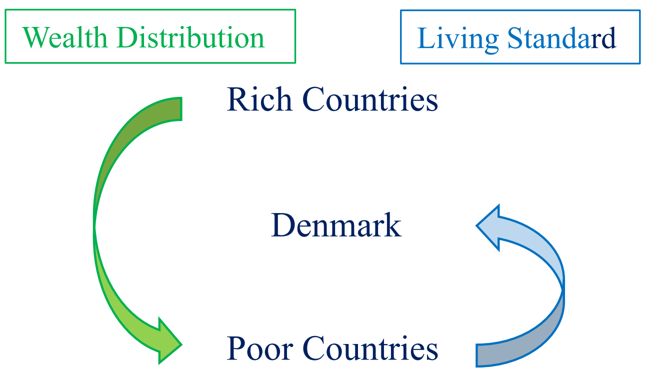
In reality, the bulk of industrially-produced grain crops goes to biofuels and confined animal feedlots rather than food for the 1 billion hungry. The call to double food production by 2050 only applies if we continue to prioritize the growing population of livestock and automobiles over hungry people.

Can conventional agriculture provide the yields we need to feed 10 billion people by 2050? Given climate change, the answer is an unsustainable "maybe." The question is, at what social and environmental cost? To end hunger we must end poverty and inequality. For this challenge, agroecological approaches and structural reforms that ensure that resource-poor farmers have the land and resources they need for sustainable livelihoods are the best way forward.

http://www.huffingtonpost.com/eric-holt-gimenez/world-hunger_b_1463429.html



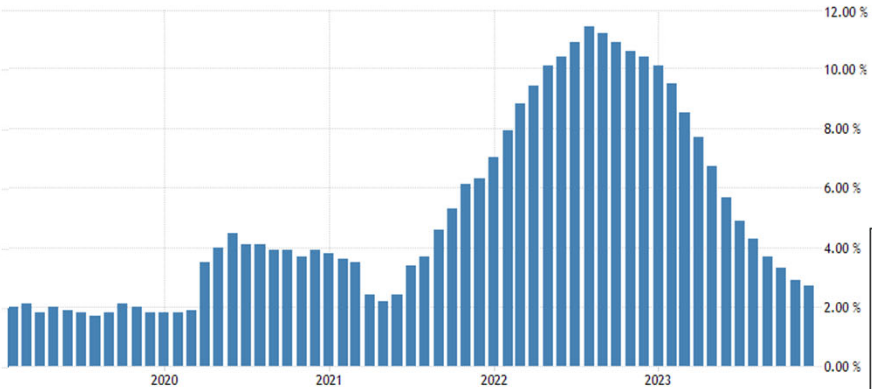

Hannah Ritchie 2024, Not the End of the World.
How We Can Be the First Generation to Build a Sustainable Planet

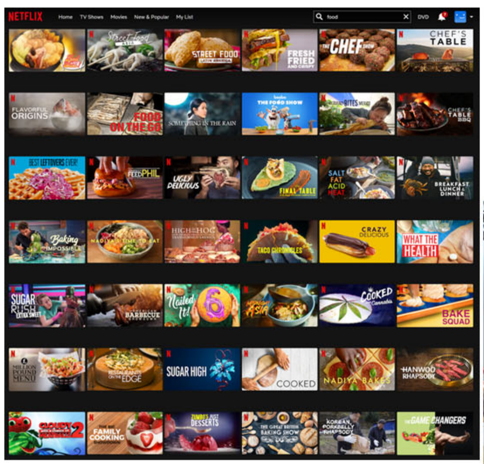


# Food: Too Much or Too Little - Uneven Distribution

## United States Food Inflation

https://tradingeconomics.com/united-states/food-inflation

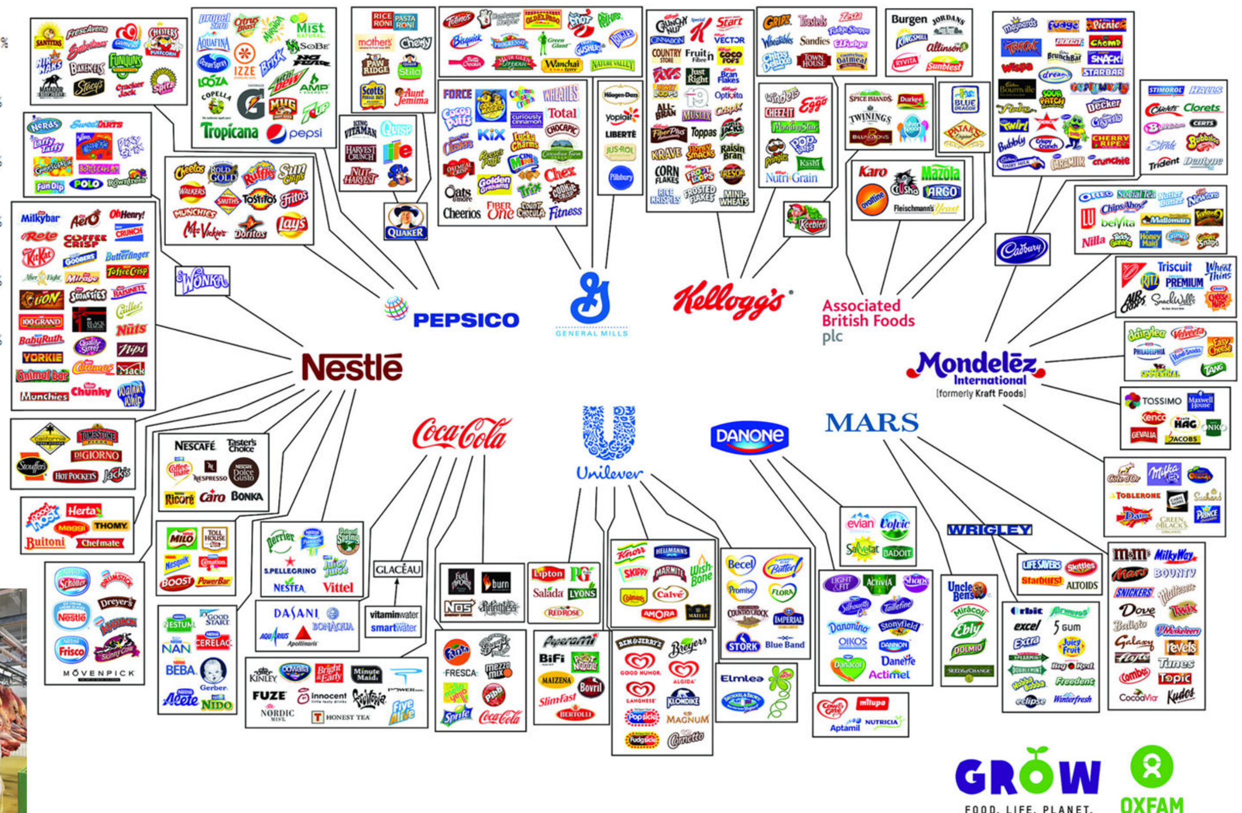


The meat industry is locus of consolidation and price inflation.

https://www.forbes.com/sites/errolschweizer/2022/01/04/why-food-price-inflation-is-not-inevitable/?sh=266ea31f649f

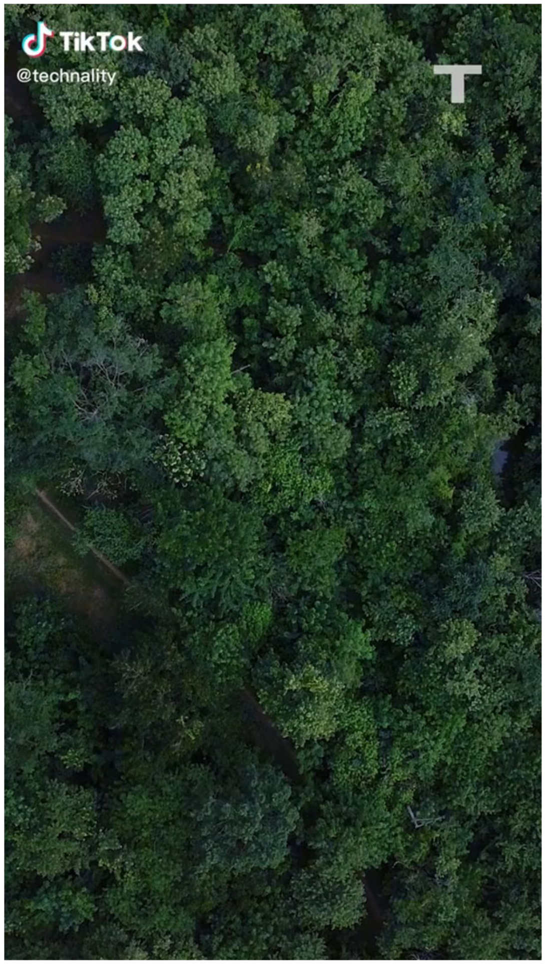
## These 10 companies make a lot of the food we buy. Here's how we made them better.



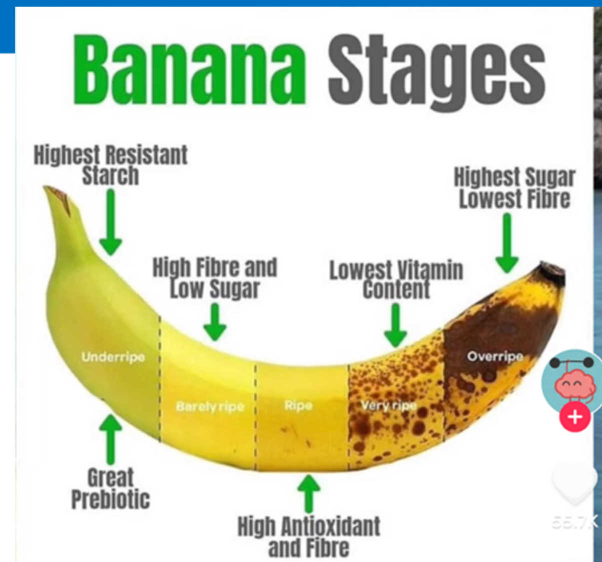

https://www.oxfamamerica.org/explore/stories/these-10-companies-make-a-lot-of-the-food-we-buy-heres-how-we-made-them-better/

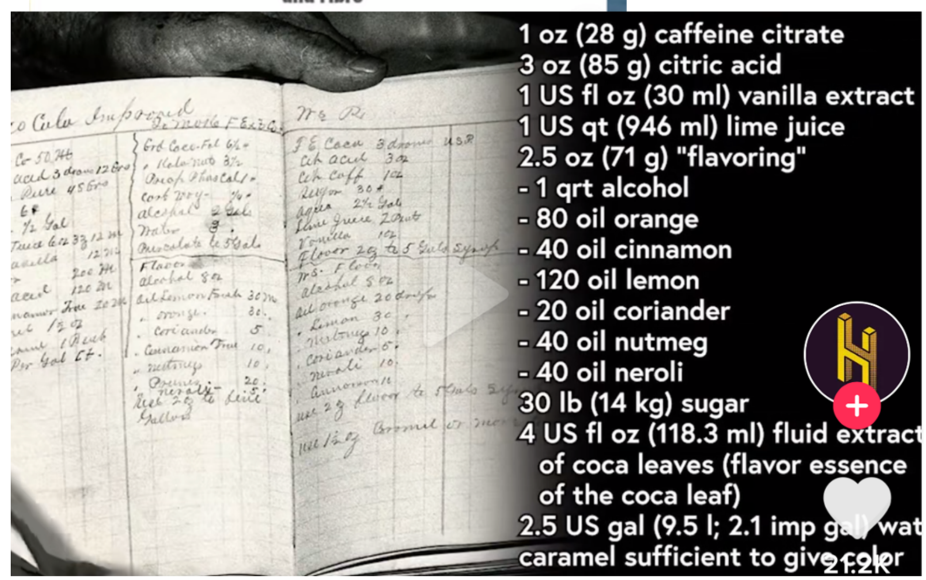
# Foods in Our Daily Life

Reducing carbon in the air by genetic engineering







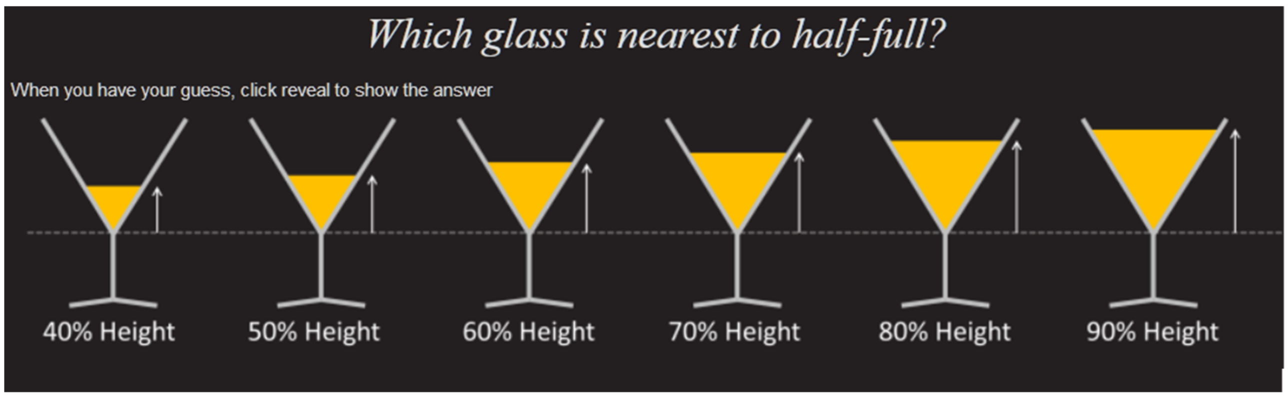
# Fill the Cup!

Watch the cup shape!

Martini Glass


https://www.tiktok.com/@producereric1/video/7181213893006478634

Which glass is nearest to half-full?




http://datagenetics.com/blog/february32020/index.html


https://abcnews.go.com/Lifestyle/ways-bartender-rip-off-order/story?id=20940303

# Importance of Diet

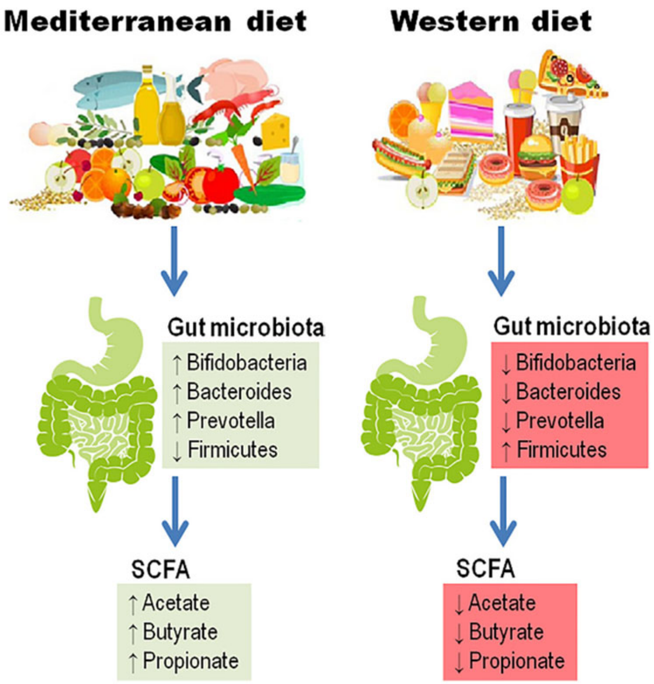



Fig. 4 The Mediterranean diet and the Western diet produce modifications in the gut microbiota composition with subsequent changes in short chain fatty acid (SCFA) production.

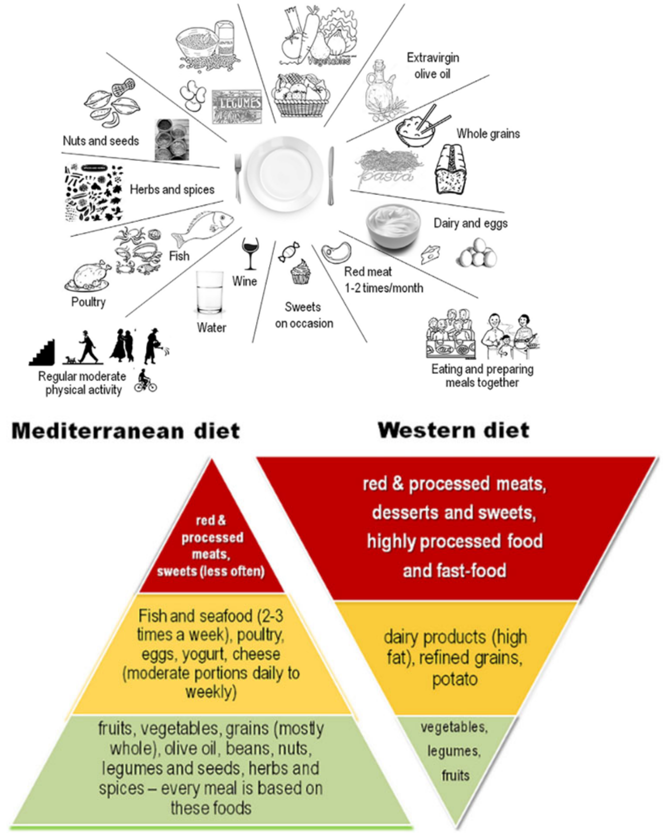
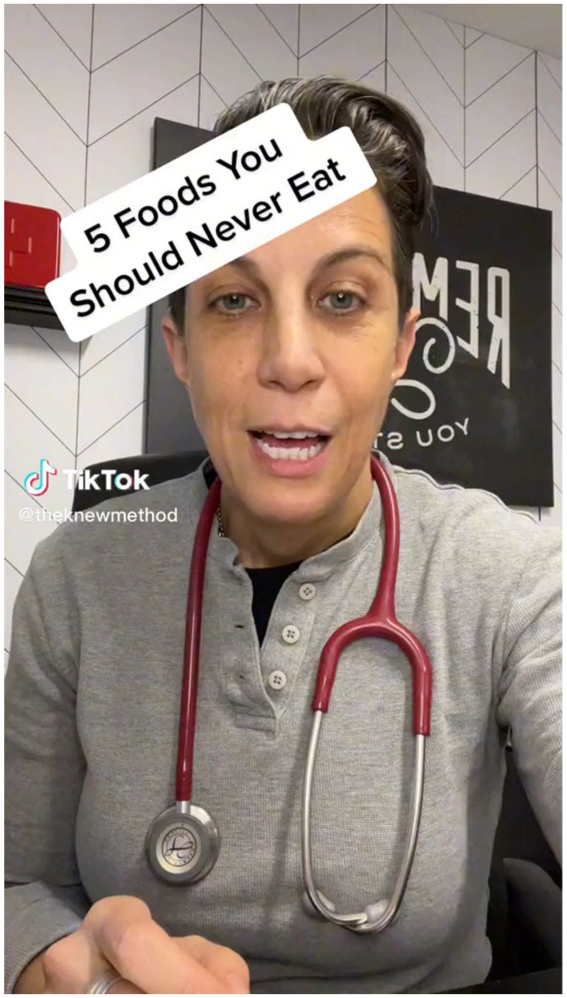



Fig. 2 Food pyramids of Mediterranean and Western diet. As illustrated by the pyramids, the basis of the Mediterranean diet (in green) is minimally represented in the Western diet, while the consumption of red and processed meats, sweets, industrial- and fast-food (in red) constitute the majority of consumption in the Western diet, while is minimally represented in the Mediterranean diet. High-fat dairy products, refined grains, and potato (yellow) are also frequently consumed in the Western diet, as opposed to the Mediterranean diet where other healthy foods are consumed instead.




Dominguez 2020, Mediterranean diet and longevity

# Foods and Cancer: Danger of Ultra-Processed Foods

## Increased Cancer Risk May Be Linked to Ultra-Processed Foods

A new study led by researchers from Imperial College London and published in eClinicalMedcine suggests that higher consumption of ultra-processed foods may be linked to increased risks of developing and dying from cancer. Ultra-processed foods include fizzy drinks, mass-produced package breads, many ready meal and the majority of breakfast cereals.

"This study adds to the growing evidence that ultra-processed foods are likely to negatively impact our health including our risk for cancer. Given the high levels of consumption in UK adults and children, this has important implications for future health outcomes," said lead senior author Eszter Vamos of Imperial College London's School of Public Health. "Although our study cannot prove causation, other available evidence shows that reducing ultra-processed foods in our diet could provide important health benefits."

Ultra-processed foods are often inexpensive and heavily marketed—sometimes even as healthy food options—but they are usually higher in salt, fat, sugar and contain a ranges of artificial additives. They are already linked to the development of other diseases such as obesity, type 2 diabetes, and heart disease.

## Chang 2023, Ultra-processed food consumption, cancer risk and cancer mortality

**Findings** The mean UPF consumption was 22.9% (SD 13.3%) in the total diet. During a median follow-up time of 9.8 years, 15,921 individuals developed cancer and 4009 cancer-related deaths occurred. Every 10 percentage points increment in UPF consumption was associated with an increased incidence of overall (hazard ratio, 1.02; 95% CI, 1.01–1.04) and specifically ovarian (1.19; 1.08–1.30) cancer. Furthermore, every 10 percentage points increment in UPF consumption was associated with an increased risk of overall (1.06; 1.03–1.09), ovarian (1.30; 1.13–1.50), and breast (1.16; 1.02–1.32) cancer-related mortality.

The researchers used records of 200,000 middle-aged adults contained in the UK Biobank for their study and monitored their health over the course of a 10 years. They looked for overall cancer risk, as well as the risk of developing 34 specific types of cancer along with cancer mortality rates.

The data from the study showed that for every 10% increase in a person's diet of ultra-processed food, they had a 2% greater risk of developing any kind of cancer, but 19% increased risk of developing ovarian cancer. Each 10% increase was also associated with an increased cancer mortality risk of 6% from all cancers, and 16% and 30% increased risk of mortality from breast cancer and ovarian cancer respectively. The investigators said all the links remained even after adjusting for a range of social determinants of health such as socio-economic, dietary, and behavioral factors such as smoking, exercise, and body mass index.

The team, which included researchers from the International Agency for Research on Cancer (IARC), University of São Paulo, and NOVA University Lisbon, has previously reported findings linking a diet high in ultra-processed foods to greater risks of obesity and type diabetes in adults in the U.K. and greater weight gain in U.K children, which extends into young adulthood.

"The average person in the UK consumes more than half of their daily energy intake from ultra-processed foods," noted first author Kiara Chang of Imperial College London. "This is exceptionally high and concerning as ultra-processed foods are produced with industrially derived ingredients and often use food additives to adjust color, flavor, consistency, texture, or extend shelf life. Our bodies may not react the same way to these ultra-processed ingredients and additives as they do to fresh and nutritious minimally processed foods. This shows our food environment needs urgent reform to protect the population from ultra-processed foods."

Some countries have taken steps to reduced ultra-processed food consumption with Brazil, France, and Canada updating their dietary recommendations in an attempt to lower their consumption. Brazil has taken the additional step of banning the marketing of these foods in schools. Further, The WHO and the United Nations' Food and Agricultural Organization have recommended restricting ultra-processed foods in the diet.

"Lower income households are particularly vulnerable to these cheap and unhealthy ultra-processed foods," Chang said, further suggesting that fresh meals with minimal processing could be subsidized as a part of public policy to ensure all people have access to healthier food options.

https://www.insideprecisionmedicine.com/topics/oncology/increased-cancer-risk-may-be-linked-to-ultra-processed-foods/?MailingID=%DEPLOYMENTID%c

# Sea Food Restaurants: 13 Dishes you should never order

### Tilapia

Tilapia is a popular fish, especially among those who don't like fishiness, due to its mildly sweet taste and flaky texture. This fish is almost exclusively farm-raised, and its feed dictates its flavor. Farming tilapia comes with two significant concerns.

### Stone crab

Seafood Watch considered the stone crab a highly sustainable species before 2018 rolled around. It's necessary to explain the unique harvesting practice to understand the change in opinion.

Each fall, Floridians eagerly await the harvesting season of stone crabs, starting in mid-October and lasting until the beginning of May. Stone crabs are harvested for their claws and returned to the water after removal. Crabbers formerly removed one claw only, which would regrow with time, and the crab still had the other claw to feed and defend itself. Regulations

### Eel

Eel -- unagi in Japanese -- is most commonly found on sushi menus in the U.S. It's typically grilled and bathed in a sweet sauce of mirin, rice wine, sugar, and soy sauce. The biggest reason for cooking eel, rather than serving it raw like many other types of seafood in sushi, is that one of the eel's natural defense mechanisms is its toxic blood, which becomes safe for consumption when fully cooked.

### Fried calamari

While there's nothing inherently wrong about squid, what we do to it makes it worthy of questioning when encountering it on a menu. Squid was considered bait in the U.S. until about 50 years ago when fishing regulations changed, and fishers had to pivot to find a new species to harvest. Through a careful marketing spin, Americans got familiar with this now ubiquitous squid dish and its preparation by its Italian name, calamari fritti.

### Pacific bluefin tuna

Bluefin tuna is one of the most sought-after sushi dishes because of its flavor, texture, and fat content. Bluefin tuna is particularly prized for parts like otoro (fatty belly) or chu-toro (medium fatty belly). Unfortunately, Pacific bluefin populations are burdened and close to unsustainable. The Marine Conservation Society explains that overfishing of bluefins in all areas of the Pacific outpaces births of new tuna. But it notes the populations are "beginning to recover" -- not to be confused with "recovered."

### Shark

Shark populations see a lot of stress due to the practice of finning. The practice involves removing the sharks' fins, often while still alive, because the fins bring more money than the other body parts and it's easier to store and transport the fins than the whole carcass on a boat. The fins are often used to make shark fin soup -- a Chinese cultural status symbol thought to have medicinal properties. It contributes to the shark fin trade, which accounts for many of the 100 million sharks killed annually around the globe, per the Smithsonian Institution.

### Red snapper

The red snapper is only a sustainable option depending on the catch location's population. Compounding that is the rampant mislabeling of red snapper. A National Library of Medicine study revealed that 90% of the red snapper sampled from menus and grocery stores in North Carolina were other snapper species or even tilapia, which comes with its own set of problems. A 2019 CNN report showed that mislabeling was commonplace in a larger sampling that spanned 24 states. The

### Atlantic cod

Cod is an excellent fish to eat and can be from a sustainable fishery, but you'll have to ask. Pacific cod fisheries around Alaska and the west coast of the U.S. are considered well-managed and certified by the Marine Stewardship Council. Atlantic cod, however, don't share the same designation.

### Catfish

Wild and farm-raised U.S. catfish are excellent, very sustainable options. However, they tend to be more expensive than those you shouldn't order. Hence, it was once commonplace to label Vietnamese-raised swai, a distant, cheaper relative of catfish, as catfish.

### Swordfish

Swordfish is an excellent source of lean protein, but it comes with a few problems that could, or, in some cases should, put you off the idea of ordering it. We'll start with a warning from the U.S. Food and Drug Administration (FDA). It recommends that those who are pregnant or might become pregnant, breastfeeding, or 11 years old and under avoid swordfish altogether.

### Marlin

Marlin, which belongs in the same family as sailfish, is another problematic fish for two reasons. The first is sustainability. The Atlantic blue marlin, found in the Atlantic Ocean and the Gulf of Mexico, is overfished, according to the Pew Environment Group. Overfished refers to the catch rate exceeding the birth rate, resulting in the fish being listed as vulnerable to extinction. On the other hand, NOAA considers Pacific blue marlin a "smart seafood choice" because it's neither overfished nor subject to periodic overfishing. But it's best to pass it up if you can't verify the

### Seafood pasta

Generic seafood pasta is the modern equivalent of the fish specials chef Gordon Ramsay warned about. If the menu doesn't lead with the specific type of seafood and pasta used in the dish's preparation, it could be a dumping ground for fish scraps. For example, compare "Seafood Pasta" to "Spaghetti with Clams and Green Olives" as menu titles. The former is generic, while the latter is a very intentional combination of a particular pasta, specific shellfish, and the accompanying ingredients. Which inspires more trust from you?

### White tuna

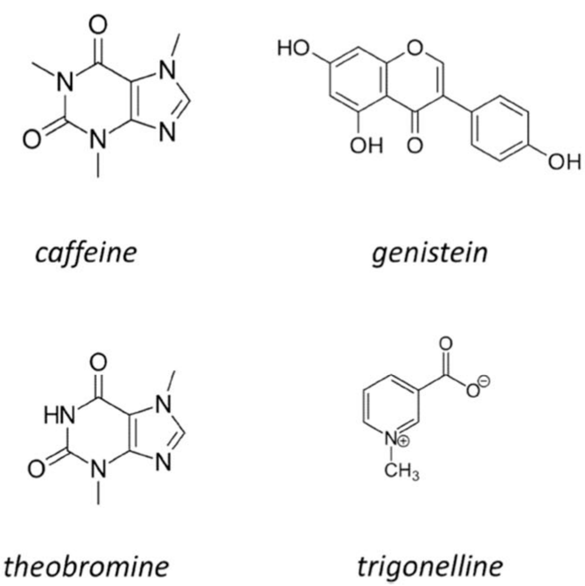
White tuna isn't tuna at all. It's a bycatch of the tuna fishing industry. It started appearing on restaurant menus in the 1990s after someone decided to capitalize on this incidental fish under its true name of escolar, nicknamed oil fish or butterfish.

Baker 2024, 13 Dishes you should never order at seafood restaurants

# Benefits of Coffee

**ABSTRACT:** Espresso coffee is among the most consumed beverages in the world. Recent studies report a protective activity of the coffee beverage against neurodegenerative disorders such as Alzheimer's disease. Alzheimer's disease belongs to a group of disorders, called tauopathies, which are characterized by the intraneuronal accumulation of the microtubule-associated protein tau in fibrillar aggregates. In this work, we characterized by NMR the molecular composition of the espresso coffee extract and identified its main components. We then demonstrated with in vitro and in cell experiments that the whole coffee extract, caffeine, and genistein have biological properties in preventing aggregation, condensation, and seeding activity of the repeat region of tau. We also identified a set of coffee compounds capable of binding to preformed tau fibrils. These results add insights into the neuroprotective potential of espresso coffee and suggest candidate molecular scaffolds for designing therapies targeting monomeric or fibrillized forms of tau.

**KEYWORDS:** *tau protein, coffee, protein aggregation, NMR, bioactive molecules, liquid—liquid phase separation, Alzheimer's disease*




Tira 2023, Espresso coffee mitigates the aggregation and condensation of Alzheimer's associated tau protein

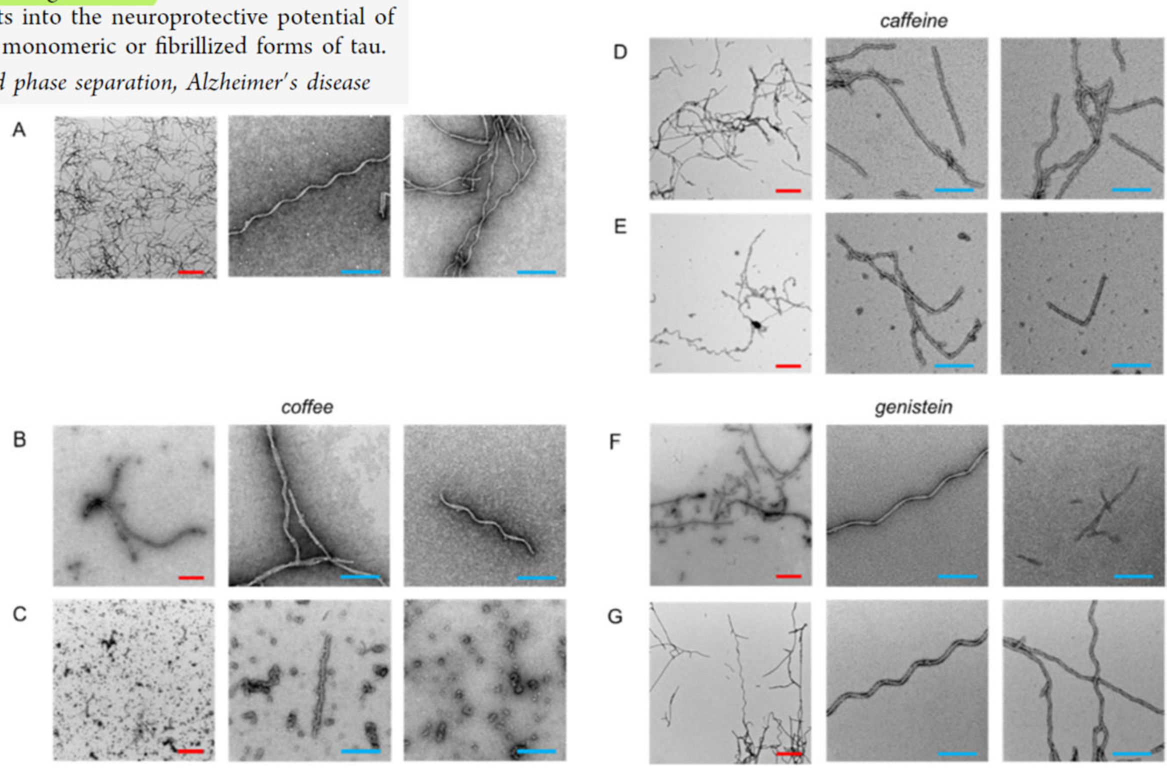



**Figure 4.** Transmission electron microscopy of tau[4RD] aggregates. Representative TEM images of tau[4RD] aggregates in the presence of different concentrations of coffee extract or single compounds. Samples contained tau[4RD] in buffer (A) with 50 μg/mL (B) or 400 μg/mL (C) coffee extract, 50 μg/mL (D) or 400 μg/mL (E) caffeine, 50 μg/mL (F) or 400 μg/mL (G) genistein. The protein was 50 μM. Samples were incubated for 48 h at 37 °C in static conditions. Scale bars are 500 nm (red) and 200 nm (light blue).

# MicroRNAs as Food

Nutraceuticals is a broad umbrella term that is used to describe any product derived from food sources with extra health benefits in addition to the basic nutritional value found in foods.
https://www.news-medical.net/health/What-are-Nutraceuticals.aspx

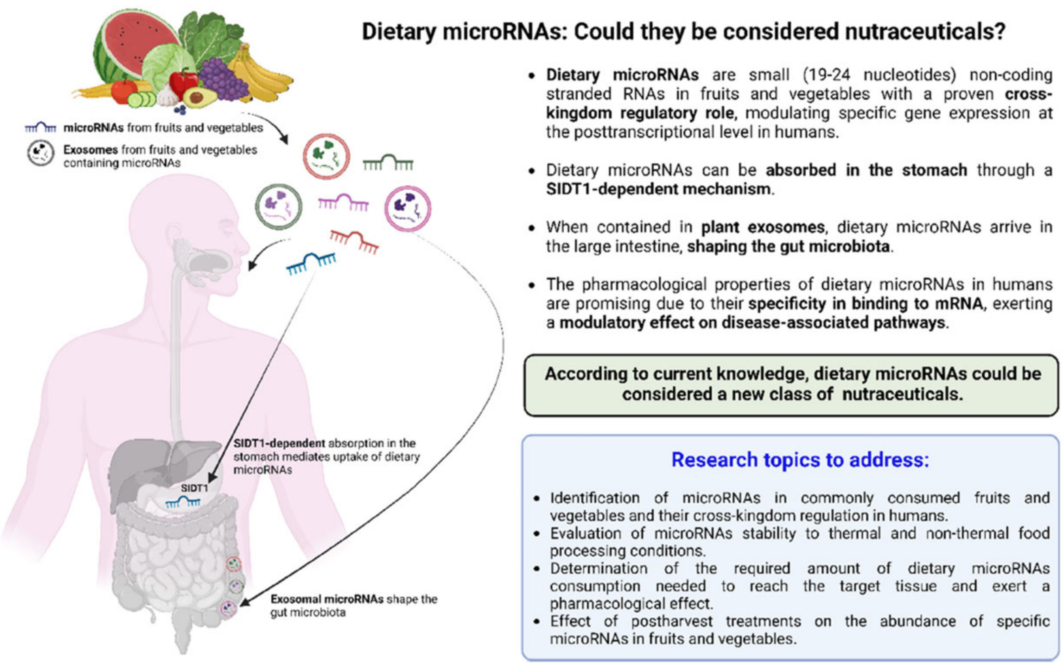



Figure 1. Current knowledge and further research topics to be addressed on determining the nutraceutical properties of dietary microRNAs.

Jacobo-Velázquez 2023, Dietary microRNAs

A plasma membrane protein, systemic RNA interference defective protein 1 (SID-1), is responsible for the transport of exogenous double-stranded RNA (dsRNA) into the cytoplasm.
Mammalian SID-1 transmembrane family member 1 (SIDT1), as its nematode homolog SID-1, also localizes to the plasma membrane and mediates intercellular miRNA transport as well as extracellular small interfering RNA (siRNA) uptake. (Chen 2020)

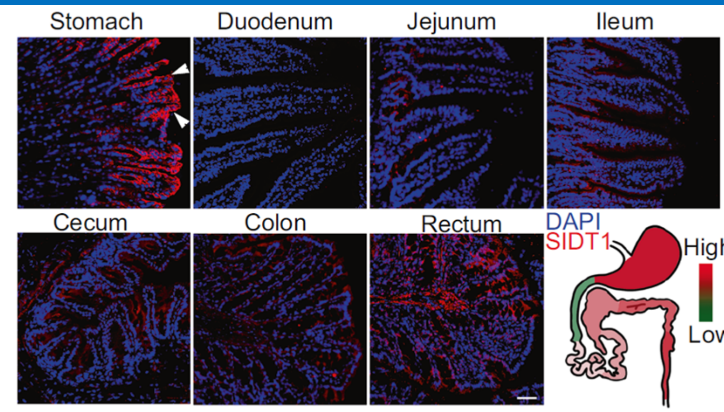



Fig. 3 SIDT1 is expressed in pit cells of the stomach epithelium and localizes to the plasma membrane. Representative images and heatmap summary of SIDT1 immunostaining along the mouse GI tract. Scale bar, 50 µm.

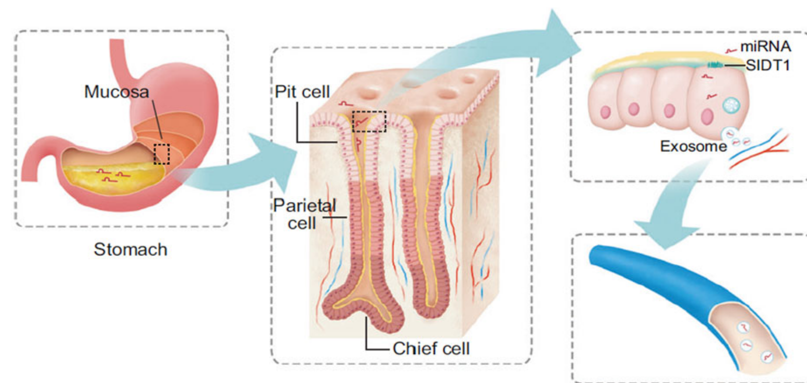



Fig. 7 A graphical model of the absorption and secretion of dietary miRNAs in the stomach. During feeding, the dietary miRNAs are released into the lumen of the stomach by mechanical digestion. In such an acidic environment, mature miRNAs escape from degradation by nuclease and the miRNAs are efficiently absorbed via SIDT1 protein which locates at the plasma membrane of pit cells. The intracellular dietary miRNAs are transported into the multivesicular bodies and the dietary miRNA-containing exosomes are secreted from pit cells. Then the secreted exosomes are pooled into the circulatory system and delivered to other tissues and organs.

Chen 2020, SIDT1-dependent absorption in the stomach mediates host uptake of dietary and orally administered microRNAs

# Big Data in Food: Deep Learning

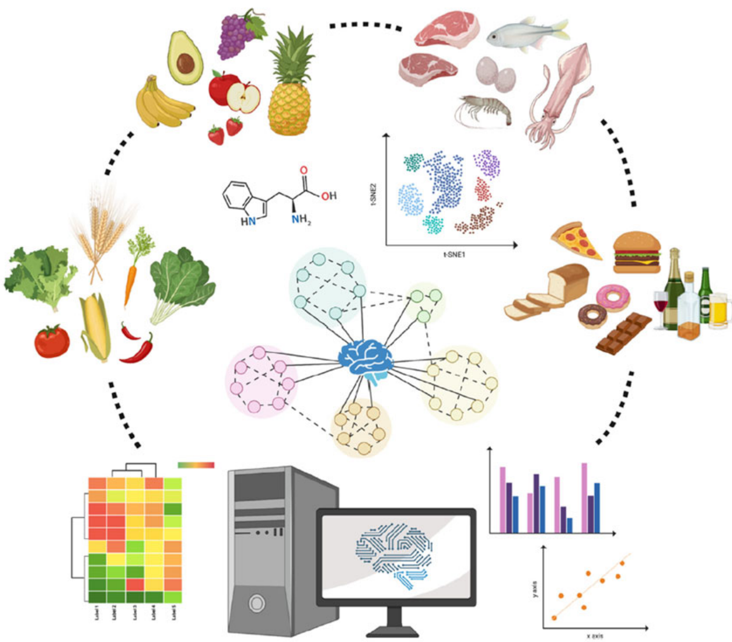


Figure 1. Big data in food.
The complex compositions and various ranges of compounds in foods can be structured into informative food databases. Food compositions' chemical information and physicochemical properties are potentially much more extensive than those of drugs. The lack of accurate information on food compounds, along with relatively little experience in beneficially applying machine learning applications or deep learning methods to these problems, seems to be a major obstacle in the area. Therefore, this review introduces the publicly available big data resources concerning food composition and chemistry and illuillustrates the learning methods applied in this area (Figure 1).

Tseng 2023, When machine learning and deep learning come to the big data in food chemistry

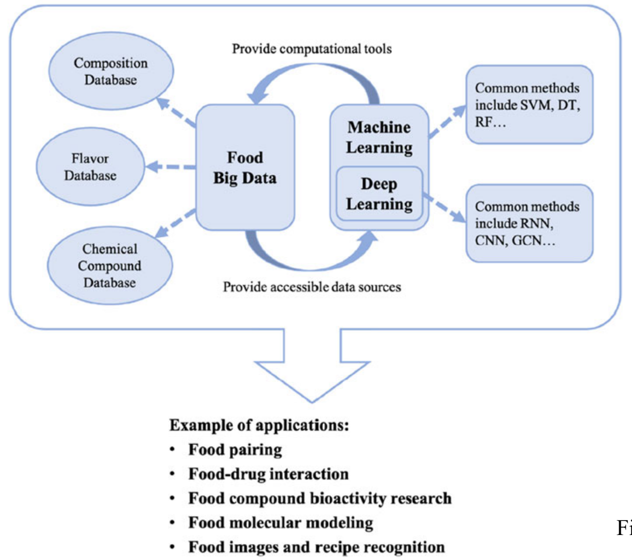
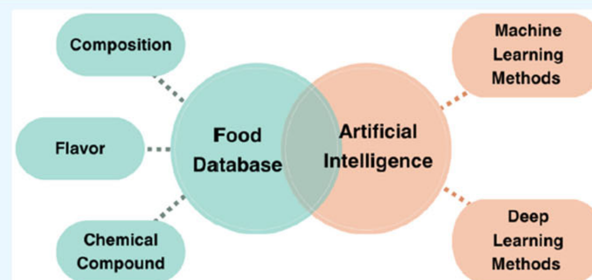


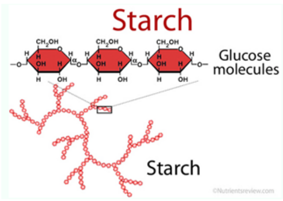

Figure 2. Concept of machine learning and deep learning in food data.

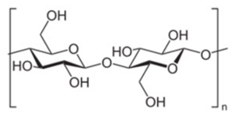

ABSTRACT: Since the first food database was released over one hundred years ago, food databases have become more diversified, including food composition databases, food flavor databases, and food chemical compound databases. These databases provide detailed information about the nutritional compositions, flavor molecules, and chemical properties of various food compounds. As artificial intelligence (AI) is becoming popular in every field, AI methods can also be applied to food industry research and molecular chemistry. Machine learning and deep learning are valuable tools for analyzing big data sources such as food databases. Studies investigating food compositions, flavors, and chemical compounds with AI concepts and learning methods have emerged in the past few years. This review illustrates several well-known food databases, focusing on their primary contents, interfaces, and other essential features. We also introduce some of the most common machine learning and deep learning methods. Furthermore, a few studies related to food databases are given as examples, demonstrating their applications in food pairing, food−drug interactions, and molecular modeling. Based on the results of these applications, it is expected that the combination of food databases and AI will play an essential role in food science and food chemistry.



# Dietary Fiber

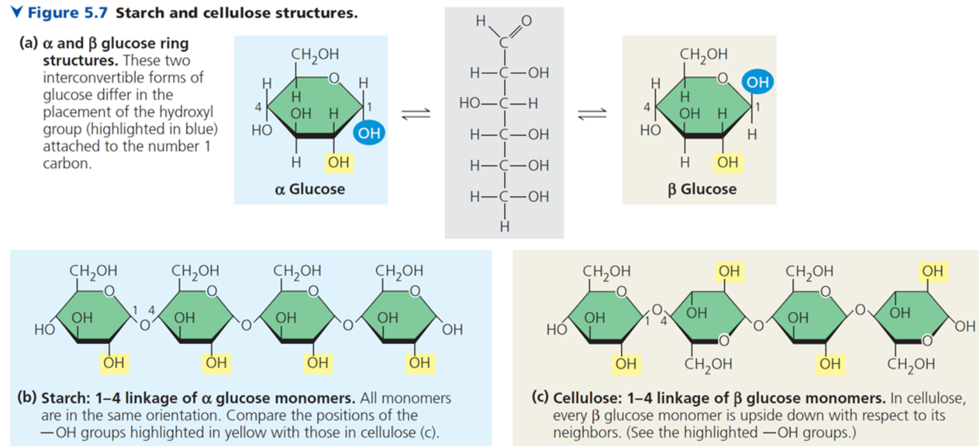
# Polymers in Foods: Digestible & Indigestible Fibers

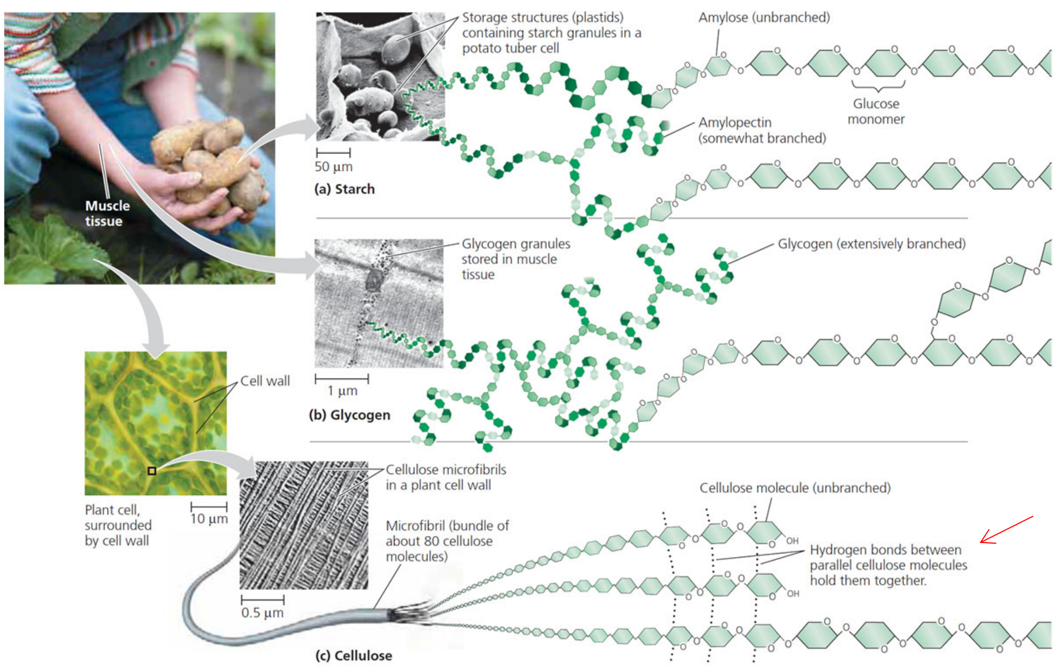




Cellulose

https://www.nutrientsreview.com/carbs/polysaccharides-starch.html

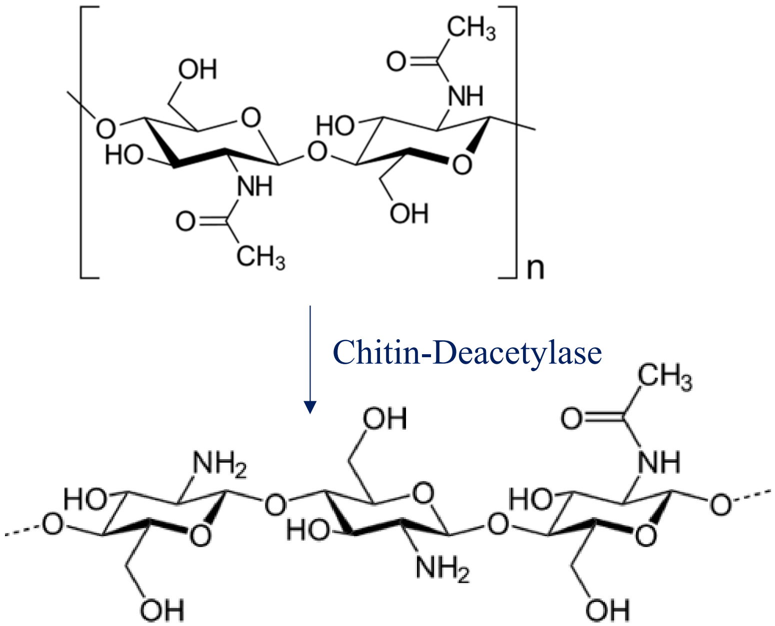



Urry 2021, The structure and function of large biological molecules

Human: The World Within. Fuel (Netflix) Robynne Chutkan, M.D. Gastroenterologist

# Dietary Fibers




Food sources of fiber include whole wheat, bran, fresh or dried fruits, and vegetables

**Plant substances that are indigestible in the digestive system.**
**20-35 g/day/adult (American Dietetic Association)**

Dietary fiber is a relatively broad term that includes many plant components that share the characteristics of being indigestible. This means that dietary fiber is not digested, absorbed by the body , or used for energy. There are two main sources of dietary fiber - **soluble fiber and insoluble fiber**. *Note many plant sources include both soluble and insoluble fiber.

**Insoluble fiber** does not dissolve in water and does not get broken down by bacteria in the intestine. Instead, it essentially absorbs water to help to increase bulk and to soften stool.

**Soluble Fiber** differs from insoluble fiber in that it dissolves in water and additionally is broken down by bacteria in the intestine. Soluble fiber helps prevent cholesterol from being absorbed by the intestines and is thought to help minimize the rise in blood sugar following a meal.

http://www.jarretmorrow.com/dietary-fiber-cheat-sheet/

# Dietary Fibers

Dietary fibre means carbohydrate polymers (1) with ten or more monomeric units (2), which are not hydrolyzed by the endogenous enzymes in the small intestine of humans and belong to the following categories:

- Edible carbohydrate polymers naturally occurring in the food as consumed.
- Edible carbohydrate polymers which have been obtained from food raw material by physical, enzymatic or chemical means and which **have a beneficial physiological effect** demonstrated by generally accepted scientific evidence.
- Edible synthetic carbohydrate polymers which have **a beneficial physiological effect** demonstrated by generally accepted scientific evidence'

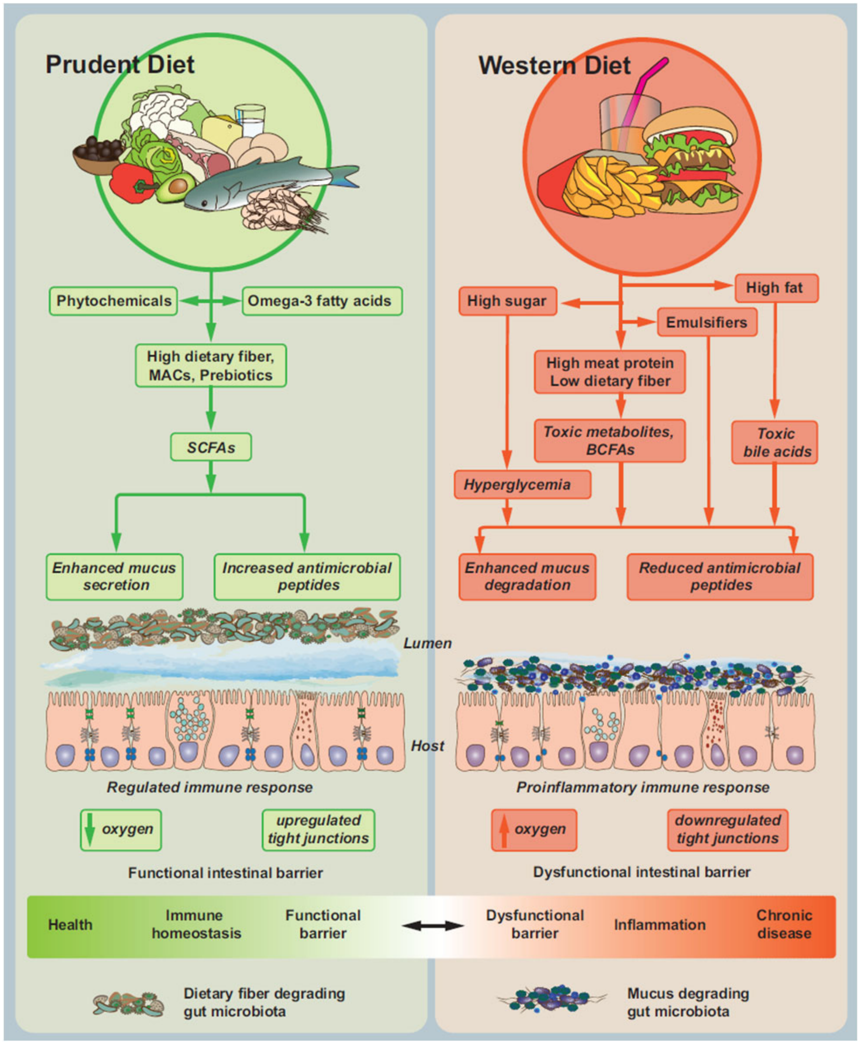
(1) When derived from a plant origin, dietary fibre may include fractions of lignin and/or other compounds associated with polysaccharides in the plant cell walls. These compounds also may be measured by certain analytical method(s) for dietary fibre. However, such compounds are not included in the definition of dietary fibre if extracted and re-introduced into a food.

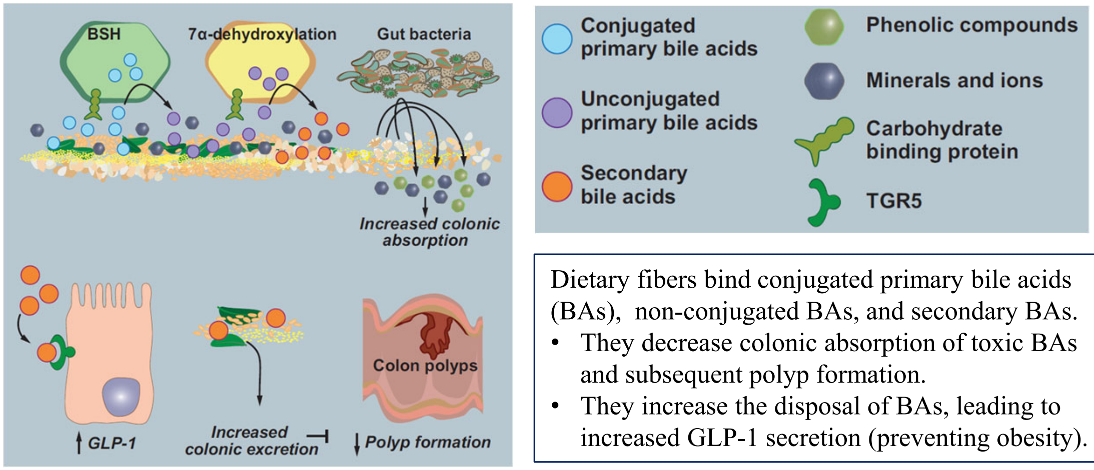
(2) Decision on whether to include carbohydrates from 3 to 9 monomeric units should be left to national authorities''.

Wenzel de Menezes 2013, Codex dietary fiber definition

| Definitions/statements |
| --- |
| "Fibre means carbohydrate polymers **with three or more monomeric units**, which are neither digested nor absorbed in the human small intestine and belong to the following categories:<br>- Edible carbohydrate polymers naturally occurring in the food as consumed;<br>- Edible carbohydrate polymers which have been obtained from food raw material by physical, enzymatic or chemical means and which have a beneficial physiological effect demonstrated by generally accepted scientific evidence;<br>- Edible synthetic carbohydrate polymers which have a beneficial physiological effect demonstrated by generally accepted scientific evidence" |
| "Dietary fibre is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fibre includes polysaccharides, **oligosaccharides**, lignin and associated plant substances, etc" |
| "Dietary fibre means that fraction of the edible part of plants or their extracts, or synthetic analogues that are resistant to digestion and absorption in the small intestine, usually with complete or partial fermentation in the large intestine; and promotes one or more of these beneficial physiological effects: laxation, reduction in blood cholesterol, and/or modulation of blood glucose and includes polysaccharides, oligosaccharides (**DP > 2**), and lignins" |
| "Dietary fibre consists of: (1) carbohydrates with **a DP[1] of 3 or more** that naturally occur in foods of plant origin that are not digested and absorbed by the small intestine; and (2) accepted novel fibres.<br>Novel dietary fibre is an ingredient manufactured to be a source of dietary fibre. It consists of carbohydrates (DP > 2) extracted from natural sources or synthetically produced, that are not digested and absorbed in the small intestine. It has demonstrated beneficial physiological effects in humans and it belongs to the following categories: it has not been traditionally used for human consumption to any significant extent; or it has been processed so as to modify the properties of the fibre; or it has been highly concentrated from a plant source"<br>[1]DP: degree of polymerisation or number of saccharide units. |
| "*Dietary Fibre* consists of **nondigestible carbohydrates** and lignin that are intrinsic and intact in plants<br>*Functional Fibre* consists of isolated, nondigestible carbohydrates that have beneficial physiological effects in humans<br>*Total Fibre* is the sum of *Dietary Fibre* and *Functional Fibre*" |
| The committees on dietary carbohydrates of ILSI Europe and ILSI North America agree with the **inclusion of carbohydrates of 3–9 DP** in the DF definition |

# Dietary Fiber




Dietary fibers bind conjugated primary bile acids (BAs), non-conjugated BAs, and secondary BAs.

- They decrease colonic absorption of toxic BAs and subsequent polyp formation.
- They increase the disposal of BAs, leading to increased GLP-1 secretion (preventing obesity).

Figure 2. Short-Chain Fatty Acid (SCFA)-Independent Effect of Dietary Fibers in Colon: **Dietary fibers bind conjugated primary bile acids (BAs)** and may serve as a platform for gut bacteria that possess the bile salt hydrolase (BSH), leading to the production of non-conjugated BAs. These can also bind to dietary fibers and be further metabolized by specific bacteria with 7-alpha dehydroxylation activity, thus generating secondary BAs. **The fact that dietary fibers can bind secondary BAs suggests that they may play a role in regulating BA levels within the gut.** This structural interaction may modulate host physiology either by preventing the accumulation of toxic BAs that can lead to the development of polyps and colorectal cancer (CRC) or by increasing the disposal of BAs that can activate TGR5 to increase glucagon-like peptide 1 (GLP-1) secretion. In addition, bacterial degradation of dietary fibers leads to the release of minerals and phenolic compounds, which can be absorbed by the distal gut.

Figure 1. Effect of Low- and High-Fiber Diet on Gut Microbiota Composition, Diversity, and Function in Host Physiology: A diet rich in fiber contributes to the maintenance of a healthy gut microbiota associated with increased diversity and functions such as the production of short-chain fatty acids (SCFAs). With the industrialization of the diet, low fiber intake, and high protein and sugar consumption, the diversity of the gut bacteria is reduced and their function is altered, including significant reduction in their ability to produce SCFAs, and associated with the appearance of chronic inflammatory diseases. High fiber intake and the production of SCFAs by the gut bacteria enhance mucus and anti-microbial peptide production, and increase expression of tight junction proteins. In addition, SCFAs reduce oxygen levels and maintain a functional immune system. These biological processes are disrupted when the diet is shifted toward a Western lifestyle and may lead to increased susceptibility to infections and IBD, and to impaired physiology.

Makki 2018, The impact of dietary fiber on gut microbiota

# Dietary Fibers

Cutin and suberin are polyesters that occur in vascular plants.

Cutin composes the macromolecular frame of the plant cuticle in which the low molecular waxes and fats are embedded. Together, they form the cuticle. The cuticle covers the epidermis and protects the surface of plants against desiccation by the atmosphere.

In contrast, suberin is a cell wall component of cork cells, which compose the periderm layer of surficial as well as subterranean parts of woody plants. The content of suberin is particularly high in bark and in plant roots. The cutin polymer is composed of di- and trihydroxy and epoxy fatty acids with a C16 and C18 chain length (Figure 5).

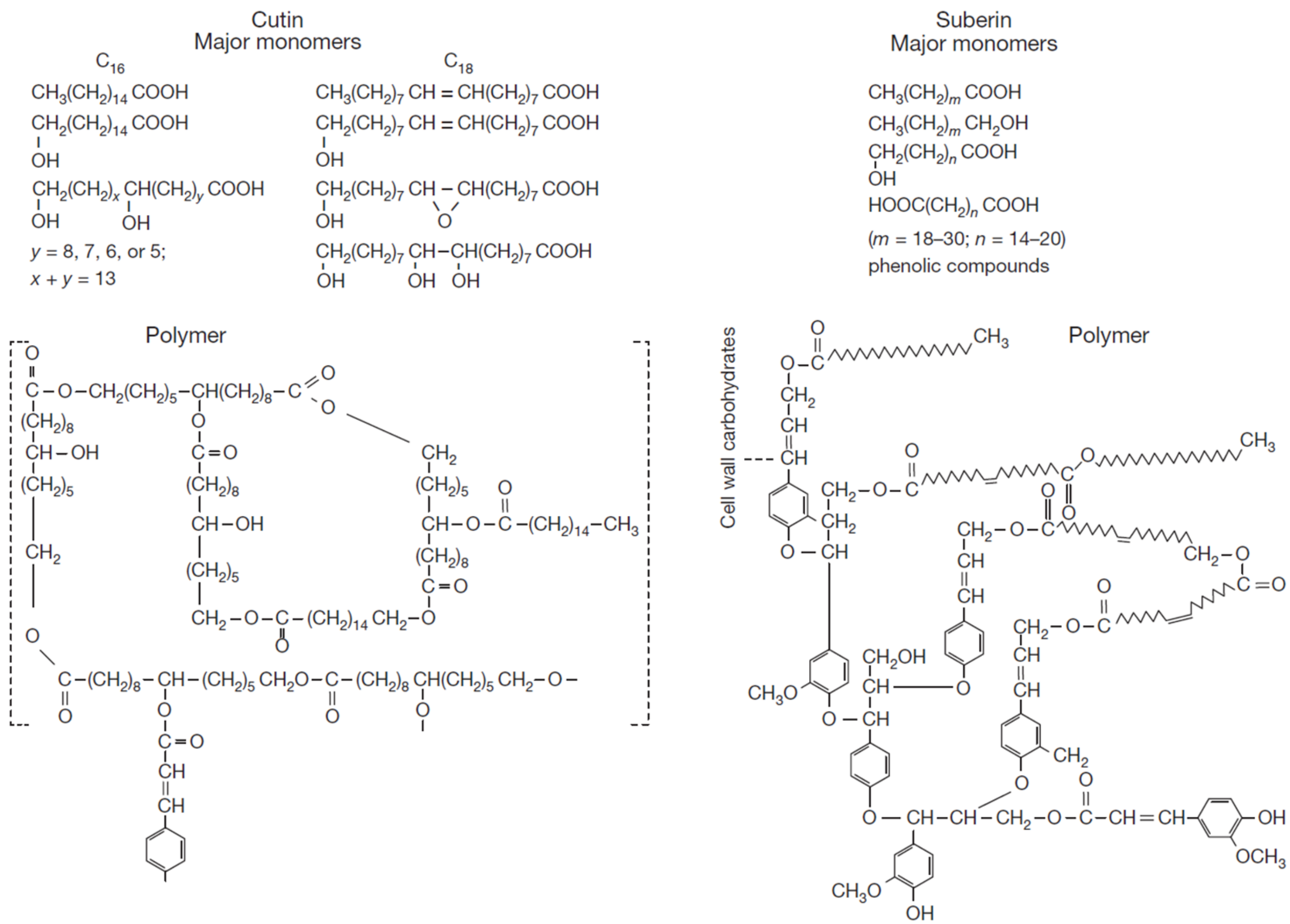



**Figure 5** Major components and their structural associations in cutin and suberin. Reproduced from Kögel-Knabner I (2002) The macromolecular organic composition of plant and microbial residues as inputs to soil organic matter. *Soil Biology Biochemistry* 34: 139–162, with permission from Elsevier.

Kogel-Knabner 2014, Dynamics, chemistry, and preservation of organic matter in soils

# Starch and Sugar

# Sugar Sugar (by The Archies)

# Sugars, Sugar Replacements, and Sweeteners

Table 3.1 Technological and Physiological Properties of Sugars, Sugar Replacements and Sweeteners

| Substance | Status | Sweetness Sucrose 100 | For Diabetics | Cariogenic | Energy Content (kcal/g) |
|---|---|---|---|---|---|
| *Part 1* | | | | | |
| Saccharose | Food | 100 | No | Highly | 4 |
| Fructose | Food | 120 | + | Highly | 4 |
| Glucose | Food | 70–80 | No | Highly | 4 |
| Lactose | Food | 30–50 | No | Highly | 4 |
| Maltose | Food | 40–50 | No | Highly | 4 |
| Invert sugar | Food | 100–120 | No | Highly | 4 |
| Tagatose | Novel food | 90 | + | Non | 1.5 (United States) |
| Trehalose | Novel food | 45 | (−) | Non | 4 |
| Sorbitol | E 420 | 50–60 | + | Non | 2.4 (EU) 2.6 (United States) |
| Mannitol | E 421 | 50–60 | + | Non | 2.4 (EU) 1.6(United States) |
| Glycerol | E 422 | 60 | + | Non | 4 |
| Erythritol | E 968 | 60 | + | Non | 0 (EU, JP) 0.2 (United States) |
| Isomalt | E 953 | 45–50 | + | Non | 2.4 (EU) 2.0 (United States) |
| Isomaltulose | Novel food | 40–50 | + | Non | 4 |
| Xylitol | E 967 | 90 | + | Non | 2.4 (EU, United States) |

| Substance | Status | Sweetness Sucrose 100 | For Diabetics | Cariogenic | Energy Content (kcal/g) |
|---|---|---|---|---|---|
| *Part 2* | | | | | |
| Lactitol | E 966 | 30–40 | + | Non | 2.4 (EU) 2.0 (United States) |
| Maltitol | E 965 | 75–90 | (+) | Non | 2.4 (EU) 2.1 (United States) |
| Hydrogenated starch hydrolysate | GRAS | 25–50 | (+) | Non | 2.4 (EU) 3.0 (United States) |
| Polydextrose | E 1200 | <5 | + | Non | 1 (EU, United States) |
| Inulin | Food | 1–14 | + | Yes | 1 (EU) |
| Acesulfame-K | E 950 | Up to 13,000 | + | No | 0 |
| Aspartame | E 951 | Up to 18,000 | * | No | |
| Aspartame–Acesulfame-Salt | E 962 | Up to 35,000 | + | No | |
| Cyclamate Na | E 952 | Up to 3,000 | + | No | |
| Neohesperidine DC | E 959 | Up to 100,000 | | | |
| Saccharin Na | E 954 | Up to 30,000 | + | No | 0 |
| Sucralose | E 955 | Up to 40,000 | + | Non | |
| Thaumatin | E 957 | Up to 200,000 | + | No | 4 |
| Neotame | GRAS EU: no | Up to 700,000 | | No | |

Tiefenbacher 2017, Technology of main ingredients- Sweeteners and lipids

**3.1.1.3 The Properties of Sweeteners**

Sucrose and other sugars are components in many wafer and waffle baking mass recipes, as well as in most adjuncts such as fillings and enrobings. Not only to impart the characteristic sweetness, there are many more technological effects that will be discussed in detail.

Any requirement to replace a bulk ingredient like sucrose for nutritional, quality or marketing reasons requires some technological adaptations. These have to compensate for differences in the physicochemical as well as in the sensory properties of the substitutes. Table 3.1 provides an overview on technological and physiological properties of sugars, sugar replacements and high-intensity sweeteners (HISs).

The columns of the table contain the following:

1. The name of the sugar, syrup, sugar replacement and HIS
2. The legal status
3. The relative sweetness compared to sucrose. The data refer to sweet bakery foods
4. The suitability for diabetics; the sign * indicates that a warning label is required for persons with phenylketonuria (PKU)
5. The cariogenic potential, see Fed. Reg. 21 CFR Part 101.80
6. The energy content in kcal/g. Unfortunately there are still differences between Europe, the United States and Japan on the authorized data
7. The solubility in water at 20°C
8. Information on any cooling effect during the dissolution in the mouth, depending on the heat of the solution of the sugar. Strong: heat of the solution is over25 kcal/g; medium: heat is from -25 to -15 kcal/g; low: heat is from -15 to -5 kcal/g
9. Information on the hygroscopic properties
10. For solids: the melting point in °C. In case two data are given, the first is for the anhydrous form, and the second for the hydrate form
11. Some brand names Table 3.2 provides an overview on relevant terms for sweeteners.

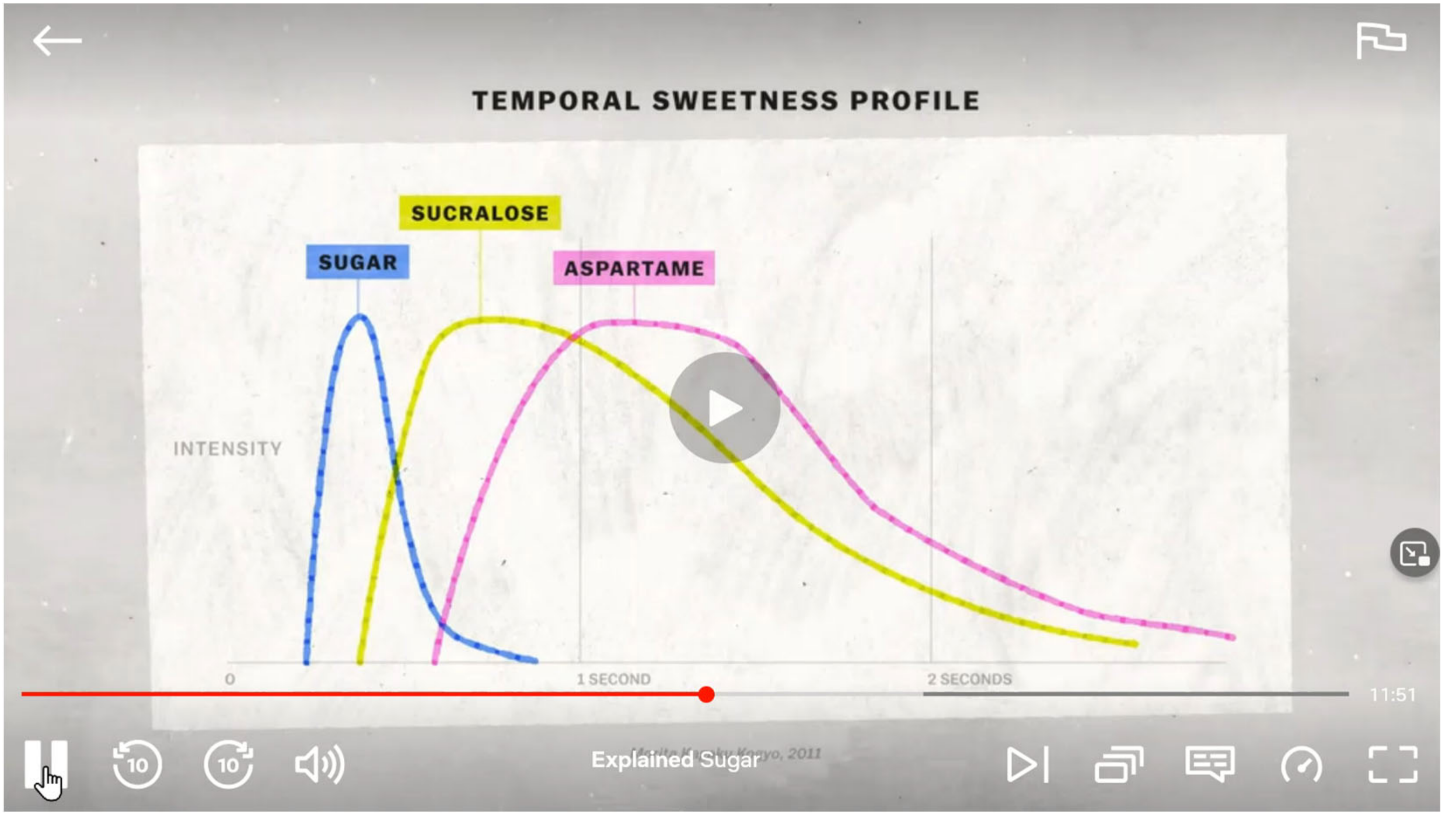
# Sugars, Sugar Replacements, and Sweeteners

**Table 3.2 Sugars and Sweeteners—Glossary of Substances and Terms**

Tiefenbacher 2017, Technology of main ingredients- Sweeteners and lipids

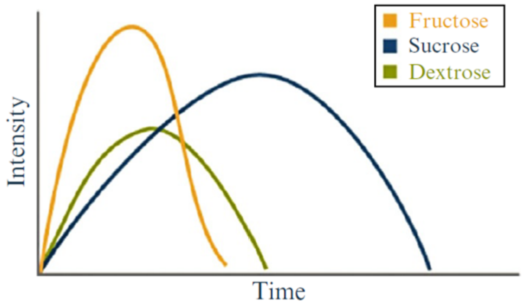
| Substance or Term | Comment |
|---|---|
| Brown sugar | Less refined sugar from sugar cane (muscavado) or white sugar covered with brown cane syrups or caramelized sugar syrup (demerara). Sticky due to a little moisture and minor nonsucrose residues |
| Caramel | Brown, sweet to bitter flavourful product from heating sugar solutions |
| Caramel colour | Dark brown food colour from heating sugar, optionally with additives |
| DE | Dextrose equivalent, measure of the degree of hydrolysis of starch into maltodextrins, glucose (corn) syrups, maltose syrups, or dextrose. Starch has a DE=0. Dextrose has a DE=100 |
| Dextrose | Glucose (D-glucose), grape sugar (a sugar found in the bloodstream) |
| Fondant | Saturated mass of fine sugar crystals and some percentage of glucose syrup |
| Fructose | Fruit sugar, laevulose; main component in high fructose corn syrups (HFCS) |
| Glucose | Grape sugar, dextrose (a sugar found in food) |
| Glucose, corn, or starch syrup | Made from starch by acid and/or enzyme hydrolysis. Most frequent the DE is 34, 42 or 62 |
| HFCS | High fructose corn syrup is enzymatically prepared from glucose syrup; in Europe isoglucose is syrup with some fructose percentage |
| High-intensity sweetener | Intensely sweet tasting, food approved chemicals, 30 to over 100,000 times sweeter than sucrose |
| Instant sugar | Agglomerated powder sugar, nondusting and quickly soluble |
| Inversion | Cleavage of sucrose into glucose and fructose, catalysed by enzymes and/or acids |
| Invert syrup | 1:1-mixture of fructose and glucose, from sucrose by inversion |
| Lactose | Milk sugar, a disaccharide, composed of glucose and galactose |
| Liquid sugar | Concentrated sucrose solution in distilled water |
| Maltodextrin | Made from starch by acid hydrolysis, the DE is 5–20 |
| Maltose | Malt sugar, a glucose disaccharide |
| Maltose syrup | Made from starch by acid and enzyme hydrolysis with typically 40–50 DE and 45%–60% maltose. For hard candy as it tends not to crystallize and is comparatively nonhygroscopic |
| Molasses | Dark, aromatic syrup remaining from cane sugar crystallization |
| Oligosaccharide | From the polysaccharide starch by cleavage, typically 3 to 10 glucose units |
| Pearl sugar | Bigger chunks of agglomerated sugar, 5–8 mm, applied in Liège waffles |
| Polyol | Sugar alcohol; used for sugar replacement such as glycerol, sorbitol, erythritol, maltitol, isomalt, lactitol, or xylitol |
| Polysaccharide | Starch, cellulose from many (>10) glucose units, no sweet taste |
| Saccharose | Plain sugar, sucrose, from cane or beets |
| Sugar replacement | Sometimes synonymous for nonsucrose sugars or polyol sweeteners used in bulk |
| Sugar substitute | Replaces sugar by other natural or synthetic sweet-tasting substances such as for diabetics or for calorie reduction |

# The Truth about Sugar




Explained/Sugar. Netflix

Sweetness profile: onset and intensity.

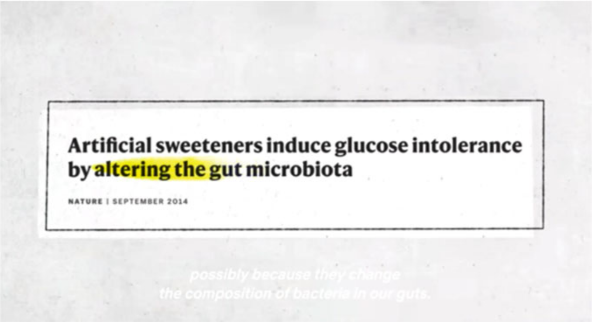



Tiefenbacher 2017, Technology of main ingredients- Sweeteners and lipids

# The Truth about Sugar

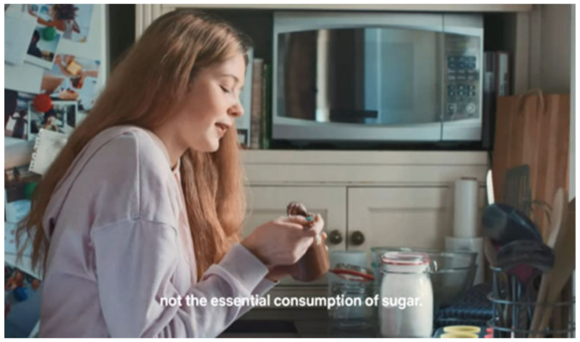












# Intensely Sweet Proteins

2.1.5. Thaumatin Extract.

Thaumatin, a vegan sweetener desired inside the global market nowadays, is derived from the fruit arils of a tropically grown plant referred to as Thaumatococcus daniellii. Thaumatins are a class of intensely sweet proteins found in the arils of T. daniellii fruits. Their current production method through aqueous extraction and the uncertainty of harvest from tropical rainforests limit their supply while the demand has been increasing. Thaumatin sweetener has been extracted and sold globally by Tate and Lyle (UK) under the brand name of Talin. Thaumatins are the first sweet-tasting proteins that have been found in nature with 2000−3000 times sweetness compared to sucrose and neither allergic nor mutagenic or teratogenic properties. The barks are fastened around the nuts which produce the jelly, that upon swelling to many folds of its weight, houses the Thaumatin. The arils which contain the Thaumatin constitute 4.8% of the fruit while the remaining fleshy part and seed account for 72.4% and 22.8%, respectively. Thaumatin is currently used as a flavor modifier in food items such as ice creams, chewing gum, dairy, pet foods, and soft drinks and to mask undesirable flavor notes in food and pharmaceutical products. Thaumatin is called a flavor modifier, which means it has the capacity to mask an unwanted after-taste, which paves the way for a better tasting plant protein powder or whey protein complement. Thaumatins supply fantastic tasting protein powders with low caloric content but that are nutrient-dense and relatively digestible. This sweetener is approved as GRAS in the US and approved as E957 in the European Union. JECFA and FEEDAP (Additives and Products or Substances used in Animal Feed) have recommended a Thaumatin ADI of 1−5 mg/kg body weight of the animal. It is usually safe, but some people may experience different side effects (especially if used in high quantities), such as nausea, headache, chest pain, flushing and fluttering heartbeats. However, being proteinaceous instead of a sugar, it cannot satisfy most cravings for sugar. Therefore, its use may lead to overeating in the case of satisfying sweet cravings.

Apart from Thaumatin, until now, 8 different proteins have been discovered from natural plant sources, namely, mabinlin, monellin, lysozyme, pentadin, brazzein and miraculin. However, these sweet proteins are still under research and have not been completely exploited in food, nor are they commercially available. Table 2 is given to summarize the basic attributes and natural derivation sources of sweet proteins.

**Table 2. Natural Vegan Sourced Sweetening Proteins and Their Basic Characteristics**

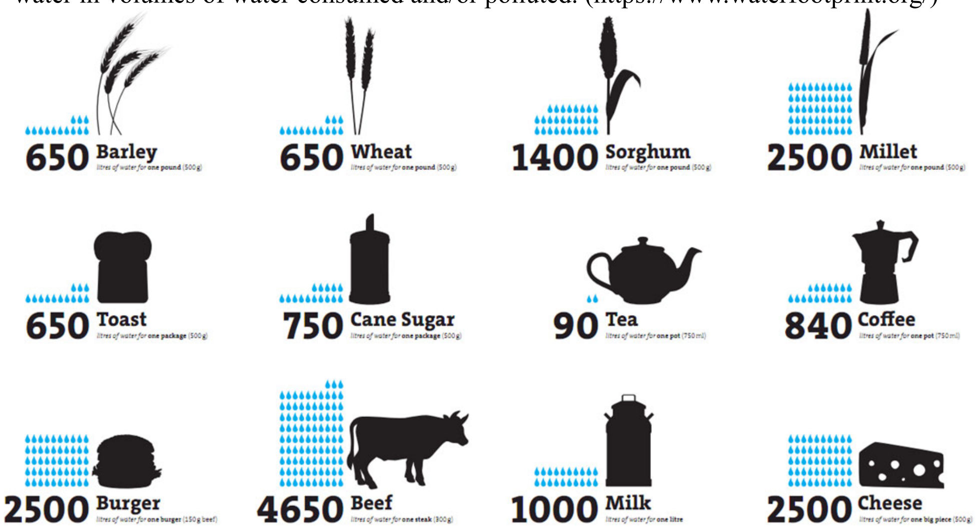
| Sweetening protein | Amino acids | Relative sweetness (weight basis) | Vegan sources |
|---|---|---|---|
| **Miraculin** | 191 | N/A | *Richadella dulcifica* |
| **Pentadin** | 54 | 500−2000 | *Pentadiplandra brazzeana Baillon* |
| **Mabinlin** | 33 (A chain), 72 (B chain) | 100 | *Capparis masaikai Levi* |
| **Brazzein** | 54 | 2000 | *Pentadiplandra brazzeana Baillon* |
| **Monellin** | 45 (A chain), 50 (B chain) | 3000 | *Discoreophyllum cumminsii Diels* |
| **Thaumatin** | 207 | 1600−3000 | *Thaumatococcus danielii* |
| **Curculin/ Neoculin** | 114 | 500 | *Curculigo latifolia* |

Anwar 2023, Inclusive overview of sweeteners trends- Nutritional safety and commercialization

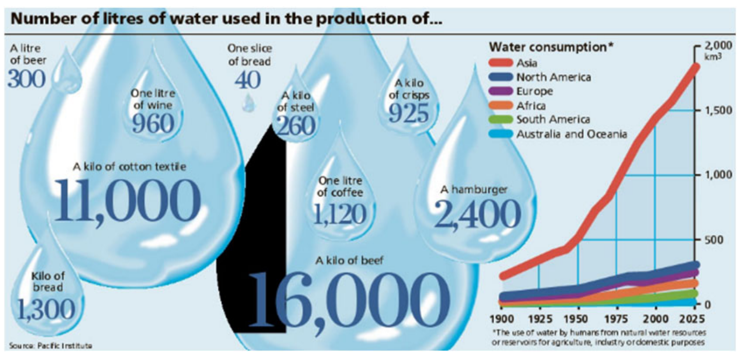
# Polymers in Food & Agriculture

# Virtual Water

Water Footprint: The water footprint is a measure of humanity's appropriation of fresh water in volumes of water consumed and/or polluted. (https://www.waterfootprint.org/)




The water footprint of a product is the volume of freshwater used to produce the product (e.g. it takes 4,650 litres of water to produce 300 g of beef).
https://undisciplinedenvironments.org/2016/01/28/what-does-virtual-water-conceal/




http://www.linv.org/virtual-water/

**$H_2O$: The molecules that made us.** (PBS)

Civilization: Water may have driven human evolution and created civilizations in the past, but it's uncertain whether Earth's water supplies can guarantee human's future.

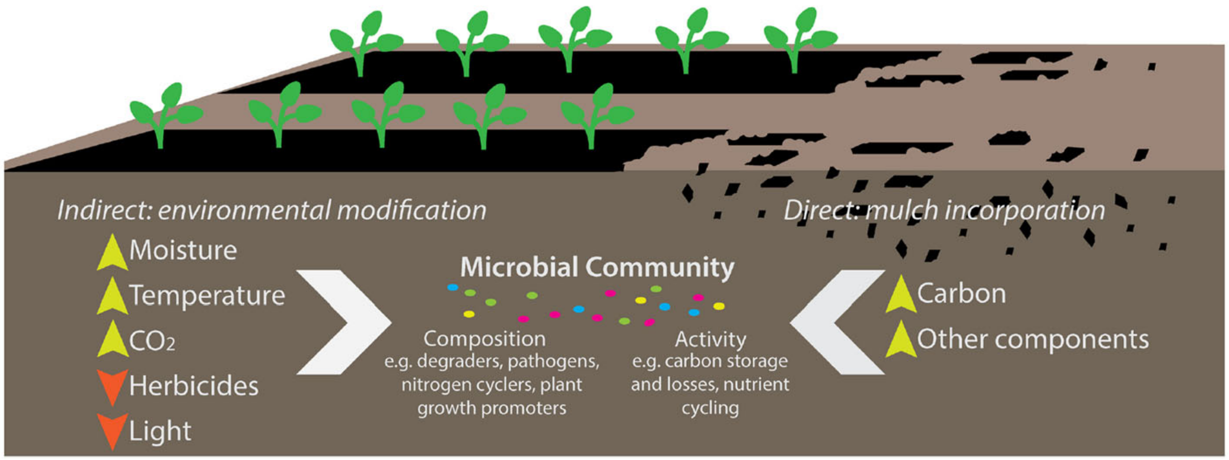
**Agriculture Circular**: 3,000 gallons/hour from the underground. Much fast use than Earth can replenish.

**Virtual water**: 26 gallons of water is needed to grow a tomato. → Enormous amounts of water to grow a cow. All cargo ship carrying foods are actually carrying virtual water that was used to grow those plants and animals. Saudi Arabia growing plants in Arizona using US water and bring the foods back to Saudi Arabia.

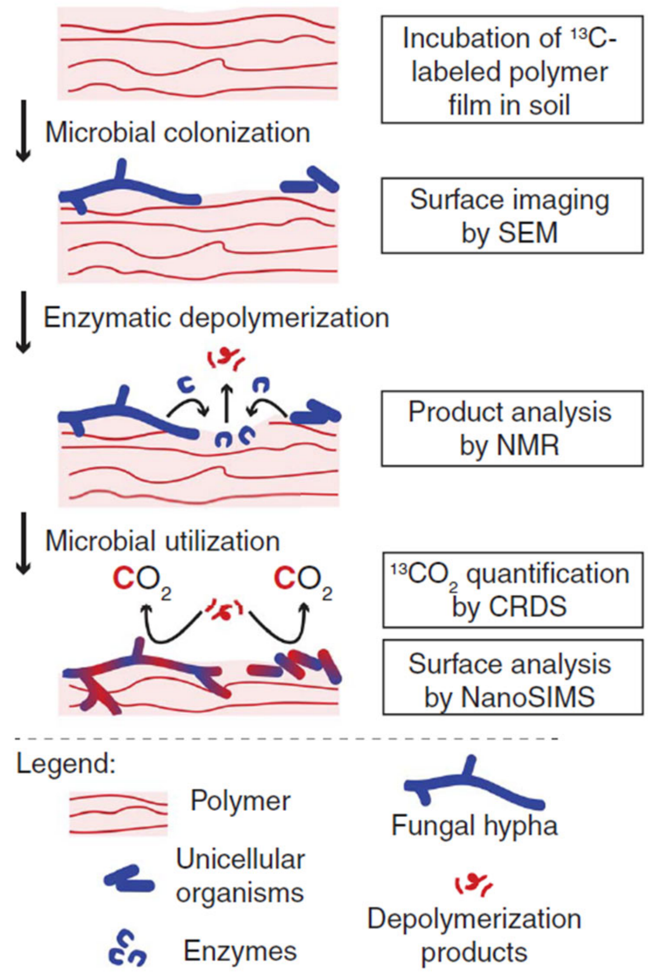
**Water footprint**
92% of the world water is used to grow plants and foods in the world. **99% of all water that plants and trees have from the ground is evaporated**, and **only 1% is used**.

(PBS)
Amazon jungle, trees release water even in dry season. Dragon fly rides a cloud and wind from Amazon to Africa, and then to India, and then back to Amazon. This is a 4-year cycle.
Pesticizers killing trees and dragon flies increases malaria in Africa, as there is less dragon flies eating mosquitos.

# Plasticulture: Plastic Mulch Films




Bandopadhya 2018, Biodegradable plastic mulch films




Zumstein 2018, Biodegradation of synthetic polymers in soils

# Walking Undersides of Leaves: Mechanism

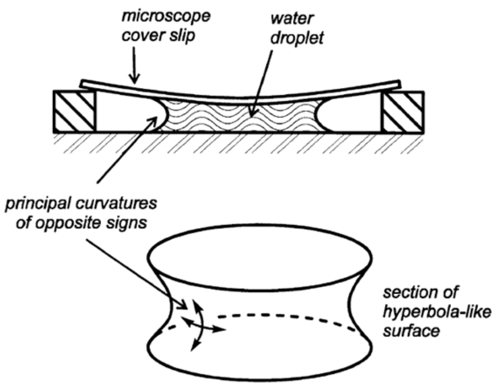



Fig. 2.10 The reduction in pressure in a drop can bend a cover-slip.

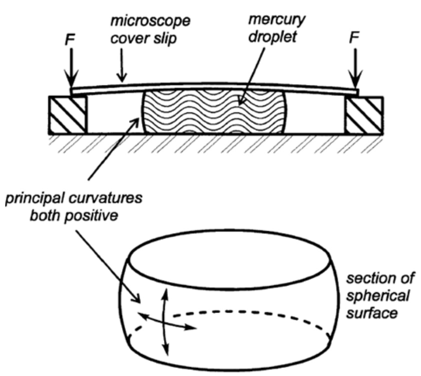



Fig. 2.11 A mercury droplet must be squeezed between the slip and the slide to deform it from a full sphere (doubly-truncated), although the surface remains 'spherical', with the two curvatures identical in value. The pressure due to the curvature is exerted on the glass.

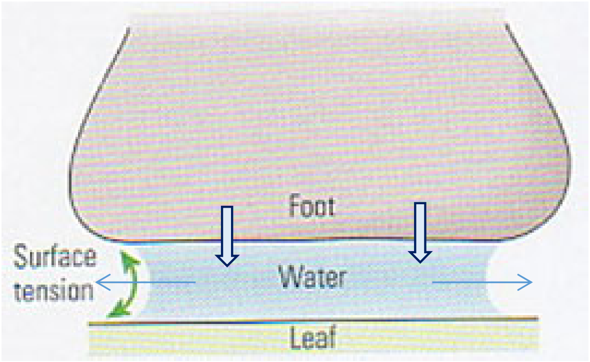
At θ = 90° exactly there will be neither capillary rise nor depression and the meniscus will be quite flat, curvature zero. (As an aside: for certain of the polymers now used for cheap chemical volumetric ware such as burettes and pipettes, instead of glass – which has θ < 90° for aqueous solutions – the meniscus is almost completely flat, θ . 90°, making reading somewhat easier.)

Clearly, with low contact angles the equalization of pressures draws more liquid from the mass, but if this reservoir is not present, a hydrostatic negative pressure is developed within the liquid and does not disappear. Thus, if we consider a liquid droplet placed beneath a supported microscope slide cover slip such as in Fig. 2.10, the tendency to spread at the TPL boundary on each glass surface (to increase the area of the wetted interface) the drop is placed under a negative pressure. The area of the interface with the air is minimized simultaneously, accounting for the strange shape of that surface.

It may be noticed that the curvature of the liquid-air surface is negative in the radial planes, while the curvature in the other sense (e.g., the horizontal plane at the 'waist') is positive; this is an anticlastic surface.

Aphids (greenfly and similar bugs) suck out the juices from plants through mouthparts that resemble a hypodermic needle. They have to walk on smooth plant surfaces, including vertical stems and the undersides of leaves, and they have to adhere strongly enough not to be blown off or shaken off as the leaf waves in the wind. The force of adhesion has been measured by putting an aphid on a clean piece of glass on the pan of a sensitive scientific balance.

The adhesive feet of insects such as this stink bug (suborder Heteroptera) enable them to walk on the surface of leaves.




**Surface tension allows negative pressure to develop** in the film of water between an aphid's foot and the surface on which is it standing.

If the sum of curvatures is positive, then the pressure is greater inside as a result (Fig. 2.11) (as it must be with a synclastic surface, i.e. both curvatures positive)

# Superhydrophobic Sand Mulches

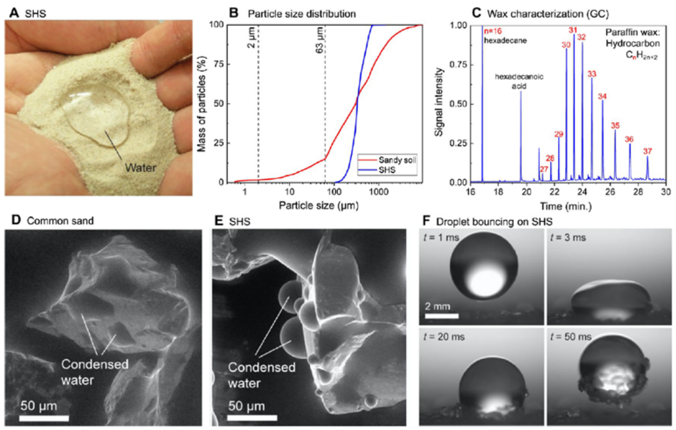



**Figure 1.** Characterization of superhydrophobic sand (SHS). (A) Photograph of SHS with water on top, demonstrating its superhydrophobicity. (B) Particle size distribution of SHS and sandy soil (loamy sand as per USDA soil texture characterization) collected at a local agriculture research facility. The fractions above and below 63 $\mu$m were determined using sieving and hydrometer methods,[33] respectively. (C) Gas chromatography of paraffin wax (~0.1 M in cyclohexane) pinpointing the chain lengths of the constituent alkanes ($n$) in red. The relative compositions of the alkanes are presented in Table S1. Note: hexadecane and hexadecanoic acid were used as internal standards. Representative environmental scanning electron micrographs of water droplets condensed on (D) common sand grains and (E) SHS grains. The apparent contact angles of water droplets are significantly higher in (E) than in (D). (F) High-speed images of a 30 $\mu$L water droplet dropped onto a 5 mm-thick SHS layer from a height of 2 cm (Movie S1).

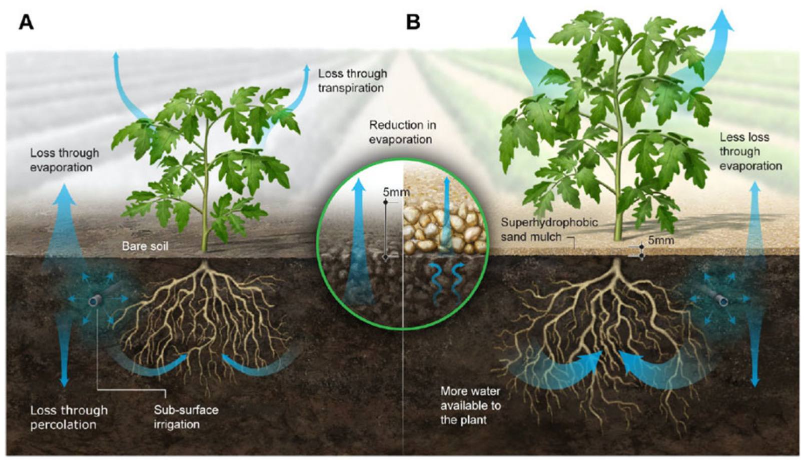



**Figure 2.** Concept of superhydrophobic sand (SHS) mulches to reduce water evaporation from soils in arid regions. Water movements for subsurface-irrigated (A) unmulched soil and (B) soil mulched with SHS. SHS prevents the capillary rise of water, thereby creating a dry diffusion barrier that allows water vapor to diffuse at a rate significantly lower than that in unmulched or bare soil.

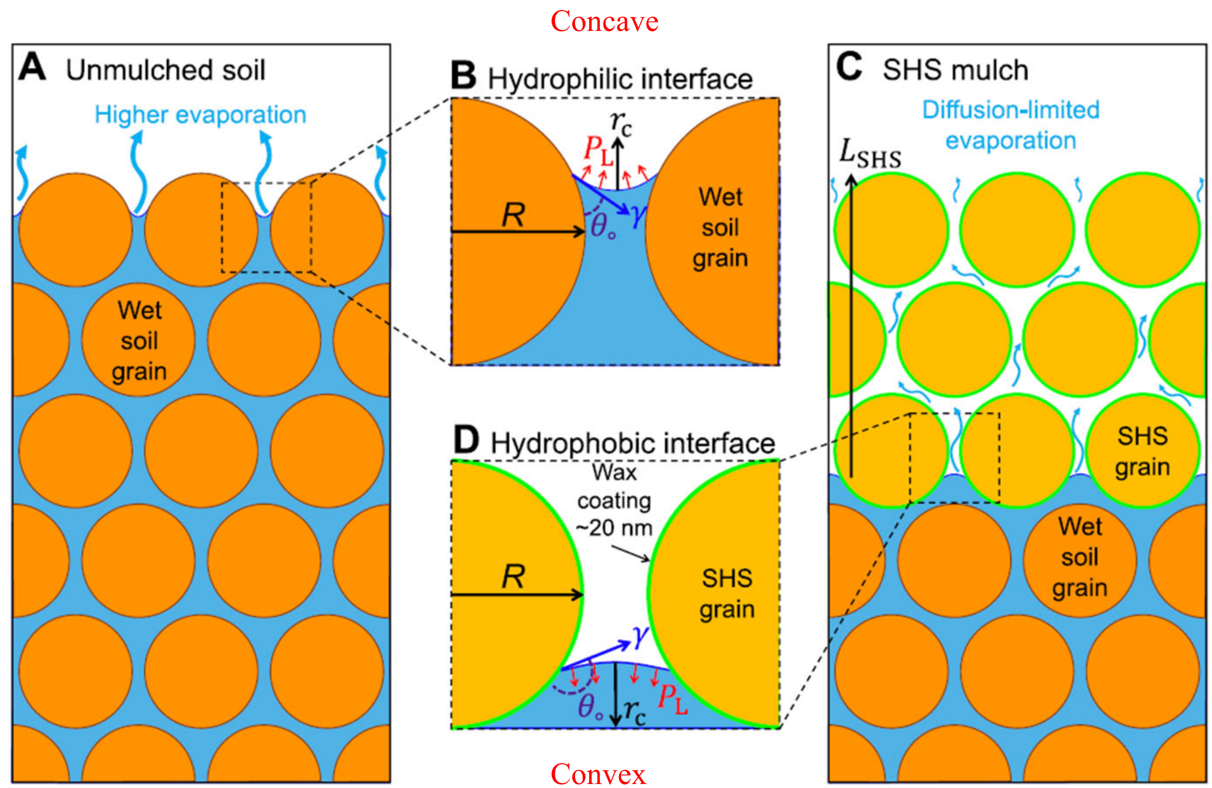


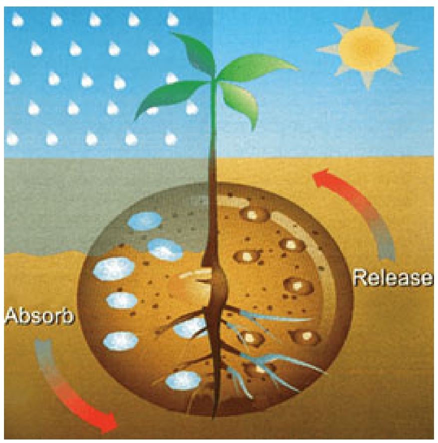

Figure 7. Mechanism for limiting water evaporation from the soil. (A) Water from subsurface irrigation is spontaneously imbibed by the soil media due to (B) positive Laplace pressure, PL (red arrows). This results in the capillary rise of water, leading to evaporation loss. (C) Water from subsurface irrigation is imbibed by the soil, but this imbibition is arrested at the soil−SHS interface due to (D) negative Laplace pressure. Subsequently, SHS acts as a barrier, limiting diffusion and significantly reducing water loss from the soil.

Gallo 2022, Nature-inspired superhydrophobic sand mulches increase agricultural productivity and water-use efficiency in arid regions

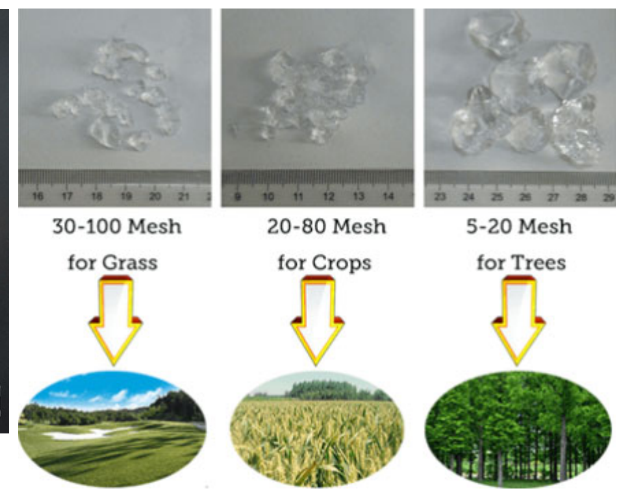
# Superabsorbent Polymers for Retaining Water

| | |
|---|---|
| Bare Root Dipping: | Use for root dipping in order to prevent the desiccation of the roots of seedlings during transplanting or transport over a long distance. |
| Floral Decoration: | Coloring the water in glass containers. The hydrogel created is placed in glass containers in which cut flowers may be placed. |
| Hydroseeding: | Mixed with or without cellulose mulch, it makes it possible to maintain a minimum of surface water, which permits rapid sprouting of seedlings even in dry areas. The vegetation cover develops uniformly and rapidly over the whole treated surface. |
| Lawns & Sod: | Water retainers are simple to use throughout the growth cycle of lawns and sod. |
| Soil Remediation: | Acts as a super absorbent water retainer to provide a reduction in water stress. |

http://www.accepta.com/environmental-water-wastewater-knowledge/accepta-newsletter/708-super-absorbent-polymer-water-retainer-for-farming-agriculture-horticulture-accepta-4301








http://www.socochem.com/super-absorbent-polymer-for-agriculture.html

http://www.climatetechwiki.org/technology/biopolymer

https://www.alibaba.com/showroom/super-absorbent-polymer-for-agriculture.html

http://www.socochem.com/potassium-polyacrylate-super-absorbent-polymer-for-agriculture.html

# Agricultural Polymers

Polymeric soil conditioners, were known since the 1950s (Hedrick and Mowry 1952). However, their wide commercial application failed even though the scientific basis for their use was quite well established. These polymers were developed to improve the physical properties of soil in view of:

- increasing their water holding capacity
- increasing water use efficiency
- enhancing soil permeability and infiltration rates
- reducing irrigation frequency
- reducing compaction tendency
- stopping erosion and water run-off
- increasing plant performance (especially in structureless soils in areas subject to drought).

Among the products which initially appeared on the market, there was a copolymer consisting of vinyl acetate and maleic anhydride units (VAMA) known under the trade name Krilium®. It was withdrawn from the market due to **high cost exceeding the value of many crops** and **complexity of application and poor distribution in the soil**.

**Most of the studies with polymers were performed in the laboratory or greenhouse without consideration for the economics at the production level in large-scale agriculture**. When the polymer is mixed into the soil at rates of about 0.1% by mass, it translates into amounts of 1,000 to 4,000 kg/Hectare. Such rates are obviously not economical for most uses. The need for more arable land in view of increasing agricultural production has renewed interest in the development of novel soil conditioner materials with new methods and lower rates of application.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.600.5229&rep=rep1&type=pdf

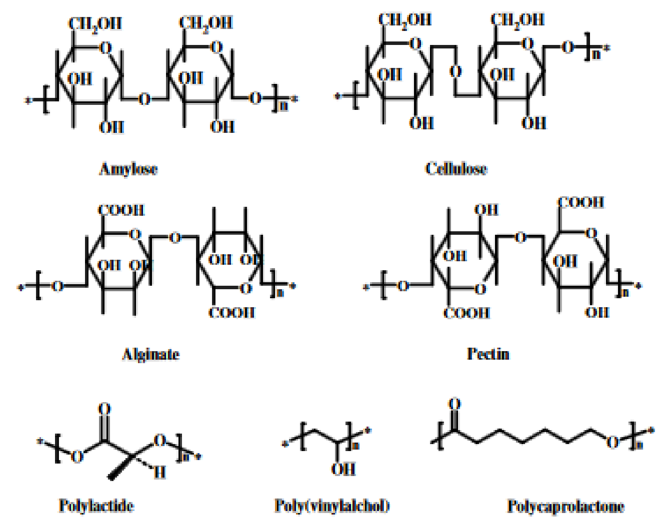
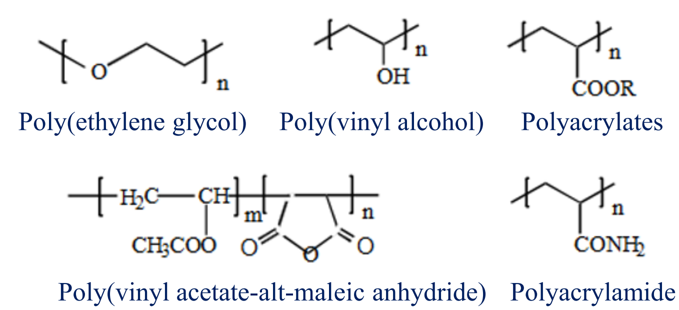



Fig. 1: Natural and synthetic biodegradable polymers

http://thescipub.com/PDF/ajabssp.2008.299.314.pdf




http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.600.5229&rep=rep1&type=pdf

# Hydrogel Farming

Hydrogels are networks of hydrophilic (which means "water-loving") polymer chains, sometimes found as a colloidal gel in which water is the dispersion medium. The hydrogel membrane in the Imec technology is only microns thick.

Mebiol is the first and only company globally to have commercialized this kind of membrane for plant cultivation. Advanced membrane technologies are used in the medical and water purification field, but not in agriculture. Other formulations of hydrogels have uses in medical treatment for blood purification and oxygen enrichment, and in water treatment for desalination and purification.

In agriculture use, along with eliminating the soil contamination that affects productivity and the quality of crops, one of the interesting side effects is that the plants synthesize a lot of sugar. The "water stress" the Imec membrane creates induces crops like tomatoes to synthesize large amounts of sugar, lycopene and other beneficial elements, leading to greater sweetness and higher nutritional value.

After testing the technology successfully in Dubai, one of the world's most inhospitable environments for agriculture, the Sahara could be next. And once he makes the desert bloom, Dr Mori believes that even less likely conditions could be roped in for producing crops for a rapidly growing world population. The technology will even allow cultivation on ice – or concrete!

http://www.greenprophet.com/2012/05/a-futuristic-hydrogel-to-grow-food-on-desert-sand/


http://www.balajigreengold.com/sap.html

# Hydrogel Farming on Desert Sand

**Mebiol's Futuristic Hydrogel to Grow Food on Desert Sand**: Japan Yuichi Mori Mebiol. May 4th, 2012. Susan Kraemer

Mebiol's hydrogel could make deserts flourish with crops grown on barren sand.
Here's another futuristic invention that could completely change the future of agriculture in a desertifying world. Substituting an industrially produced hydrogel for soil makes it possible to farm on sterile desert sand. Similarly to Pink LEDs Grow Future Food with 90% Less Water, this amazing sci-fi technology allows the farming of the desert, with 80 percent less water than needed in traditional farming.

The hydrogel technology is the invention of Waseda University Visiting Professor Yuichi Mori, who has years of experience in developing polymeric membranes for use in medical technologies such as blood purification and oxygen enrichment. But Mori saw the greatest need was in desert farming in a future world faced with **explosive population growth**, but **diminishing potential for traditional soil-based agriculture due to soil degradation, erosion, and drought**.
His hydrogel membrane–based plant cultivation technology has **a unique membrane technology (Film Farming)**. The simple system is much more portable than traditional hydroponics. Mori has launched a company, Mebiol, to commercialize the technology, which solves many of the farming problems found in deserts, the age-old agricultural problems due to the unpredictability of water supplies.

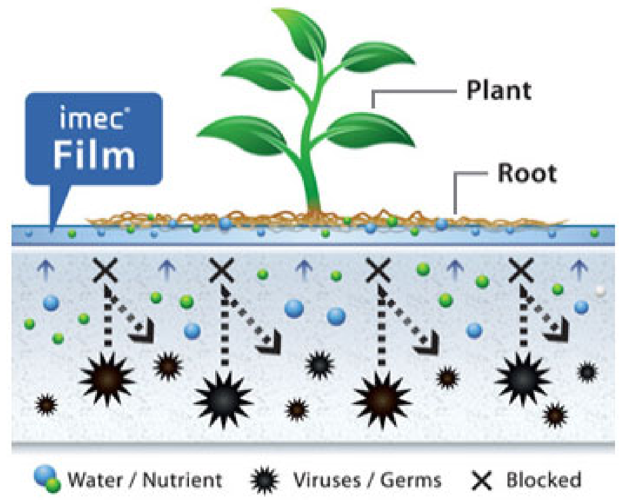
The plants grow on a thin hydrophilic film made of hydrogel, **which allows the passage of water and nutrients such as various ions, amino acids and sugars but not bacteria, fungi and viruses**. This protects plants from diseases; use of pesticide is minimized. The membrane looks like a plastic sheet allows for no-soil and low-soil farming, with the water and fertilizer separate from the plants roots. The roots remain dry while drawing water and nutrients from below the membrane, and oxygen from the air. Lettuce and other leaf vegetables can be grown with no soil.

http://www.rexresearch.com/mori/mori.htm
http://www.greenprophet.com/2012/05/a-futuristic-hydrogel-to-grow-food-on-desert-sand/

# Film Farming

Imec® (Film Farming) is the world's first hydrogel membrane based agro-technology to address some of the serious issues that our world communities' face today regarding food shortage, water scarcity and land contamination.

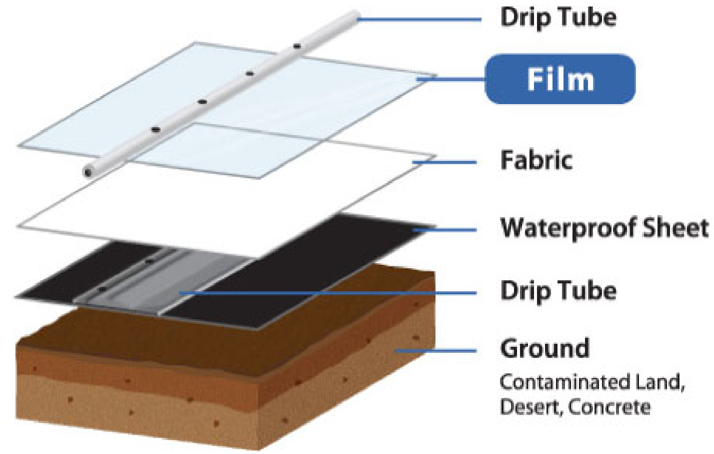
In Imec® , plants are cultivated and grown on a thin Film made of hydrogel which absorbs water and nutrients through its numerous nano-sized pores but blocks germs and viruses. Therefore, Film ensures the health of the plant and the safe produce even without the use of chemicals. Low usage of water attributed to hydrogel property of Film accelerates synthesis of sugar, amino acid, etc., leading to high sweetness and nutrition.




Plant roots are attached to the surface of the Imec® film.

Imec® system is easy and simple to set up, and **cost effective**. The system is comprised of water supplying unit and planting bed composed of Film, unwoven fabrics, waterproof sheet and two irrigation tubes.

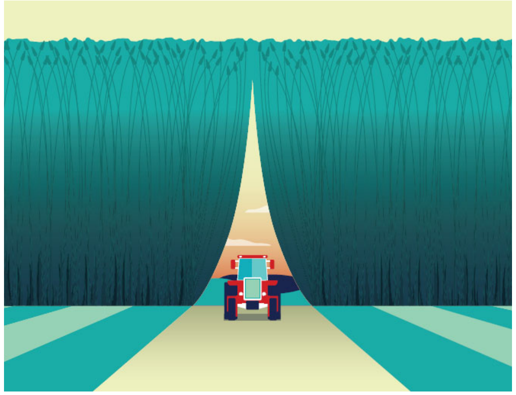
Imec® system enables farming "Anywhere" such as on desert land or even on concrete by separating the plant from the ground by the waterproof sheet. Furthermore, the system dramatically reduces the consumption of water and fertilizer and also the environmental burden, because the waterproof sheet perfectly prevents the runoff of supplied water and fertilizer to outside.




https://www.mebiol.co.jp/en/product/

# Smarter Fertilizers Can Reduce Environmental Contamination

New Formulations Deliver Nourishment On Demand (by Jeff Carbeck)



December 2019, ScientificAmerican.com 33

To feed the world's growing population, farmers need to increase crop yields. Applying more fertilizer could help. But standard versions work inefficiently and often harm the environment. Fortunately, products that are more ecologically sound- **controlled-release fertilizers**- are available and becoming increasingly smart. Farmers typically fertilize crops in two ways. They spray fields with ammonia, urea or other substances that generate the nutrient nitrogen when they react with water. And they apply granules of potash or other minerals to produce phosphorus, also in reaction to water. But relatively little of those nutrients makes its way into the plants. Instead much of the nitrogen goes into the atmosphere in greenhouse gases, and phosphorus ends up in watersheds, frequently triggering excessive growth of algae and other organisms. **Controlled- release formulations**, in contrast, can ensure that significantly higher levels of nutrients reach the crops, leading to higher yields with less fertilizer.

A class known as **slow-release fertilizers** has been sold for some time. These formulations typically consist of tiny capsules filled with substances that contain nitrogen, phosphorus and other desired nutrients. The outer shell slows both the rate at which water can access the inner contents to liberate the nutrients and the rate at which the end products escape from the capsule. As a result, nutrients are meted out gradually, instead of in a wasteful, rapid burst that cannot be absorbed efficiently. Newer formulations include substances that slow nutrient delivery still further, by retarding the conversion of starting materials, such as urea, to nutrients.

Recently fertilizers that more fully fit the description "**controlled release**" have been developed—made possible by sophisticated materials and manufacturing techniques that can tune the shells so that they alter nutrient-release rates in desired ways as the soil's temperature, acidity or moisture changes. By combining different types of tuned capsules, manufacturers can make fertilizers that have profiles tailored to the needs of specific crops or growing conditions. Companies such as Haifa Group and ICL Specialty Fertilizers are among those offering more precise control. Haifa, for instance, ties the rate of nutrient release solely to temperature; as temperatures rise, the rates of crop growth and of nutrient emission increase together.

Although controlled-release technologies make fertilizers more efficient, they do not eliminate all drawbacks of fertilizer use. The products still include ammonia, urea and potash, for example; producing these substances is energy-intensive, which means that their manufacture can contribute to greenhouse gas production and climate change. This effect could be mitigated, however, by using environmentally friendlier sources of nitrogen and incorporating microorganisms that improve the efficiency of nitrogen and phosphorus uptake by plants. There is no evidence that the materials composing the shells hurt the environment, but this risk must be monitored whenever any new substances are introduced in high volumes.

Controlled-release fertilizers are part of a sustainable approach to agriculture known as **precision farming**. This approach improves crop yield and minimizes excessive nutrient release by combining data analytics, artificial intelligence and various sensor systems to determine exactly how much fertilizer and water plants need at any given time and by deploying autonomous vehicles to deliver nutrients in prescribed amounts and locations. Installing precision systems is costly, though, so only large-scale operations tend to have them. In comparison, advanced controlled-release fertilizers are relatively inexpensive and could be a front-line technology that would help farmers to sustainably increase crop production.

# Safe Delivery of Chemical Pesticides

As the main cause of destructive plant diseases, pathogenic oomycete in plant rhizosphere brings about enormous losses to agricultural production. Although chemical pesticides are still one of the most important prevention and control methods for phytopathogens, the usage of chemical pesticides was limited by the 3R (resistance, residue, and rampant) problem. In the early stage of our research, analysis and comparison of the metabolome of resistance to Phytophthora nicotianae and common strain suggested that naringenin might be a highly efficient potential biogenic antimicrobial agent to prevent and control soil rhizosphere diseases. Unfortunately, the bioactivity and absorption capacity of active ingredients in the environment made it unsuitable for field application;

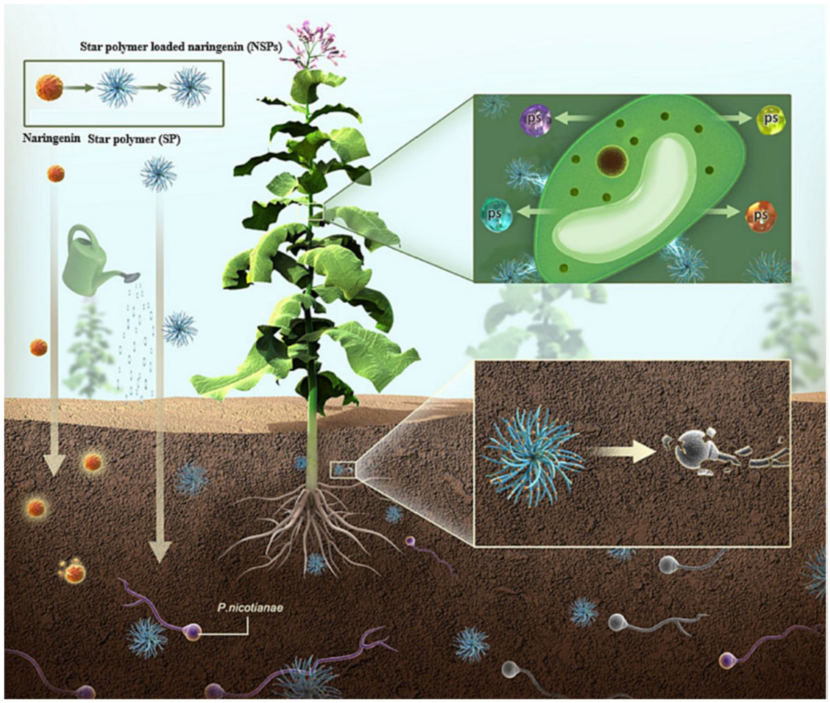



Fig. 1. The diagram of preparation and delivery of naringenin-loaded star polymers (NSPs) to improve the control efficiency of narigenin in soil.

Su 2023, Star polymer soil delivery nanoplatform for applying biological agents in the field to control plant rhizosphere diseases

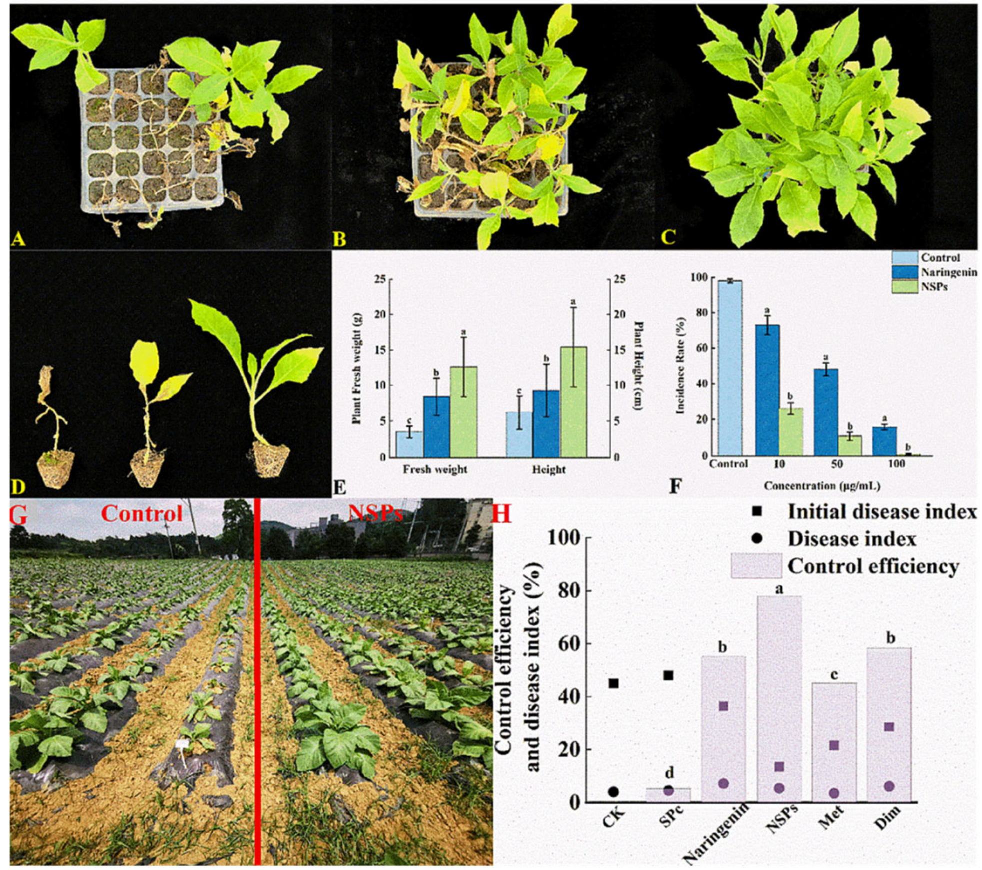
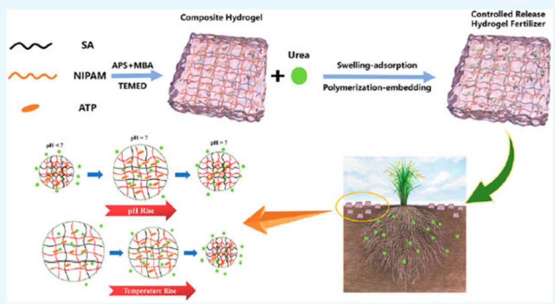


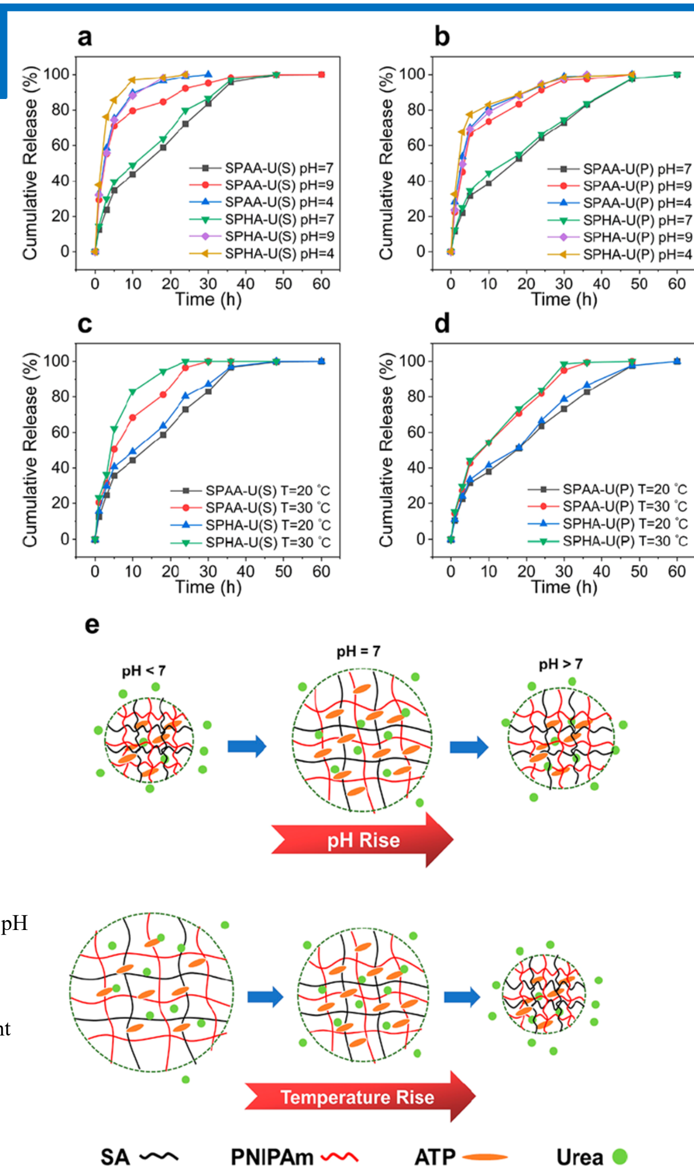

Fig. 8. The pot experiment of control (A), naringenin (B) and NSPs (C), the treated plant comparsion (D), the results of fresh weight and height of plant (E), and the incidence rate of different treatment, the control effect of NSPs to TBS in field (G), and the control efficiency of different pesticides and NSPs (H), bars with the same letters show no significant differences (LSD test, $p < 0.05$).

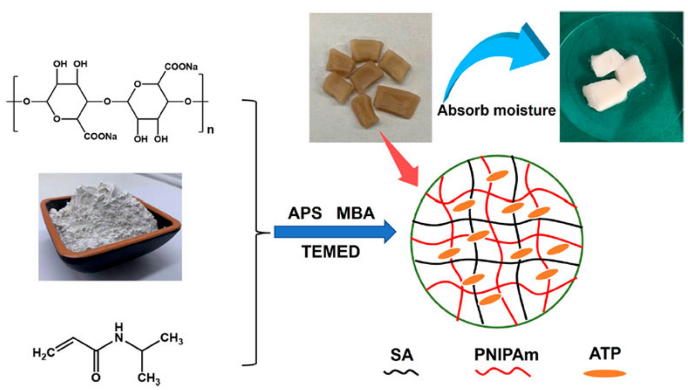
# Environmentally Responsive Green Fertilizer

ABSTRACT: Conventional fertilizers suffer from uncontrollable nutrient release rates and low utilization efficiency, which lead to environmental issues. An environmentally responsive fertilizer that can regulate nutrient release in response to environmental fluctuation is considered an essential component of sustainable agriculture. In this study, composite hydrogels with temperature/pH responsiveness were prepared by using modified attapulgite (ATP) as the inorganic filler and *N*-isopropylacrylamide (NIPAm) and sodium alginate (SA) as the temperature/pH-responsive monomer, and it was used as a carrier of urea to construct the hydrogel fertilizer. The results show that the addition of ATP modified by humic acid and hydrochloric acid to the hydrogel can significantly improve the hydrogel performance, and the hydrogel fertilizers prepared by using these two hydrogels as carriers have excellent environmental responsiveness and slow-release performances. The nutrient release behavior study showed that the hydrogel structure was more easily disrupted, and urea was released more rapidly under acidic and alkaline conditions. The network of the hydrogel collapses and shrinks at 30 °C, while urea was easily released from the hydrogel network. Compared to ordinary urea, the hydrogel fertilizer has an excellent slow-release performance. The environmentally responsive fertilizer would improve nutrient availability and avoid plant root damage and environmental pollution.




KEYWORDS: *hydrogel, controlled release, urea, environmental responsiveness, green agriculture*




ACS APPLIED POLYMER MATERIALS

Figure 7. Cumulative release of nutrient from the (a) swelling−adsorption method and (b) polymerization-embedding method of hydrogel fertilizer under different pH conditions. Cumulative release of nutrient from the (c) swelling−adsorption method and (d) polymerization-embedding method of hydrogel fertilizer under different temperature conditions. (e) Schematic diagram of nutrient release from hydrogel fertilizer at different pH and temperature values.

Attapulgite is a magnesium aluminium phyllosilicate.

Wu 2023, Preparation of an attapulgite-modified composite hydrogel and application in an environmentally responsive green fertilizer

# Environment-Responsive Hydrogel Applications in Agriculture

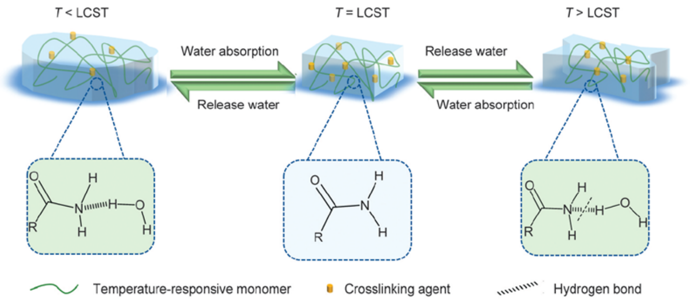



Figure 1. Sensitivity mechanism of thermally shrinkable hydrogels to temperature.

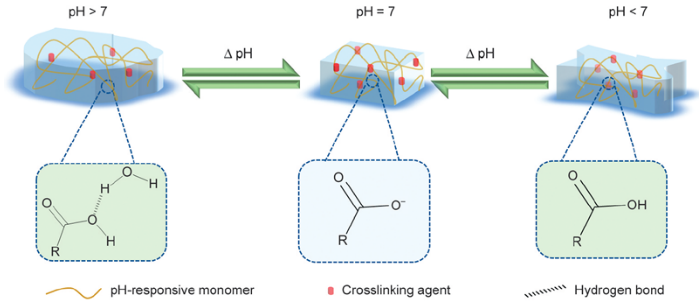



Figure 2. Mechanism of pH sensitivity of pH-responsive hydrogels.

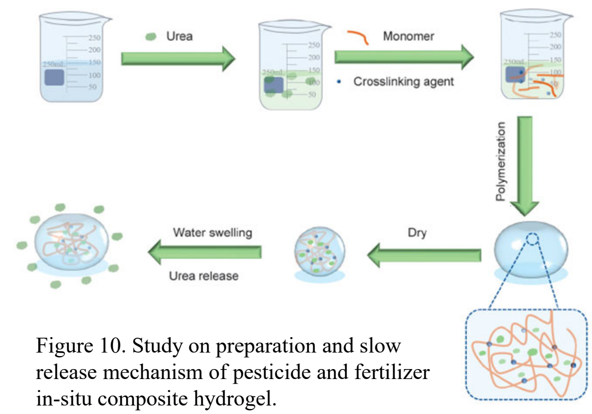



Figure 10. Study on preparation and slow release mechanism of pesticide and fertilizer in-situ composite hydrogel.

**Table 1.** Several common temperature-responsive materials.

| Material | Abbreviation | LCST [°C] | References |
|---|---|---|---|
| Chitosan and its derivatives | CTS | 200 | [31] |
| Polyethylene glycol polymer | PEG | 120 | [32] |
| Polyvinyl alcohol | PVA | 125 | [33] |
| Polydimethylaminoethyl methacrylate | DMAEMA | 42 | [34] |
| Hydroxypropyl cellulose | HPC | 55 | [35] |
| Methylcellulose | MC | 80 | [30] |
| Poly *N*-isopropyl acrylamide | PNIPAAM | 32 | [29] |

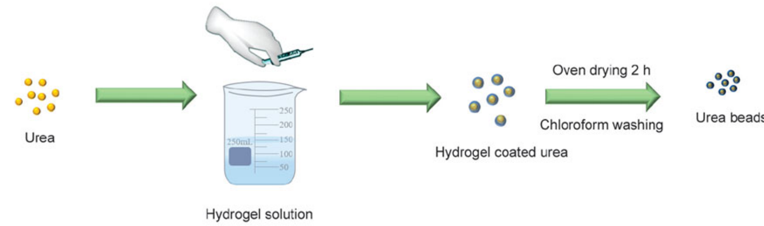



Figure 11. Schematic diagram of the preparation of hydrogel-coated urea.


**Abstract.** Environment-responsive hydrogels are environmentally friendly polymeric materials that rapidly respond to their environment by changing their volume or strength when the external environment, such as temperature, pH, light, and magnetism, changes. As environment-responsive hydrogels, they are uniquely flexible and sensitive, enabling them to be used in various applications, and are now at the forefront of polymer science research. Scholars have reviewed more environment-responsive hydrogels in biomedicine, detection sensors, and drug release. We present a detailed description of the reaction mechanism and preparation process of environment-responsive hydrogels, taking temperature-responsive, pH-responsive, and light-responsive hydrogels as examples. Finally, a summary is given at the end: 1) the application of environmentally responsive hydrogels in agriculture, and 2) the problems and future trends of their application in agriculture.


Zhang 2024, Research progress of environment-responsive hydrogel applications in agriculture

# Social and Environmental Cost of Foods

# Food for People in the World

Thomas Malthus: An Essay on the Principle of Population (1978).
Human populations grow exponentially, while food production grows at an arithmetic rate.

| Current World Population | Current World Population |
|---|---|
| 7,924,803,105 | 8,090,778,057 |
| February 3, 2022 | February 11, 2024 |

https://www.worldometers.info/world-population/

**2016 World Hunger and Poverty Facts and Statistics**

This fact sheet is divided into the following sections:

- Hunger concepts and definitions
- Number of hungry people in the world
- Progress in reducing the number of hungry people
- Children and hunger
- Micronutrients
- Does the world produce enough food to feed everyone?
- Causes of hunger

http://www.worldhunger.org/2015-world-hunger-and-poverty-facts-and-statistics/

**We Already Grow Enough Food For 10 Billion People — and Still Can't End Hunger**

The world already produces more than 1.5 times enough food to feed everyone on the planet. That's enough to feed 10 billion people, the population peak we expect by 2050. But the people making less than $2 a day — most of whom are resource-poor farmers cultivating unviably small plots of land — can't afford to buy this food.

In reality, the bulk of industrially-produced grain crops goes to biofuels and confined animal feedlots rather than food for the 1 billion hungry. The call to double food production by 2050 only applies if we continue to prioritize the growing population of livestock and automobiles over hungry people.

Can conventional agriculture provide the yields we need to feed 10 billion people by 2050? Given climate change, the answer is an unsustainable "maybe." The question is, at what social and environmental cost? To end hunger we must end poverty and inequality. For this challenge, agroecological approaches and structural reforms that ensure that resource-poor farmers have the land and resources they need for sustainable livelihoods are the best way forward.

http://www.huffingtonpost.com/eric-holt-gimenez/world-hunger_b_1463429.html

# McDonald's French Fries


# Fishery & Fishing Industry: Seaspiracy


Seaspiracy. Netflix

# Livestock Industry: Cowspiracy


Cowspiracy. Netflix

# Eggs: Enriched Cage, Cage-Free, Free Range, and Pasture-Raised


**What are the differences between cage-free, free-range, and pasture-raised eggs?**

"Cage-free," "pasture-raised," and "free-range" describe different methods of egg production. Essentially, these terms refer to the differing levels of animal welfare standards farmers use on their farms. There are no solid definitions of what constitutes cage, cage-free, free-range, or pasture-raised eggs. Often, certification programs offer the best indication of how farmers keep their hens, but there are several certification programs that they can apply to.

Cage eggs
Conventional cages tend to have a sloped floor and house between three and eight birds.

Enriched cages
Enriched, or furnished, cages have additional features, such as perches, nesting boxes, or scratching areas. These cages vary in size but can sometimes hold up to 60 birds.

Cage-free eggs
Cage-free hens can move freely both horizontally and vertically, but they may not have access to outdoor areas.

Free-range eggs
Many egg cartons carry the "free-range" label. The main difference between cage-free and free-range eggs is that the latter come from hens that, in addition to the extra space that cage-free birds have, can also access some form of outside area. However, there are no uniform standards regarding how long they are outside for or what the outside space is like.

Pasture-raised
Hens that produce pasture-raised eggs have regular access to a large outdoor space that is covered in grass or other vegetation. This is the pasture. There are various definitions of constitutes pasture-raised eggs.

Summary
Cage, cage-free, free-range, and pasture-raised are four different egg production methods. Hens that produce cage eggs are kept in cages, while cage-free hens have much more space but no access to outside areas. Hens that produce free-range eggs have some form of access to outside spaces, though the specifics depend on the certification program. Hens that lay pasture-raised eggs have regular access to vegetation-covered outside space, but again, the specifics will depend on the certification program.

https://www.medicalnewstoday.com/articles/327383
Marengo 2019, What are the differences between cage-free, free-range, and pasture-raised eggs

# Sustainable Future Protein Production


Figure 1. **External forces**, such as population growth and dynamics in the face of climate change, are leading to consumer concerns over the impact of their diet on the planet, their own health, and animal welfare. Consumers are increasingly making discerning choices looking for tasty, convenient, affordable, natural, clean label, nutritious products with verifiable credentials. Protein industries face a range of challenges from social license and consumer acceptance to research translation/ adoption to scaled production. To address the forces, drivers, and desires, **sustainable solutions**, such as nutritionally optimized foods, innovative food manufacturing, novel protein production systems, and co-product valorization and/or waste utilization must be implemented.

An increasing world population, rising affluence, urbanization, and changing eating habits are all contributing to the diversification of protein production. Protein is a building block of life and is an essential part of a healthy diet, providing amino acids for growth and repair.

**Animal protein**

Livestock-Derived Protein: Meat, eggs, and dairy
Aquaculture-Derived Protein

**Plant Protein**

**Marine protein**

Algae, seaweed

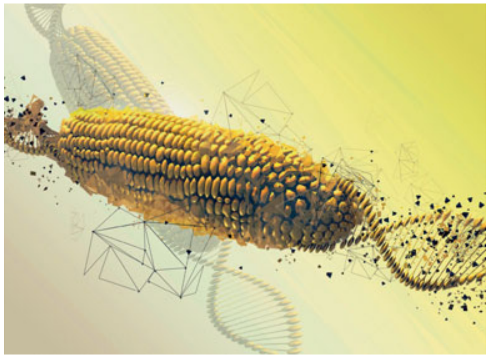
**Food waste and Insects**

**Protein from fermentation**

Colgrave 2021, Perspectives on future protein production

# Genetically Modified Food

Explore the production of human-made food perfection that takes place in science labs. (Ailsa Harvey: How It Works.  Issue 134, 2020).



A gene gun is used to alter the DNA of corn cells (Jurvetson/Flickr)

The majority of what we eat has been sourced from farms and factories which breed and produce especially for the food industry. For centuries humans have been manipulating the outcome and appeal of food sources by changing traits. Selecting the ideal features, people have systematically created many combinations of favourable features in food that would not naturally have occurred.

**Genetic modification is one way of ensuring our food has the desired outcome, in a precise and scientific procedure**. Previous selective breeding methods relied on luck in some parts of the process, but for this more advanced technique, an organism's DNA structure is cut and modified in a more direct act. This closely controls the outcome and standard of produce.

In order to grow food that is best suited to its environment while incorporating the best traits, scientists look to naturally thriving organisms. Taking the advantageous aspects of their DNA, these are incorporated into mass food production and the creation of crop perfection. Experimenting with new varieties, genetically engineered foods can increase flavour and nutrition, while also protecting the organism against disease. Created in laboratories, scientists play with the combinations of genes in various food sources for an end result that is superior to natural qualities.

But are there any negative impacts of food produced in this way? Over the years many have raised concerns over whether growth and consumption of these foods are bad for our health and that of the environment. Altering nature's course can introduce beneficial aspects to each food source, but it is also important to acknowledge where the method could have downfalls. Some believe modified foods could increase the likelihood of allergic reactions in those who eat them, as well as justifying the creation of more toxic herbicides and pesticides by chemical companies to be used on resistant crops.

# Genetically Modified Foods

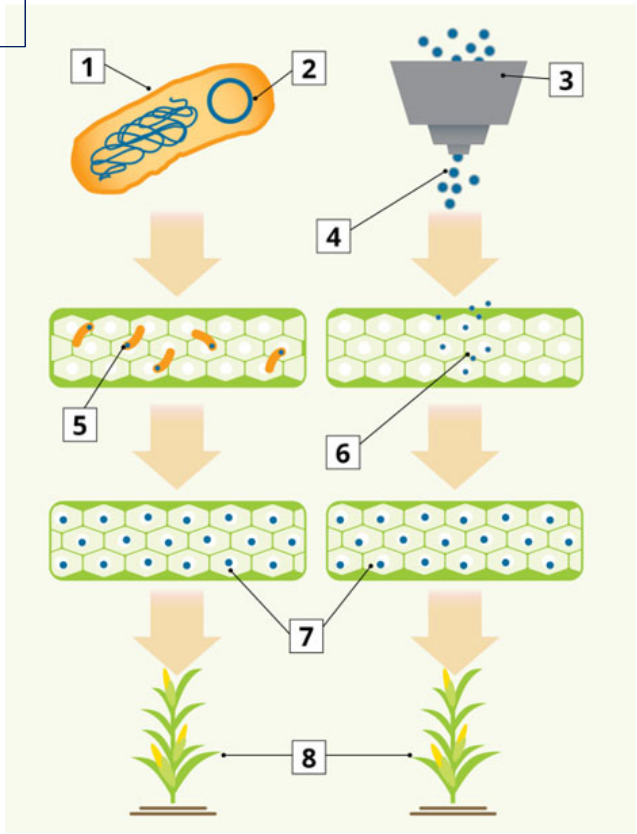
## Future food

**DID YOU KNOW?**
The first-ever genetically modified food was the 'Flavr Savr' long-life tomato in 1994

Crops such as wheat and soybeans could be engineered to close pores where water is lost.

Beginning only as a way to enhance the value of plants, genetic modification techniques are now being explored within the animal food industry. The first animal genetically edited for food quality was salmon. These fish were modified in Canada to adopt the ability to reach full size in only 18 months - half the time it would usually take – while being fed less. The next steps in genetic modification could be more radical. Pigs and chickens are being worked on to create disease-resistant animals alongside dairy cows without horns and sheep with the ability to produce more offspring.
In terms of crops, being able to grow food that is resistant to harsh environments may be a saviour in preventing famine. Some areas of the globe struggle with an extreme lack of rainfall during their driest seasons, suffering from droughts that hinder their ability to provide food. With climate change likely to only exacerbate these conditions, scientists worldwide are experimenting with the development of drought-tolerant crops in preparation.

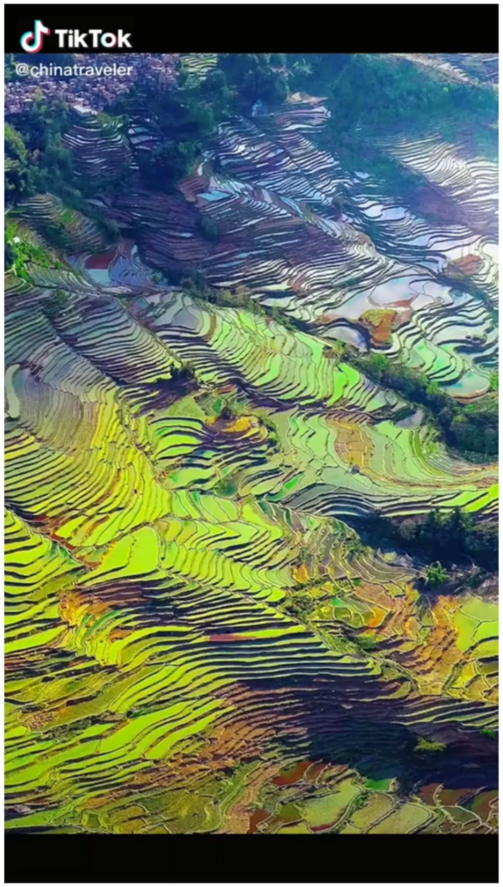
## Forced evolution:
How favourable genes are passed into plants




1. **Beneficial bacteria**
   In one method, some bacteria and viruses are used. They transfer their DNA into host cells as part of their usual cycle. Most commonly the bacteria Agrobacterium tumefaciens is used.
2. **Gene transferral**
   The desired gene is put into the bacterial cell. To ensure it is accepted, bacteria are shocked with either electricity or heat.
3. **Gun precision**
   Gene guns are often used to alter plant genomes. These precise guns are filled with DNA-coated metal particles.
4. **Dense bullets**
   Metal is used to increase the density and allow particles to penetrate plant cells. Using metal means that less DNA needs to be used in each shot – only a thin coating.
5. **Entering the plant**
   The bacteria take their newly acquired genes into the plants' cells.
6. **Forceful firing**
   The particles bombard the plant cells as they are fired into the tissue. Any cells that have been successfully targeted now have the genetic trait incorporated within their DNA.
7. **Embedded genes**
   Some of the plants' cells successfully take up the newly introduced DNA.
8. **New plant**
   The cells that now have the chosen DNA are used to grow new varieties of plant. Each plant cell has the capacity to individually create an entire new plant.

# Alternative Ways of Farming

# The Land for Farming is Limited



# Rethink How We Make Food

https://time.com/collection/davos-2020/5764621/rethinking-food-environment/

## Dinner As We Know it Is Hurting the Planet. But What If We Radically Rethink How We Make Food? (By Alana Semuels)


Farmers have grown food in roughly the same way for thousands of years: planting seeds and watching them grow; raising animals from birth to slaughter; hoping that nature provides them the right amounts of rain and sun. Now, entrepreneurs say they have a better idea. Agriculture in its current form is bad for the planet, they say—fields for crops and animal grazing occupy land where trees could be planted, and farming sucks up vast amounts of increasingly precious water. Why not make food in a completely different way, maybe growing lettuce in skyscrapers and creating meat from cells in a petri dish? There is a dire need to change how food is produced. An August U.N. report prepared by more than 100 experts warned that exploitation of land and water is already putting pressure on humanity's ability to feed itself. Those pressures will grow as the world's population reaches 9.7 billion by 2050 and as high temperatures and floods make it more difficult to grow crops in some regions. That's why -mission-driven entrepreneurs and funders see food tech as the ultimate investment opportunity, making money while also creating food that makes the planet a better place.

Consumers seem to be in no hurry to change their food habits, despite climate concerns. More than a decade ago, after a U.N. report found that **farmed animals produced 35% to 40% of all methane emissions**, newspapers including the Baltimore Sun encouraged consumers to "save the planet with a vegetarian diet." But despite a plethora of other reports since then suggesting that eating meat contributes to climate change, meat consumption has climbed and is at an all-time high in the U.S. Global meat consumption rose by an average of 1.9% a year in the decade leading up to 2017, about twice as fast as population growth.

The money poured into food startups may just reflect wishful thinking on the part of investors who want to do something about the climate, even if consumers won't follow. "The idea that new tech can fix a major problem that threatens the life of your grandchild is very tempting," says Benjamin Aldes Wurgaft, the author of Meat Planet, a book about the future of food. "People hate to feel disempowered—they always want to have a lever to pull."

The August U.N. report put a number on just how much the agricultural system contributes to climate change. **From 21% to 37% of greenhouse-gas emissions caused by humans derive from agriculture and food processing**, according to the report. Using land in different ways, like planting more trees instead of grazing cattle, can help mitigate climate change, said Cynthia Rosenzweig, a senior research scientist at the NASA Goddard Institute for Space Studies and one of the authors of the report. But as the world's population grows, trees are instead being cut down to grow crops. "There's the potential for real competition between mitigating climate change and ensuring food security," she said.

# Hydroponics

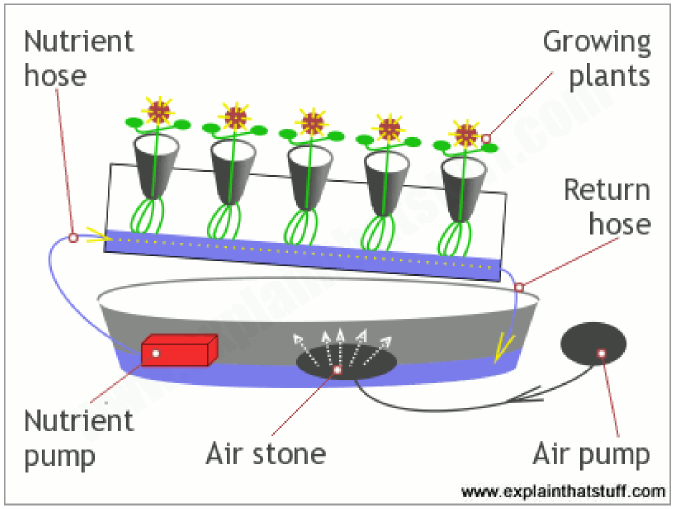
Hydroponic: Growing plants in water (from two Greek words meaning "water" and "toil"). Because you can grow plants without actually standing them in water, most people define the word to mean growing plants without using soil.

Although the benefits of hydroponics have sometimes been questioned, there seem to be many advantages in growing without soil. Some hydroponic growers have found they get yields many times greater when they switch from conventional methods. Because hydroponically grown plants dip their roots directly into nutrient-rich solutions, they get what they need much more easily than plants growing in soil, so they need much smaller root systems and can divert more energy into leaf and stem growth. With smaller roots, you can grow more plants in the same area and get more yield from the same amount of ground (which is particularly good news if you're growing in a limited area like a greenhouse or on a balcony or window-ledge inside). Hydroponic plants also grow faster. Many pests are carried in soil, so doing without it generally gives you a more hygienic growing system with fewer problems of disease. Since hydroponics is ideal for indoor growing, you can use it to grow plants all year round. Automated systems controlled by timers and computers make the whole thing a breeze.

It's not all good news; inevitably there are a few drawbacks. One is the cost of all the equipment you need—containers, pumps, lights, nutrients, and so on. Another drawback is the ponic part of hydroponics: there's a certain amount of toil involved. With conventional growing, you can sometimes be quite cavalier about how you treat plants and, if weather and other conditions are on your side, your plants will still thrive. But hydroponics is more scientific and the plants are much more under your control. You need to check them constantly to make sure they're growing in exactly the conditions they need (though automated systems, such as lighting timers, make things quite a bit easier). Another difference (arguably less of a drawback) is that, because hydroponic plants have much smaller root systems, they can't always support themselves very well. Heavy fruiting plants may need quite elaborate forms of support.

https://www.explainthatstuff.com/hydroponics.html

Onions, lettuces, and radishes all grow well with hydroponics. The white surface of hydroponic containers like these helps to reflect light evenly onto the plant leaves, improving growth. Photo by courtesy of NASA Kennedy Space Center (NASA-KSC).



# Hoosier Hydroponic Farm

## Hoosier grows 5 acres of food in only 80 feet

London Gibson Indianapolis Star
USA TODAY NETWORK

DeMario Vitalis, urban farmer, moves large panels of LED lights in between rows of vegetables, Friday, March 26, 2021, in Indianapolis. GRACE HOLLARS/INDYSTAR

An unassuming plot of land sits on the east side of Indianapolis on 30th Street. From the outside, it looks like an empty lot with a couple of shipping containers on it. But inside those containers is an entire garden.

And among the plants, you can find DeMario Vitalis.

Vitalis was the first in Indiana to own this type of hydroponic farm inside of a shipping container. The unique method involves planting seedlings of plants such as herbs and lettuces on vertical panels and feeding them controlled levels of water, nutrients and light – no soil required.

It's a mode of farming uniquely suited for urban environments. Vitalis is able to produce almost 5 acres of food a year from two 40-foot shipping containers. It also uses 99% less water than traditional farming, according to the company that makes the containers.

Vitalis sells his fresh herbs, lettuces and more to people in the community through online platforms such as Market Wagon.

The climate control is a huge advantage for Vitalis, who set up his farm, called New Age Provisions, in the latter half of last year. Regardless of the outside weather, he can grow anything he wants.

"It can be 30 degrees outside and raining," he said, "but inside it's 65 degrees. In here I'm watching Netflix and planting seeds."

Even though he now spends much of his time dedicated to plants, Vitalis wasn't a farmer when he started all of this. He was just an entrepreneur looking for his next project, and farming – which connected to his history as a descendent of enslaved people and Southern sharecroppers – felt like the right choice.

**'It's in his blood'**

Vitalis was looking for something that would put a piece of property he owned to use, and he had a hunch shipping containers were key.

At first, he thought he would set up some modular tiny homes built out of containers. But then he came across Freight Farms, a Boston-based company that could cram 2.5 acres of production into one shipping container, and the decision was made.

Although born in San Francisco, Vitalis' family is originally from the South, and he moved around quite a bit before settling in Indiana.

"Three of my four grandparents started off from the South," Vitalis said, "so we were part of that Black migration when we moved eventually from the South to San Francisco on the West Coast."

After living in Germany, Kansas and other places as his stepfather moved around with the military, Vitalis' mother decided to move him to Indianapolis, where he stayed and attended Arlington High School and Purdue University.

Vitalis' mother, Barbara Johnson, is a cook, so food has always been important to the family. And the herbs and vegetables grown by her son, she said, are "absolutely wonderful."

"I just believe that you can always inspire a person with a good meal," she said.

Even so, farming or food production was never anything they did at home, she said. But she knows it's something he feels close to because of the family's history.

"I guess it was just in his blood," she said.

Vitalis was one of the first Black owners using a Freight Farms shipping container to start a small business in the country, said Caroline Katsiroubas, marketing and communications director for the company.

**Overcoming learning, funding hurdles**

It wasn't easy learning how to grow food.

Despite two degrees from Purdue University and a master's degree from Wayne State University, Vitalis doesn't have a background in farming, and had to put himself through some education before diving into his urban farm. He took online classes and even visited Freight Farms in Boston to learn about the equipment and process.

"It does take a learning curve," he said.

Sometimes his daughter will help him with the planting. Johnson, too, will help out and trim plants, clean or help with planting, and occasionally brings her grandson along. Understanding how the farm works was a learning curve for her, too. "I didn't know anything about hydroponic farming," she said. "When I saw that wall of plants, I didn't think it was possible."

Funding was another obstacle. The farms cost $100,000 each.

After some research, Vitalis found that the U.S. Department of Agriculture will supply loans for these types of businesses, so he requested $50,000 to help him pay for one container and was promptly denied.

The people evaluating the profitability of these containers simply didn't understand how it worked or how much it could produce, he said. But instead of giving up, he pushed back. Black farmers have historically been discriminated against when trying to obtain USDA loans, and he was motivated to make sure his business plan was being fairly evaluated.

"There's a history behind that," he said. "I was just one of many." Vitalis appealed the decision and won. Then, he turned around and asked for $200,000 instead – and got it. Finally one day, a semi-trailer pulled up outside his property with the containers, picked them up with a huge crane and plopped them right down behind the nearby building.

JCONLINE.COM. Sunday, May 16, 2021. 3A

Hoosier grows 5 acres of food in only 80 feet. London Gibson Indianapolis Star USA TODAY NETWORK

An unassuming plot of land sits on the east side of Indianapolis on 30th Street. From the outside, it looks like an empty lot with a couple of shipping containers on it. But inside those containers is an entire garden. And among the plants, you can find DeMario Vitalis. Vitalis was the first in Indiana to own this type of hydroponic farm inside of a shipping container. The unique method involves planting seedlings of plants such as herbs and lettuces on vertical panels and feeding them controlled levels of water, nutrients and light – no soil required. It's a mode of farming uniquely suited for urban environments. Vitalis is able to produce almost 5 acres of food a year from two 40-foot shipping containers. It also uses 99% less water than traditional farming, according to the company that makes the containers. Vitalis sells his fresh herbs, lettuces and more to people in the community through online platforms such as Market Wagon. The climate control is a huge advantage for Vitalis, who set up his farm, called New Age Provisions, in the latter half of last year. Regardless of the outside weather, he can grow anything he wants. "It can be 30 degrees outside and raining," he said, "but inside it's 65 degrees. In here I'm watching Netflix and planting seeds." Even though he now spends much of his time dedicated to plants, Vitalis wasn't a farmer when he started all of this. He was just an entrepreneur looking for his next project, and farming – which connected to his history as a descendent of enslaved people and Southern sharecroppers – felt like the right choice.

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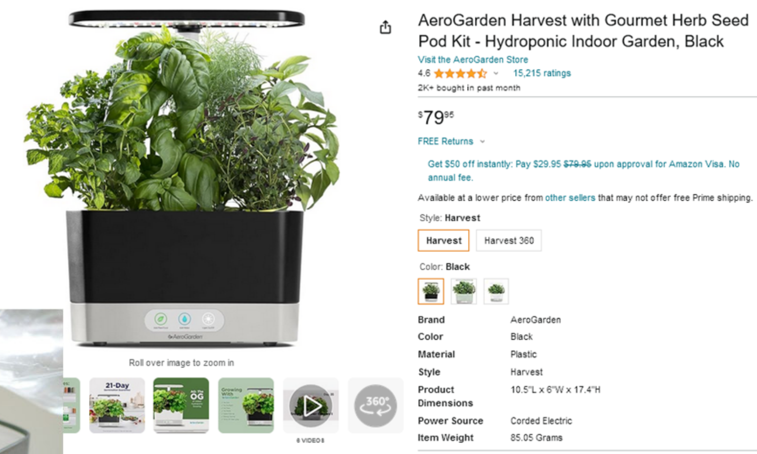
# Hoosier Hydroponic Farm

IT ALL STARTED WITH A NEED....

Hoosier Growers was started to provide vegetables year around to those in Indiana and has grown from there. We noticed there was a large gap in Indiana for year around produce.
We also wanted to provide these greens at the most sustainable way we knew how - Hydroponics.

Hydroponic Vegetables

Bibb Lettuce. Romaine Lettuce. Loose Leaf Lettuce Mix. Swiss Chard. Lettuce. Cabbage. Spinach. (Seasonally).
Vegetables grown in this manner conserve water, are less susceptible to diseases, and grow much quicker. This allows us to proved a stronger, healthier vegetable.





Mushrooms
Shiitake. Grey Oyster, Chestnut.
Our mushrooms are grown in a controlled environment which allows us to maintain their high quality and ensure a long shelf life. Mushrooms are grown from an organic growing medium block inoculated with the associated strain of fungi. This process allows us to provide a high quality and great tasting mushroom, in fact it's what we strive for.

https://localfarmsharvest.com/hoosier-growers


INDOOR GARDENING MADE EASY: Enjoy abundant harvests year round with the AeroGarden Harvest, an indoor hydroponic gardening system that grows your favorite vegetables, herbs, or flowers in water without the mess of soil

ROOM FOR 6 PLANTS: This compact countertop garden features a spacious grow deck and water bowl so you can grow 6 different live plants at once, all up to 12 inches tall

HIGH-PERFORMANCE GROW LIGHT: The full spectrum 20W LED grow light with an automatic on/off timer mimics natural sunlight to help plants germinate up to 5x faster than in soil

FEATURES AND BENEFITS: Our indoor garden's touch-sensitive illuminated control panel reminds you when to add water and plant food, making for a simplified, worry-free gardening experience

WHAT'S INCLUDED: The AeroGarden Harvest comes with a 20W LED grow light system, power adapter, one 3 oz. bottle of liquid plant food, and the Gourmet Herb Seed Pod Kit featuring Genovese Basil, Curly Parsley, Dill, Thyme, Thai Basil, and Mint

https://www.amazon.com/stores/AeroGarden/page/1C957391-DD17-4684-B4E7-94CFD437E4B2?ref_=ast_bln

# Aeroponic: How to Grow Food in Space

**At a remote outpost in Antarctica, scientists are growing vegetables**
Today's astronauts have to exist largely on pre-packed meals, with fresh fruit and veg being a rare treat. But indoor farming technologies are advancing, and the race is on to find effective ways to grow food in space – both for long-duration missions, and for future settlements on the Moon or Mars. So where's the best place to test these technologies? The bottom of the world, it turns out. At the Alfred Wegener Institute's Neumayer III station in Antarctica – a German base for polar research – scientists have created a standalone greenhouse as part of a project called EDEN ISS, which develops food production techniques for the International Space Station (ISS) and future human space colonies. Here, researchers are already seeing the fruits, or at least vegetables, of their labour.
The cultivation process at EDEN ISS is **aeroponic – a soilless system where the crops absorb nutrients from a water mist applied at the roots**. The vegetables are grown in vertical racks, giving a total growing area in the greenhouse of 12.5 square metres, with the roots exposed in plant growth trays.

Everything in the greenhouse can be regulated remotely from mission control at the German Aerospace Centre in Bremen, except, notes Schubert, seeding, harvesting and cleaning up – these have to be done by hand. Here, horticultural engineer Markus Dorn (above) prepares the seed trays using blocks of rock wool soaked in nutrient solution. **Rock wool, which is made by spinning molten rock into fibre, has a candy floss-like texture that holds onto water and helps stabilise roots.** The seeds will germinate in the seed trays for about two weeks before being transferred to the vertical racks.

Hayley Bennett - Hayley is a science writer based in Bristol, UK. BBC Science Focus Magazine. Christmas 2019

**Largest US Indoor Vertical Aeroponic Farm Plants Roots in Indiana**

Munice, Indiana — Living Greens Farm, the largest indoor vertical aeroponic farm in the U.S., announced plans to locate operations in Delaware County, creating up to 120 new jobs by the end of 2024.

"Indiana's central location, strong agriculture sector and business-friendly climate make the Hoosier state the perfect place for companies like Living Greens Farm to put down roots," said Governor Eric J. Holcomb. "As a state, we're committed to creating an environment that enables companies like Living Greens Farm to scale operations, while continuing to innovate and grow agtech solutions geared toward a 21st century economy."

https://www.expansionsolutionsmagazine.com/vertical-aeroponic-farm-indiana/

# Vertical Farming

https://time.com/collection/davos-2020/5764621/rethinking-food-environment/

## Dinner As We Know it Is Hurting the Planet. But What If We Radically Rethink How We Make Food? (By Alana Semuels)

Plenty grows leafy greens year-round in a fully automated farm in South San Francisco. Courtesy Spencer Lowell—Plenty

Leafy greens grow under LED lights in an indoor vertical farm run by Aerofarms Courtesy Aero Farms

Startups are thinking beyond meat too. Indoor-agriculture companies such as Plenty in California and AeroFarms in New Jersey, which grow food in tightly packed towers called vertical farms, have together raised more than $300 million. A competitor, Crop One, is partnering with Emirates Flight Catering to build a 130,000-sq.-ft. vertical farm in Dubai, which will be the world's largest.

**Vertical farms are expensive to run because they have to use power to provide the one thing that's free in traditional farming: light from the sun.**

Scaling obstacles also exist in vertical farming, and two vertical-farming startups already went out of business in 2016 and 2017. Plants need a tremendous amount of **light to photosynthesize**, about 50 times more than humans need to see, says Neil Mattson, a professor of plant science at Cornell University who is conducting a large-scale study of vertical farms. Vertical farms use LED lights to grow plants, and though the costs of LED lights have fallen significantly in recent years, lettuce grown in vertical farms in New York and Chicago was **twice as expensive** as lettuce grown in the California fields and shipped to those cities, according to a study co-authored by Mattson. Labor was costlier in New York and Chicago, and the structures that housed the vertical farms were expensive to build and maintain. Vertical-farm companies are experimenting with using solar and wind power to reduce their energy bills, but Mattson believes vertical farms will be cost-effective only when renewable-energy prices fall.

# AeroFarms Vertical Farming


Millions of people around the globe suffer from food insecurity, and experts say that number could increase as the climate changes. The founders of AeroFarms say its technology, which includes a technique for indoor farming that uses 95% less water than field farming, can help. A key advance to the company's patented technology is a new growing medium: rather than grow in dirt, these crops grow in a reusable cloth made from recycled water bottles. Instead of being doused with water, the crops are hydrated with a gentle mist. AeroFarms has already produced crops like kale and arugula at scale, selling to big grocery chains, restaurant providers and, beginning this year, even an airline. "We're the only commercial grower in the world doing what we're doing," says co-founder Marc Oshima. —Justin Worland

https://time.com/collection/best-inventions-2019/5733085/aerofarms/

# Vertical Farming

**Is the future of farming underground?**
How an old freeway tunnel in South Korea might hold the answers to sustainable food production in the face of the climate crisis. Fruits and vegetables grow hydroponically - with no soil - in vertically stacked layers inside, illuminated by neon-pink LEDs instead of sunlight.




https://apnews.com/4b5d3e22448d4db6bce4aea19b53f32e/As-temperatures-rise,-farmers-plant-crops-in-S.Korean-tunnel
https://learningenglish.voanews.com/a/south-korean-smart-farm-built-inside-former-road-tunnel/4552507.html
https://www.cnn.com/videos/world/2019/11/22/vertical-tunnel-farming-south-korea-lon-orig-c2e.cnn

# Vertical Farming

**This vertical farm is growing food - but it's for cows.**

We use an exceptional amount of land to grow food for cows.

Vertical farms could change that, if we used them to grow cow feed.

https://www.fastcompany.com/90573086/this-vertical-farm-is-growing-food-but-its-for-cows?partner=rss&utm_campaign=rss+fastcompany&utm_content=rss&utm_medium=feed&utm_source=rss

# Vertical Farming: LED Lighting

## New LED strategies could make vertical farming more productive, less costly


https://www.purdue.edu/newsroom/releases/2023/Q1/new-led-strategies-could-make-vertical-farming-more-productive,-less-costly.html

WEST LAFAYETTE, Ind. — Purdue University researchers have designed two simple LED lighting strategies to increase yield and reduce energy costs for the vertical farming sector of indoor agriculture.

The close-canopy and focused-lighting strategies developed by PhD candidate Fatemeh Sheibani and professor Cary Mitchell, both in the Department of Horticulture and Landscape Architecture in Purdue's College of Agriculture, capitalize on LED lighting's special properties.

"One is that they are relatively cool at the emitting surface, in contrast with other lighting choices," Sheibani said. Thus, the lighting system works closer to plants without scorching them. LEDs are also current driven, unlike many energy-intensive, voltage-driven lighting sources.

Their work is part of a project called OptimIA (Optimizing Indoor Agriculture). The project, led by Michigan State University, includes collaborators at Purdue, University of Arizona and Ohio State University. OptimIA is sponsored by the U.S. Department of Agriculture's Specialty Crop Research Initiative.

Fatemeh Sheibani, a PhD candidate in horticulture and landscape architecture, examines lettuce plants in a controlled environment chamber using LED lighting. Sheibani's research focuses on finding the best strategy for using LEDs in vertical farming that will maximize crop yield and decrease production costs associated with lighting. (Purdue Agricultural Communications photo/Jessica Kerkoff)

Michael Gildersleeve, a graduate student in Purdue's Department of Horticulture and Landscape Architecture, works with lettuce plants grown under close-canopy LED lighting to maximize energy efficiency and crop yield. (Purdue Agricultural Communications photo/Tom Campbell)

# Alternative Ways of Making Foods

# Feeding A Changing World

TIME, February 3, 2020

Dinner as we've known it takes a toll on the planet. As businesses invest in making meat without animals and crops without soil, the question is whether consumers will buy in. (Alan Semuels)


*Leafy greens grow under LED lights in an indoor vertical farm run by AeroFarms*

*At an indoor farm owned by Crop One, seeds placed in trays will be grown into leafy greens using hydroponics*

## Plant-Based Meat

**Beyond Meat** uses sources including peas, mung beans, fava beans, brown rice and sunflower to create plant-based sausages, burgers and meat crumbles; the company rolled out a breakfast sausage at Dunkin' in 2019 and now sells food at 67,000 stores in 50 countries

## Meal Replacement

**Huel** makes powders and drinks that it says are nutritionally equivalent to a meal and that contain 27 essential vitamins and minerals, as well as carbohydrates, protein, fat, fiber and phytonutrients; it's sold more than 50 million meals in 80 countries

Odontella combined algae and microalgae into a substance with the texture and flavor of salmon, then wood-smokes it to create a vegan product called Samon. After selling at vegan grocery stores in Europe, it is now scaling up production to expand to restaurants globally in 2020.

## Protein From Thin Air

Solar Foods uses microbial fermentation — a process similar to producing yeast — to grow a protein resembling wheat flour from water, nutrients and carbon dioxide. Courtesy Solar Foods

# Sustainable Versions of Meat and Dairy Products

The Economist. March 7th, 2015

**Silicon Valley gets a taste for food Tech startups are moving into the food business to make sustainable versions of meat and dairy products from plants**

A PLANT-BASED hamburger patty that bleeds. Meatless chicken strips with the same fleshy and fibrous texture as cooked poultry. Mayonnaise made without eggs that is creamy and smooth. And a vegan beverage that contain all the ingredients for human sustenance, making it unnecessary to bother eating ordinary food every again. Hungry yet?

These are the offerings from a recent crop of Silicon Valley-funded startups which are trying to change the way people eat. The idea of making such products is attracting entrepreneurs and venture-capital firms who think that the traditional food industry is ripe for disruption because it is inefficient, inhumane and in need of an overhaul. The companies have different approaches, but they share the ambition of creating new plant-based food that they say will be healthier, cheaper and just as satisfying as meat, egg, dairy and other animal-based products- but with a much lower environmental impact.

"Animal farming is absurdly destructive and completely unsustainable. Yet the demand for meat and dairy products is going up," says Patrick Brown, founder of one such startup, **Impossible Foods**, based in Redwood City in the heart of Silicon Valley. It has raised $75m to develop plant-based meat and cheese imitations.

According to the United Nations, livestock uses around 30% of the world's ice-free landmass and produces 14.5% of all greenhouse-gas emissions. Making meat also requires supplying animals with vast amounts of water and food: in the United States producing 1kg of live animal weight typically requires 10kg of feed for beef, 5kg for pork and 2.5kg for poultry. Yet between now and 2050, the world's population is expected to rise from 7.2 billion to over 9 billion people- and the appetite for meat to grow along with it. To keep up with demand, food production will need to increase significantly.

**It is a big challenge, but also an economic opportunity.** "Anytime you can find a way to use plant protein instead of animal protein there's an enormous efficiency in terms of the energy, water and all sorts of other inputs involved- which translates at the end of the day to saving money," says Ali Partovi, a San Francisco-based entrepreneur and investor in tech startups, such as Dropbox and Airbnb, as well as half-a-dozen sustainable-food companies.

The problem is many people shun vegetables and prefer to eat meat or dairy products. Dr Brown and others think **the solution is to mimic the taste of meat and other animal-derived foods with plants** and take the animal out of the equation. In theory at least, there would be plenty of food for everyone and fewer resources needed to produce it. "We're reinventing the Technology Quarterly entire system of transforming plants into meat and milk," he says. Other startups have similar aspirations. **Beyond Meat,** which makes plant-based chicken strips and beef "crumbles", is already selling its products in stores. As is **Hampton Creek**, whose eggless mayonnaise has become a bestseller at Whole Foods Market, a big American chain.

**Beyond vegetarianism**

Of course, the food giants already offer a variety of meat and dairy alternatives that many vegetarians and vegans buy. What is different with this new approach is that the startups are not targeting the small percentage of the population who largely live on a plant-based diet already. They are after people who love meat and dairy products, and that means replicating the meaty, cheesy or creamy flavours and textures that so many people crave. "We want to have a product that a burger lover would say is better than any burger they've ever had," says Dr Brown.

This is also different from "growing" meat in a laboratory using tissue engineering, which involves culturing cells taken from live animals. **Modem Meadow**, a New York company, is working on this technology, although its more immediate aim is to grow unmarked cultured leather.

Introducing a new food category is risky as it takes a lot of time and money. Big food firms prefer to acquire innovative products rather than develop them internally, explains Barb Stuckey, chief innovation officer at Mattson, a California-based food and beverage consultancy which has developed many new products. "It may take someone from outside the food industry to really disrupt it," reckons Ms Stuckey. And Silicon Valley has enough hubris to do so.

The business has already attracted a fair share of famous venture-capital firms and investors, including Kleiner Perkins, Google Ventures, Andreessen Horowitz, Khosla Ventures, Bill Gates and others. "If we can provide [plant-based] food that's healthier, tastes equal to better, at an equal to lower cost, it'll go everywhere," says Khosla's Samir Kaul. If the companies they are backing succeed, the returns could be massive. The US beef industry alone is worth $88 billion. And even for condiments, such as mayonnaise, the market totals $2 billion. Still, not everyone is bullish on the prospects. These are high-risk endeavours and some of them might fail, cautions Michael Burgmaier of Silverwood Partners, an investment bank involved in dozens of food and beverage deals. The question is, he says: "Is the consumer ready for some of these products?"


# Sustainable Versions of Meat and Dairy Products

The Economist. March 7th, 2015

Impossible Foods' Dr Brown thinks they are. The inventor of a DNA chip now widely used in gene-expression analysis, his firm has been developing meat and cheese imitations from plants for three years. For meat, the aim is to recreate its key components- **muscle, connective and fat tissue**- using suitable plant materials. The company's first product, **a hamburger patty**, already looks and cooks like meat, and will taste as good or better by the time it reaches the shops, Dr Brown promises.

To do this he has assembled a team comparable to one at a biotech or pharma company. It is largely made up of molecular biologists and biochemists, as well as some physicists; only a few members of his staff have a background in food science or have culinary training. In the company's laboratory scientists break down plant materials and extract individual proteins with functional properties that can, for example, make foods firm up or melt down during cooking or baking.

The company has also spent a lot of time working out what gives **meat its unique flavour**. According to Dr Brown. the secret to a burger's taste is **haem**, a compound found in all living cells, including plants. It is especially abundant in haemoglobin in blood, and in muscle tissues as myoglobin. It also gives a burger its red colour. During the cooking process haem acts as a catalyst that helps transform the amino acids, vitamins and sugars in muscle tissue into numerous volatile and flavourful molecules, he explains. To create the meaty flavour in its burger patties, the company uses **a heme protein equivalent to one found in the roots of legumes**.

Development of the burger has come a long way. Dr Brown says one person described the taste of the very first prototype as "rancid polenta". Recent versions have been reviewed much more favourably as "better than a turkey burger". In terms of nutrition, the patty's protein content may be slightly higher than that of a conventional burger and have at least as many micronutrients. Because it is made from plants, it will not contain any traces of antibiotics, hormones or cholesterol. The company hopes to start selling the burger before the end of this year.

**Getting the flavour**

Beyond Meat, based in Southern California, has also been studying the components of meat to emulate its texture and flavour. "We're smart enough now to understand the architecture and the composition of a piece of muscle," says Ethan Brown (no relation to Dr Brown), the company's CEO. The firm's flagship product, **Beyond Chicken Strips**, has been on sale since 2012, and has a surprisingly authentic feel when eaten. When several Whole Foods Markets accidentally sold mislabelled chicken salads with the company's plant-based strips there were no complaints. Only when an employee discovered the mix-up after two days were the salads officially recalled. The product's texture is based on years of research at the University of Missouri, and it can now be created in a process that takes less than two minutes. An extruder rapidly heats. cools and pressurises a mixture of proteins and other ingredients into a structure that mimics the fibrous tissue of muscle.

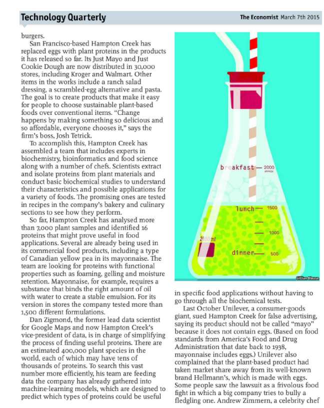
The company's most recent product, **the Beast Burger**, was released last month. It has more protein, more iron and is overall more nutritious than actual meat burgers. "The entire quest for meat in human evolution is really about a nutrient-dense source of food," explains Mr Brown. "I wanted to build on that theme."

But marketing plant-based burgers to carnivores is not easy. "My view is that meat has a masculine bent to it. You can't sell it the same way you sell lettuce," says Mr Brown. Hence the company is building the brand with images of vitality, fitness and health. In promotions it is using athletes. David Wright, captain of the New York Mets baseball team, has already signed up. In return, he is getting a small stake in the company.

Still under development is what may be Beyond Meat's most ambitious product to date- **a raw ground beef equivalent** which it hopes will be offered in supermarkets' meat sections right next to actual beef. Due for release later this year, it can be cooked and moulded into a meatloaf or meatballs-or, as Mr Brown hopes, even supplied to a fast-food chain to make Technology Quarterly burgers.

San Francisco-based Hampton Creek has replaced eggs with plant proteins in the products it has released so far. **Its Just Mayo** and **Just Cookie Dough** are now distributed in 30,000 stores, including Kroger and Walmart. Other items in the works include a ranch salad dressing, a scrambled-egg alternative and pasta. The goal is to create products that make it easy for people to choose sustainable plant-based foods over conventional items. "Change happens by making something so delicious and so affordable, everyone chooses it," says the firm's boss. Josh Tetrick.

To accomplish this, Hampton Creek has assembled a team that includes experts in biochemistry, bioinformatics and food science along with a number of chefs. Scientists extract and isolate proteins from plant materials and conduct basic biochemical studies to understand their characteristics and possible applications for a variety of foods. The promising ones are tested in recipes in the company's bakery and culinary sections to see how they perform.

# Sustainable Versions of Meat and Dairy Products

The Economist. March 7th, 2015

So far, Hampton Creek has analysed more than 7,000 plant samples and identified 16 proteins that might prove useful in food applications. Several are already being used in its commercial food products, including a type of Canadian yellow pea in its mayonnaise. The team are looking for proteins with functional properties such as foaming, gelling and moisture retention. Mayonnaise, for example, requires **a substance that binds the right amount of oil with water to create a stable emulsion**. For its version in stores the company tested more than 1,500 different formulations.

Dan Zigmond, the former lead data scientist for Google Maps and now Hampton Creek's vice-president of data, is in charge of simplifying the process of finding useful proteins. There are an estimated 400,000 plant species in the world, each of which may have tens of thousands of proteins. To search this vast number more efficiently, his team are feeding data the company has already gathered into machine-learning models, which are designed to predict which types of proteins could be useful in specific food applications without having to go through all the biochemical tests.

Last October Unilever, a consumer-goods giant, sued Hampton Creek for false advertising, saying its product should not be called "mayo" because it does not contain eggs. (Based on food standards from America's Food and Drug Administration that date back to 1938, mayonnaise includes eggs.) Unilever also complained that the plant-based product had taken market share away from its well-known brand Hellmann's, which is made with eggs. Some people saw the lawsuit as a frivolous food fight in which a big company tries to bully a fledgling one. Andrew Zimmern, a celebrity chef who had preferred Just Mayo over Hellmann's in a blind taste-test, even started an online petition to urge Unilever to drop the lawsuit. It gathered over 100,000 signatures.

"This was great for Hampton Creek because it got their name out there and people on their side," says Matthew Wong, a research analyst at CB Insights, an analytics firm. Initially Unilever demanded that Hampton Creek rename its product, take existing inventory off the shelves and pay damages. But in December, the company suddenly dropped its lawsuit. It was on the same day that Hampton Creek announced its latest funding round of $90m, bringing its total raised to $120m.

**Hampton Creek** has been successful with the products it already sells. However, it is not trying to build a burger patty from scratch with plants, as Impossible Foods is trying to do, and it has not yet released its scram bled-egg replacement. "It's much easier to make a cookie dough without egg than it is to create a scrambled egg without egg," says Mattson's Ms Stuckey. In a cookie dough or mayonnaise there are plenty of other ingredients to work with. But in creating an egg or meat analogue there is a higher bar in the consumer's mind, she adds, because the product is not combined with other ingredients it can hide behind.

Perhaps the most radical approach to disrupting the food industry comes from **Soylent**, whose beverage is designed to be a complete substitute for food and not just one of the many diet drinks or nutritional supplements. Sold as a powder to be mixed with water, it contains all the ingredients needed for sustenance, says Rob Rhinehart Soylent's founder. It also eliminates the need to plan meals, cook and clean up afterward. "I see it as a life-simplification tool," he says.

The name originates from the sci-fi novel "Make Room! Make Room!" in which people in an overcrowded, apocalyptic world live on foods made of soy and lentils. (A twist in the movie version "Soylent Green" is that its secret ingredient is human flesh.) The company moved from the San Francisco area to Los Angeles in late 2013 in search of cheaper office space.

Some users of the first version of the beverage complained of flatulence because of the high fibre content. That problem has now largely been solved by changing the carbohydrate blend and adding some digestive enzymes. Mr Rhinehart likens the improvements to the continuous updates to software that tech companies make. Soylent 1.3, the most recent version, has a smoother texture than the original, a more neutral taste and its omcga-3s now come from algae as opposed to fish oil.

**Out with the dishes**

Mr Rhinehart himself uses Soylent for about 80% of his dietary needs. As a result he has not made a trip to the grocery store in years. He owns neither a fridge nor dishes. And he has turned his kitchen into a library. "I've also been able to separate the feeling of biological hunger from the craving of food from an experiential aspect," explains Mr Rhinehart, who still enjoys "recreational food" on occasion.

As of mid-February his firm had a four-to-flve-month backlog for new orders. Customers subscribe online to receive monthly shipments with a "meal" costing roughly $3. According to Mr Rhinehart, his company is already profitable and will use a recent $20m cash infusion to expand production and sales.

Mr Rhinehart is, to put it mildly, a little extreme. Not everyone may want to separate eating into utility versus pleasure. Impossible Foods' Dr Brown does not believe such a compromise is necessary. "I don't see any reason why you can't have it all-the best tasting food, healthiest, best for the planet and most affordable."

But even if the scientific hurdles of making plants taste like meat and other animal-based products are overcome, **the bigger obstacle these companies face may be cultural**. People have been eating meat and having meals together for thousands of years. Meat in particular is not only prized for its taste but also perceived as a force of vitality, strength and health.

A recent study by the Humane Research Council, an animal advocacy group, says most vegetarians and vegans, about 2% of America's population, go back to eating meat eventually. In the future that may not be an option. "We can't sustain the number of people that we're going to need to feed over the next couple of decades with the current way that we're eating, "says Ms Stuckey. Whether out of necessity or choice, Silicon Valley's vision of a big shift to plant-based foods may be inevitable. (The Economist March 7th 2015).

# Plant-Based Protein & Meat

https://time.com/collection/davos-2020/5764621/rethinking-food-environment/

### Plant-Based Meat

**Beyond Meat** used sources including peas, mung beans, fava beans, brown rice and sunflower to create plant-based sausages, burgers and meat crumbles; the company rolled out a breakfast saugage at Dunkin' in 2019 and now sells food at 67,000 stores in 50 countries.

### Plant-Based Protein

Just (formerly Hampton Creek) launched its egg product made from mung beans in late 2018 in grocery stores: It's now sold by dozens of restaurant chains and grocers like Walmart.

The result has been billions of dollars invested in companies that promise to reinvent the food that ends up on your dinner plate. More than 47 companies making meat and dairy products from plants, including Impossible Foods and Beyond Meat, have raised $2.29 billion from venture capitalists in the past decade, one-quarter of it invested in 2019 alone, according to PitchBook, which tracks private equity and venture capital worldwide. Shares of Beyond Meat, which sells **plant-based meat substitutes** in grocery stores and in restaurants including Dunkin' and TGI Fridays, are trading at roughly three times their IPO price. Nearly 40 more companies trying to grow proteins like meat and fish from cells, such as the Dutch company Mosa Meat and the San Diego firm BlueNalu, have raised $1.1 billion, almost all of that funding in the past five years, PitchBook says. While most of the investment is from venture capitalists, a handful of countries, including the Netherlands, Japan and New Zealand, have funded research i But the billions of dollars being poured into startups may not change farming anytime soon. Some scientists are dubious that the many companies that say they can grow fish and steak from cells will actually be able to do so on a large scale in the next decade.

Plant-based-meat companies, which have reached millions of consumers, are still scrambling to make a burger that tastes as satisfying as conventional meat. **Vertical farms are expensive to run because they have to use power to provide the one thing that's free in traditional farming: light from the sun.** "The timescales of disrupting the agriculture industry are not what they are in the software industry," says David Lobell, director of the Center on Food Security and the Environment at Stanford University. "**People who have come from tech and get into ag are often frustrated by the pace of change**."

Food-tech companies say younger generations care more about the planet than older ones, and so will choose climate-friendly foods. Of all the consumers polled by Michigan State University who said they were already eating plant-based meat, nearly half were under 40. Besides, the companies say, their products are healthier. Conventional meat contains cholesterol and doesn't have the fiber and complex carbohydrates that plant-based meat has, says Bruce Friedrich, executive director of the Good Food Institute, which advocates for cultured and plant-based meat. Crops grown locally in vertical farms are fresher, so people will eat more of them, and since they're grown indoors, they don't use pesticides, companies like Plenty say.

But traditional food companies have challenged food-tech companies at every step. "What's hiding in your plant-based meat?" the Center for Consumer Freedom, a nonprofit supported by restaurants and food companies, asked in a full-page ad directing consumers to a website that compared plant-based meat with dog food. Chipotle CEO Brian Niccol said meat substitutes "wouldn't fit" into Chipotle's menu because of **the "processing" required to make a plant taste like meat**. Congressional lawmakers have introduced a bill supported by the U.S. Cattlemen's Association that would require makers of plant-based and cell-cultured meat to put the word imitation on their labels, following dozens of states that have passed or introduced bills requiring plant-based-food companies to label their products **"imitation meat**."

# Plant-Based Protein & Meat

https://time.com/collection/best-inventions-2020/5911377/impossible-pork/

**Impossible Pork. A Sustainable Substitute.** The Best Inventions of 2020.


The world's most- consumed animal protein is pork—and its farming results in a slew of environmental issues, including pollution due to swine waste. Impossible Foods, which wowed the world with its rendition of a burger in 2015, aims to tackle these issues with a plant-based pork substitute, Impossible Pork. Previewed at CES 2020, Impossible Pork is made from soy and said to taste uncannily like the real deal. While the favorable environmental impacts of a pork alternative are clear, plans for a commercial rollout of Impossible Pork are still in the works. —Nadia Suleman

# Plant-Based Seafood

Food & Drink:
Catch of Tomorrow. Kuleana tuna (by Sanya Mansoor)

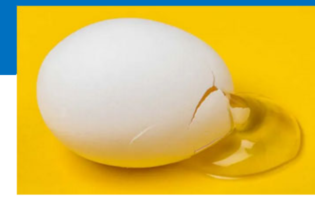
Tasty and nutritious plant-based alternatives for meat and chicken have been available for years. But seafood? Not so much. That's the void that Kuleana is trying to fill with its 100% plant-based, sushi-grade, ready-to-eat tuna made from ingredients including algae, koji (a fungus that grows in East Asia), radish, bamboo and potato. Deep red in color and designed to be prepared as sushi, nigiri, carpaccio, poke or ceviche, the alt-tuna retains the iron, vitamin B12 and omega-3 fatty acid of the real thing—without the microplastics, mercury or high cholesterol. And the benefits are more than nutritional—it may also help to alleviate reliance on industrial fishing in the face of increasing demand for fresh food. The product is currently available at select markets in Los Angeles, restaurants in the Midwest and Poké Bar locations nationwide, with a wider rollout via e-commerce slated for the near future. Next on the menu: high-quality, sushi-grade, plant-based salmon.

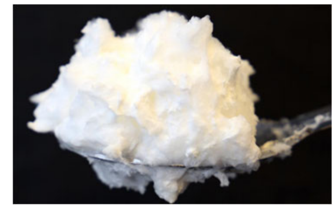
TIME. The 100 best inventions 2021

# Egg White Alternative

Ovalbumin production using Trichoderma reesei culture and low-carbon energy could mitigate the environmental impacts of chicken-egg-derived ovalbumin (Natasha Järviö, et al. Nature Food volume 2, pages 1005–1013, 2021)

Ovalbumin (OVA) produced using the fungus Trichoderma reesei (Tr-OVA) could become a sustainable replacement for chicken egg white protein powder—a widely used ingredient in the food industry. Although the approach can generate OVA at pilot scale, the environmental impacts of industrial-scale production have not been explored. Here, we conducted an anticipatory life cycle assessment using data from a pilot study to compare the impacts of Tr-OVA production with an equivalent functional unit of dried chicken egg white protein produced in Finland, Germany and Poland. Tr-OVA production reduced most agriculture-associated impacts, such as global warming and land use. Increased impacts were mostly related to industrial inputs, such as electricity production, but were also associated with glucose consumption. Switching to low-carbon energy sources could further reduce environmental impact, demonstrating the potential benefits of cellular agriculture over livestock agriculture for OVA production.





Egg white protein produced by precision fermentation has excellent foaming properties. (Image: VTT Technical Research Centre of Finland)


**Biotechnology could provide an environmentally more sustainable alternative to egg white protein production**

The research by the Future Sustainable Food Systems research group at the University of Helsinki together with VTT Technical Research Centre of Finland shows that fungus-produced ovalbumin could have the potential to mitigate part of the environmental burden associated with chicken egg white powder. This is especially true when using low carbon energy sources in the production. Chicken egg white powder is a commonly used ingredient in the food industry due to the high-quality protein it contains. The yearly consumption of egg proteins in 2020 was around 1.6 million tons and the market is expected to expand further in the coming years. The growing demand is raising questions about both sustainability and ethics. Parts of the egg white powder production chain, such as rearing chickens for egg production, generate large amounts of greenhouse gas emissions and contribute to water scarcity, biodiversity loss, and deforestation. Additionally, intensive chicken farming has resulted in outbreaks of zoonotic diseases by serving as an important reservoir for human pathogens.

Searching for sustainable alternatives to animal-based proteins has been of growing interest within the food industry. Cellular agriculture, also called precision fermentation when used for recombinant ingredient production, offers a biotechnology-based solution to decouple the production of animal proteins from animal farming by using a microbial production system to produce the specific proteins instead. "For example, more than half of the egg white powder protein content is ovalbumin. VTT has succeeded in producing ovalbumin with the help of the filamentous ascomycete fungus Trichoderma reesei. The gene carrying the blueprints for ovalbumin is inserted by modern biotechnological tools into the fungus which then produces and secretes the same protein that chickens produce. The ovalbumin protein is then separated from the cells, concentrated and dried to create a final functional product," says Dr Emilia Nordlund from VTT Technical Research Centre of Finland. Cell-cultured products generally need more electricity than typical agricultural products, and therefore the type of energy source used affects the level of environmental impact. However, the amount of agricultural inputs needed for ovalbumin production by microbes – such as glucose – is generally substantially lower per kilogramme of protein powder. "According to our research, this means that the fungus-produced ovalbumin reduced land use requirements by almost 90 per cent and greenhouse gases by 31–55 per cent compared to the production of its chicken-based counterpart. In the future, when production is based on low carbon energy, precision fermentation has the potential to reduce the impact even by up to 72 per cent," says Doctoral Researcher Natasha Järviö from the University of Helsinki. For the impact of water use on the environment, the results were less conclusive, showing a high degree of dependency on the assumed location of the ovalbumin production site. In general, the study shows the potential of the precision fermentation technology to increase the sustainability of protein production, which can be further increased by the use of low-carbon energy sources.

https://www.helsinki.fi/en/news/life-sciences/biotechnology-could-provide-environmentally-more-sustainable-alternative-egg-white-protein-production

# Food from Insects

https://time.com/collection/davos-2020/5764621/rethinking-food-environment/

Exo, which makes cricket protein bars and sells **whole-roasted crickets**, was acquired by the Aspire Food Group in 2018, and Soylent, a meal-replacement beverage, has raised more than $70 million. "We're on the cusp of some breakthroughs in the development of food," said Jeff Housenbold, a partner at SoftBank who headed the firm's investment in Plenty, a vertical farm.

https://time.com/collection/davos-2020/5764621/rethinking-food-environment/


**Exo** calls crickets the perfect protein source, since they are high in essential amino acids, B12 and iron; it sells cricket protein bars and whole roasted crickets

Get ready to eat bugs if you want to live beyond 2050. Beef won't be what's for dinner much longer.

**Insects**

https://www.engadget.com/2020/01/28/crickets-algae-lab-grown-meat-future-of-protein/

# Ocean-Grown Foods: Sea Plants

https://www.engadget.com/2020/01/28/crickets-algae-lab-grown-meat-future-of-protein/

https://time.com/collection/best-inventions-2019/5734537/akua-kelp-jerky/

**A Sustainable Snack**

AKUA Kelp Jerky
*SPECIAL MENTION:* Kelp jerky is not only a nutritious snack, its production could help fight climate change. Kelp is an underwater crop that draws in carbon and nitrogen from the oceans. AKUA, the startup behind the snack (available for $7), estimates that the kelp it used in 2019 helped to pull 2,000 pounds of carbon from the water. —*Sanya Mansoor*

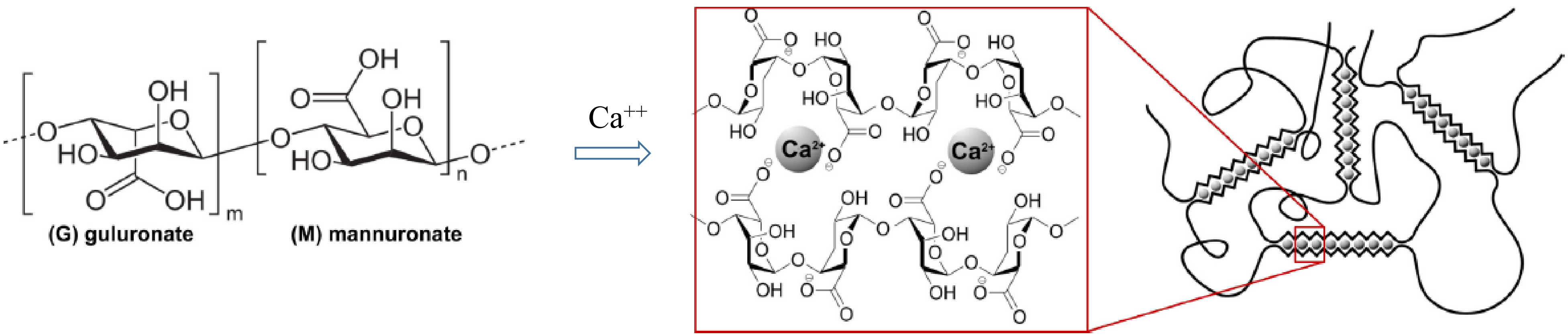



Fig. 1. Structure of alginate and its binding of calcium cations in egg-box model (Grant et al., 1973).

Bruchet 2015, Fabrication of patterned calcium cross-linked alginate hydrogel films. Grant 1973, Biological interactions between polysaccharides and divalent cations. Egg-box model

# Edible Blob Filled with Water by Notpla

Notpla: Not plastic & Not PLA

This edible blob filled with water means you don't need a plastic bottle. Notpla has found a way to make water bottles that you can eat (or compost) when you're done. What's next? Getting rid of plastic ketchup packets. (Adele Peters. 02-18-20.)

[Photo: Ooho]

Paslier, a former packaging engineer at L'Oréal, began working on the concept along with designer Rodrigo Garcia Gonzalez in 2013 while they were studying innovation design engineering at Imperial College London and the Royal College of Art. The designers used a technique from molecular gastronomy to create the package—if you dip a sphere of ice in a mixture of calcium chloride and brown algae extract, an edible membrane forms around the ice, holding everything in place as the ice melts back to room temperature. A small version of the package is designed to break open inside your mouth. "It's a bit like a cherry tomato," says Paslier. "You put it in your cheek and bite on it. It explodes, so it's quite a surprising experience." The startup partnered with the Scottish whisky brand Glenlivet last year to make a "glassless cocktail" capsule that customers can imbibe along with whisky. The seaweed coating, which is tasteless, can either be eaten or composted.

The design isn't likely to replace the plastic bottles that are ubiquitous in retail stores, for simple reasons of convenience: it holds a small amount of water, and like a piece of fruit, it's perishable. If it was sitting on a store shelf, it would also have to be washed off to make it hygienic to eat. For the bulk of the plastic water bottles in the world—more than one million of which are sold every minute—other solutions will be necessary. "The edible blob definitely isn't going to replace plastic everywhere," he says. But for certain applications, like a race where gloved volunteers hand the pods directly to runners, it works perfectly. The company is also expanding into other applications, including sachets that can hold ketchup or mayo with takeout orders in restaurants. Small sachets are a type of plastic packaging that have been difficult to replace in the past, and aren't recyclable. Just Eat, a food delivery service in London, is now using the packaging, and Notpla is also working with Unilever. The company is also developing a coating for compostable paper takeout containers to make them waterproof and greaseproof but still compostable.

Like other companies making alternatives to plastic packaging, Notpla says that the landscape has radically changed since it began in 2013, as plastic pollution has become a mainstream concern. "Consumers have become not just aware but emotionally connected with the issue," Paslier says. "It's great, because I think packaging has been very commoditized, and it was something that no one would talk about or care about," he says. "And all of a sudden, it becomes something that people feel can either damage their brand, or give the wrong impression of what their values are. I think that they're starting to realize that they need to really raise the game in terms of sustainability."

https://www.fastcompany.com/90464501/this-edible-blob-filled-with-water-means-you-dont-need-a-plastic-bottle?partner=rss&utm_campaign=rss+fastcompany&utm_content=rss&utm_medium=feed&utm_source=rss

# Lab-Grown Meat

https://time.com/collection/davos-2020/5764621/rethinking-food-environment/

## Dinner As We Know it Is Hurting the Planet. But What If We Radically Rethink How We Make Food? (By Alana Semuels)

TIME, February 3, 2020

Food startups are quick to tout their environmental benefits. BlueNalu cultures fish tissue from cells to help avoid overfishing at a time when demand for seafood is growing. Plenty, the vertical-farming company, says it can grow the same amount of fruits and vegetables on a space the size of a soccer goal as is usually grown on a football field, while using 1% to 5% of the water of a traditional farm. Just egg products, which are made from mung beans, require a fraction of the water and carbon dioxide needed to produce other proteins, including beef, pork, chicken and even tofu.

The taste and health obstacles facing plant-based-meat companies are driving more entrepreneurs to the lab-grown-meat space. But meat grown from cells might not be ready for public consumption anytime soon. The process starts with putting an animal like a cow under anesthesia, cutting open a muscle and removing a small sample of tissue. Scientists use enzymes to break that tissue down into muscle and fat cells, which are then put, along with a growth medium, into a bioreactor that looks like the fermentation tanks where beer is brewed. Then the cells multiply.

**But meat has been grown from cells only on a small scale.** Growth mediums, which include fetal bovine serum (essentially blood from a cow fetus), are costly, and scientists have struggled to ensure that cells grown in larger containers get enough oxygen and nutrients. No cellular-agriculture company has explained how these obstacles have been overcome, says Ricardo San Martin, research director at the Alternative Meats Lab at the University of California, Berkeley. They are very evasive, he said. "When you ask them A, they answer B." Growing meat from cells for public consumption "is not going to happen on a large scale anytime soon," says San Martin, "maybe even ever." There is almost no publicly funded research on lab-grown meat, and private companies aren't forthcoming about their methods. But cellular--agriculture startups have been granted only a small number of patents despite their high valuations, says Babak Kusha, a patent lawyer at -Kilpatrick Townsend.

Food-tech companies say big change can happen now. In a lab in Boston looking out onto a dry dock where ships are repaired, Motif FoodWorks is preparing to ramp up production of animal-free ingredients that make plant-based food taste better. With the help of advances in synthetic biology, Motif inserts genes into yeast microbes to create things like animal-free milk-protein isolates that could make almond milk creamier. Motif's lab uses computer-assisted machines to tinker with ingredients in test tubes the size of pencils, a scene far removed from that of a muddy dairy farm in rural America, where big companies currently get milk-protein isolates from cow's milk. But Michael Leonard, the chief technology officer at Motif, says it's the future of food. The cost of sequencing genomes has fallen dramatically, and computers have become more adept at scanning genomes to find alternative sources of protein, he says. Motif plans to have its first products ready to sell to food giants by 2021, when consumers will have become much more comfortable with the intersection of technology and food. "I think what we'll see over time with the undeniable reality of population growth is the need to do more with less," he says. "And I think plant-based eating can really help to bring that into balance."

https://time.com/collection/davos-2020/5764621/rethinking-food-environment/

# Engineered Whole Cut Meat-like Tissue

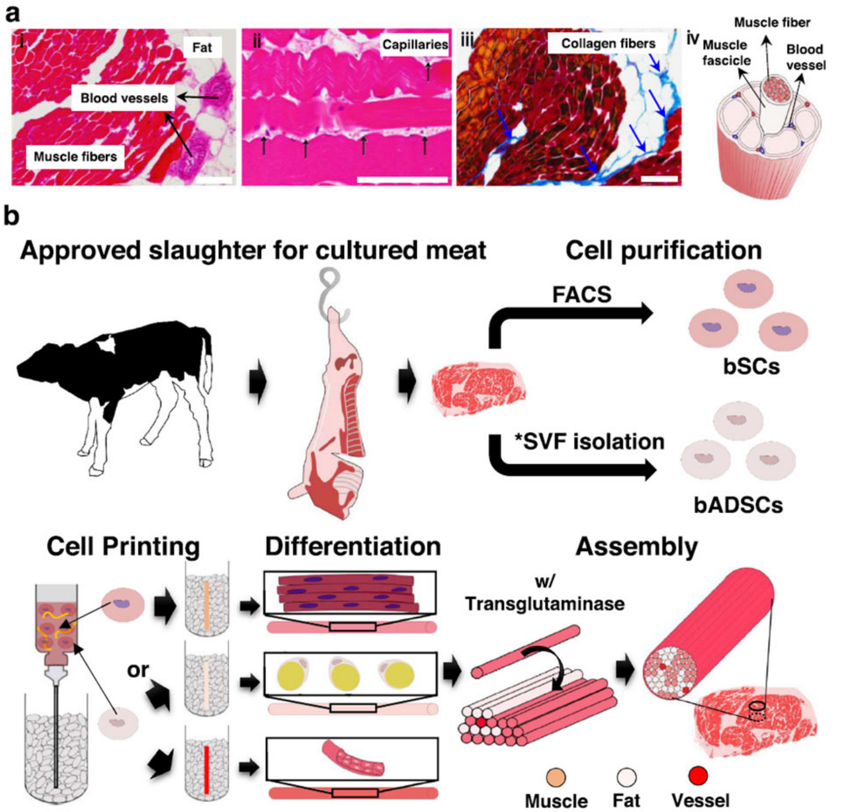



Fig. 1 Overview of the work. a Structure of steak. (i, ii) H&E- and (iii) Azan-stained images of a piece of steak. Representative images from three independent experiments are shown. All scale bars denote 100 μm (iv) Schematic of a hierarchical structure in muscle. b Schematic of the construction process for cultured steak. The first step is cell purification of tissue from cattle to obtain bovine satellite cells (bSCs) and bovine adipose-derived stem cells (bADSCs). The second is supporting bath-assisted printing (SBP) of bSCs and bADSCs to fabricate the muscle, fat, and vascular tissue with a fibrous structure. The third is the assembly of cell fibers to mimic the commercial steak's structure. *SVF stromal vascular fraction.

Kang 2021, Engineered whole cut meat-like tissue by the assembly of cell fibers using tendon-gel integrated bioprinting

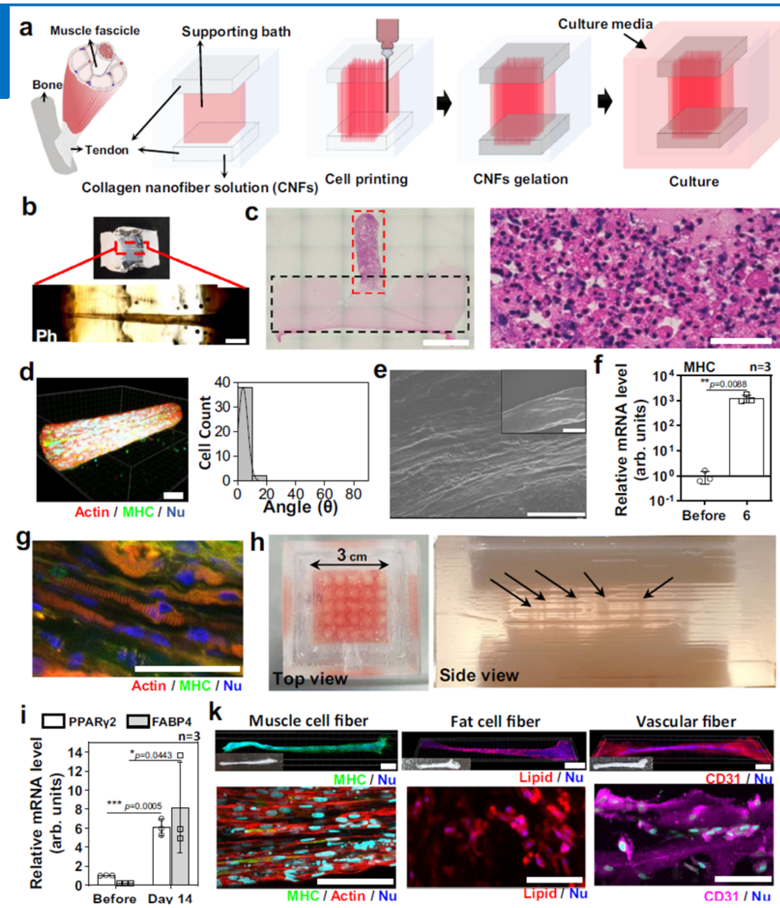
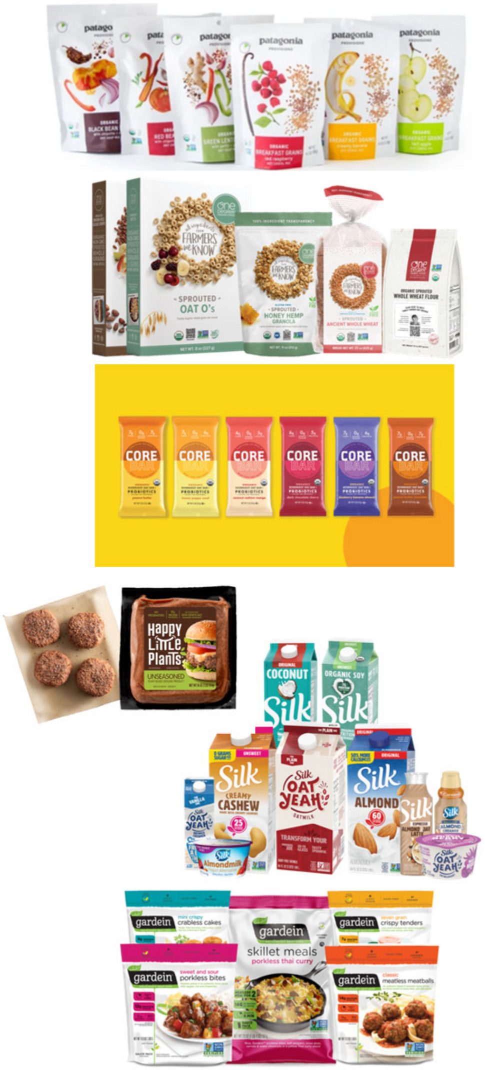



Fig. 4 Tendon-gel integrated bioprinting (TIP) for muscle, fat, and vascular tissue fabrication. a The schematic of TIP for cell printing. b Optical (upper) and phase-contrast (lower) images of the bSC tissue printed by TIP, keeping the fibrous structure on day 3. The images were taken after fixation. Scale bar, 1 mm. c The H&E-stained image of half of collagen gel (dotted black line)—fibrous bSC tissue (dotted red line) and a magnified image of the fibrous bSC tissue (right). Scale bars, 2mm (left) and 50 μm (right). d 3D fluorescence image (left) and cell alignment measurement (right) of the TIP-derived bSC tissue stained with actin (red), MHC (green), and nucleus (blue) on day 3 of differentiation. Scale bar, 50 μm. e SEM images of TIP-derived bSC tissue on day 3 of differentiation. Scale bars, 10 μm and 100 μm (inset). f MHC mRNA expression levels of bSCs before printing and TIP-derived bSC tissue on day 3 of differentiation (n = 3 independent samples, pairwise t-test comparison). g Fluorescence image of TIP-derived bSCs tissue stained with actin (red), MHC (green), and nucleus (blue) on day 14 of differentiation. Scale bar, 50 μm. h The optical images of multiple tissue fabrication (25 ea.) by multiple printing. Black arrows indicate printed cell fibers. i, j mRNA levels (i) and protein expression levels (j) of TIP-derived fat tissues before printing and at day 14 of differentiation (at day 17 of total culture) (n =3 independent samples, pairwise t-test comparison). k Whole fluorescence (left), optical (inset), and magnified (right) images of muscle (on day 4 of differentiation, green: MHC & blue: nucleus), fat (on day 14 of differentiation, red: lipid and blue: nucleus), and vascular (on day 7, magenta: CD31 and blue: nucleus) tissues fabricated by TIP. Scale bars, 1mm (left) and 100 μm (right).

# Sustainable Food

What do you want to eat? Your answer has an profound impact on the planet. The modern food supply chain accounts for just over a quarter of all greenhouse gas emissions (U. of Oxford). By choosing more environmentally-friendly food options, you can play an important role in helping the planet (now). Even businesses are joining the rising trend and making it easier for you to choose a product that supports our Earth.


Propelled by sustainability and animal welfare concerns, lab-grown foods have the potential to disrupt the industry by mainstreaming the use of new technologies.


https://www.theplanetnow.com/sustainable-food
https://www.foodingredientsfirst.com/news/sustainable-and-organic-values-plant-based-proteins-cultivated-meat-and-developing-dairy.html

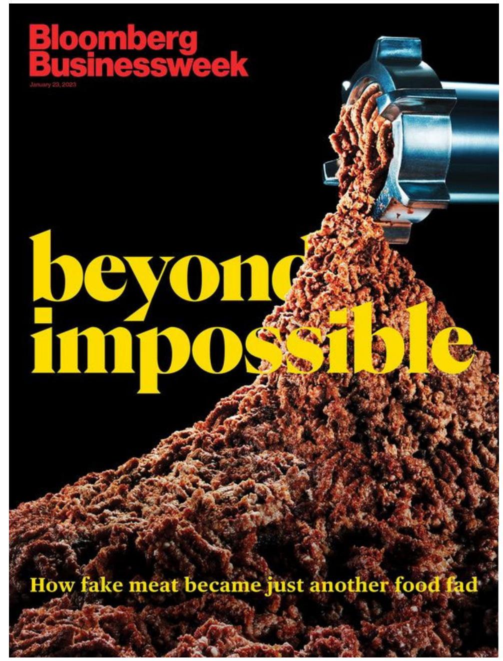
# Fake Meat: Just Another Fad

Bloomberg Businessweek 1/19/2023

Many meat eaters initially excited by fake meat, who didn't mind the not-quite-there taste or texture, eventually took a closer look at the ingredient list and couldn't figure out whether they were actually trading up. Were they eating these burgers to curb carbon emissions or lower their blood pressure? Was it a healthier alternative or a sodium-filled, overprocessed substitute? Plant meat still costs more than the real thing, and with inflation pushing up prices across the supermarket, many grocery shoppers have swapped the expensive imitation for chicken or, in some cases, beans and lentils

Meatless meat, it turns out, seems less a world-changing innovation than another food trend whose novelty is wearing thin.

A frozen Beyond Burger plant-based patty.
Photographer: AKIRA for Bloomberg Businessweek




How fake meat became just another food fad.
Bloomberg Businessweek. January 23, 2023



Shanker 2023, Fake meat was supposed to save the world. It became just another fad

# Meatless Meat


**Meatless meat is becoming mainstream — and it's sparking a backlash** (By Kelsey Piper Oct 7, 2019)
The growing pushback against Impossible and Beyond burgers in fast-food chains, explained

https://www.vox.com/future-perfect/2019/10/7/20880318/meatless-meat-mainstream-backlash-impossible-burger

**The dark side of plant-based food – it's more about money than you may think** (December 10, 2019)


https://theconversation.com/the-dark-side-of-plant-based-food-its-more-about-money-than-you-may-think-127272

## Remember Virtual Water?
## What Virtual Xs are in these products?

The Race to Bring Meat Alternatives to Scale.
Memphis Meats' lab-grown flesh approach is still far off, but Impossible Foods' plant-based approach is already on the menu at Burger King. (Megan Molteni 2019)

https://www.wired.com/story/uma-valeti-memphis-meats-wired25/

## Ingredients in Ground Beef from a Cow

12 — Water (63%), **Triglycerides** (19%) (Oleic Acid (7%), Palmitic Acid (5%), Stearic Acid (3%), Palmitoleic Acid (1%), Myristic Acid (<1%), Trans-Fatty Acid (<1%), Linoleic Acid (<0.5%), Margaric Acid (<0.5%)), Pentadecanoic Acid (<1%), Conjugated, Linoleic Acid (<1%), Margaroleic Acids (<1%).

15 Amino Acids, Not Proteins — **Protein** (17.6%) (Alanine (1%), Arginine (1%), Aspartic Acid (2 %), Gluatamic Acid (3%), Glycine (1%), Histidine (1%), Isoleucine (1%), Leucine (2%), Lysine (2%), Methionine (<1%), Phenylalanine (<1%), Proline (1%), Serine (<1%), Tyrosine (<1%), Valine (<1%)).

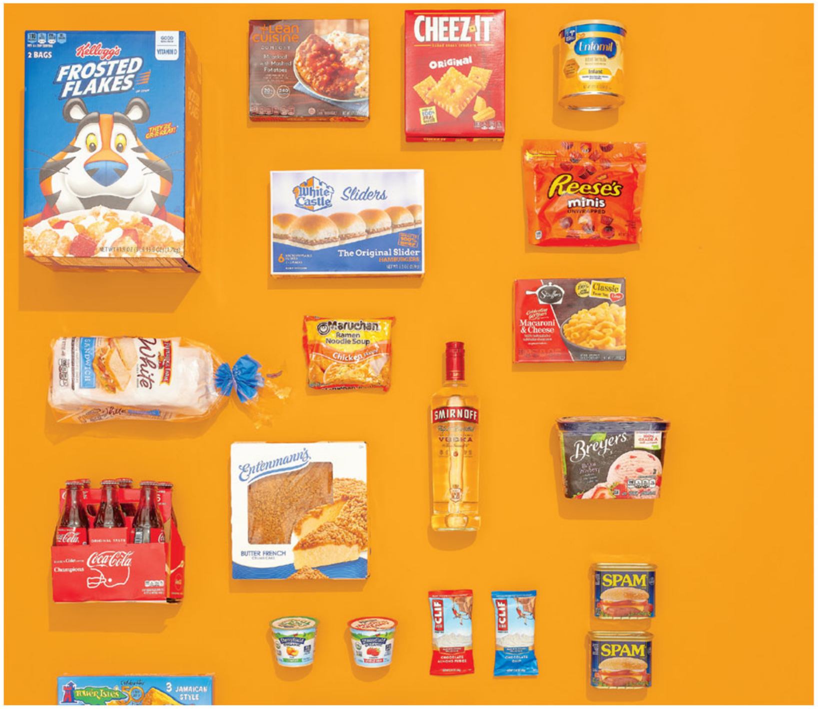
34 — Less Than 2%. Acetic Acid, Ash, Heme, Glucose, Ribose, Glycerol, Fructose, Taurine, Creatine, E306 (Tocopherol), E260 (Acetic Acid), E160A (Beta Carotene), E101(Riboflavin), Histamine, Cadaverine, Putrescine, Cholecalciferol (Vit D), Thiamine, Cyanocobalamin (Vit B12), Folate, Niacin, Patothenic Acid, Vitamin B6, Aluminum, Calcium, Cobalt, Copper, Iron, Magnesium, Phosphorus, Potassium, Sodium, Titanium, Zinc.

42 — **Flavors:** 2,5-Dimethyl-Pyrazine, Acetoin, 2,3-Butanedione, 1-Hydroxy-E-Propanone, Hexanal, Benzeneacetamide, 1-Pentanol, 1-Octen-3-Ol, 2,3-Pentanedione, 1-Hexanol, E,E-2,4 Decedienal, Methional, Pentanal, (E)-2-Decenal, Butyrolactone, 4-Penten-2-Ol, Tetradecanoic Acid, Tetradecanoic Acid, 4-Hydroxy-4-Methyl-2-Pentanone, 5-Methyl-5-Hexen-2-One, Formamide, 2,4-Di-Tert-Butylphenol, Fufural, Alpha-Actin, Myosin-2, Fructose-

Proteins — bisphosphate aldolase A, Serum albumin precursor, myosin-7, Creatine kinase M, Cytoplasmic-actin, Myosin-8, Beta-enolase, Myosin-4, Carbonic anhydrase, Myoglobin, Glyceraldehyde-3-phosphate dehydrogenase, Myosin-6, Pyruvate kinase, Myosin light chain, myosin-3, L-lactate dehydrogenase, Myosin regulatory light chain, Triosephosphate isomerase.

# (Ultra)processed Foods

“Ultraprocessed” foods seem to trigger neural signals that make us want more and more calories, unlike other foods in the Western diet (By Ellen Ruppel Shell)



ULTRAPROCESSED foods and drinks are designed to be ready-to-consume, with numerous additives that can include oils, fats, color enhancers, flavor enhancers, nonsugar sweeteners, and bulking and firming agents. (No specific brand has been linked to obesity.)

UNPROCESSED FOODS are the edible parts of plants (such as seeds or roots or leaves) and animals (such as meat and eggs). The main processing of this food type is freezing, drying or pasteurizing to extend storage life. Salts, sugars, oils and fats are not added.

Shell 2019, Obesity on the brain

# The Same Foods in the U.S. vs in the U.K.

# Polymers for Foods: Edible Food Packaging

# History of Food Packaging

## History of Food Packaging

**Gordon L Robertson,** University of Queensland and Food Packaging Environment, Brisbane, QLD, Australia





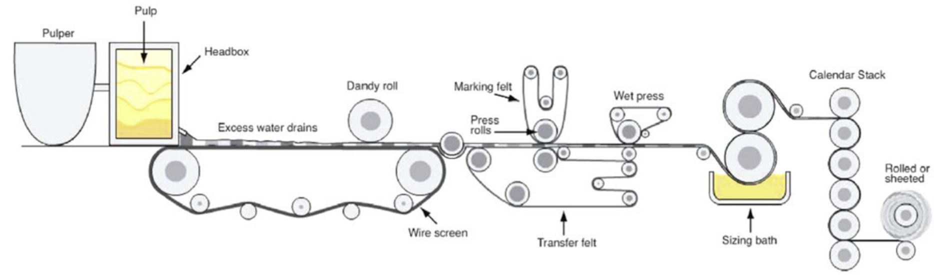



**Figure 3** Fourdrinier machine for making paper. https://www.strathmoreartist.com/faq-full-eu/how-is-paper-made-705.html.



**Figure 20** DOYPACK® pouches (left) and Ecolean pouch (right).

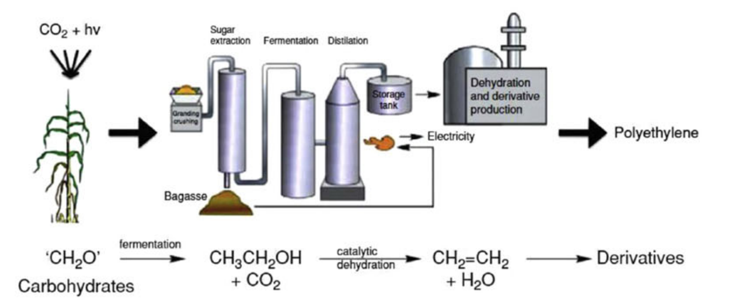



**Figure 22** Schematic flow diagram of the production of biopolyethylene from sugarcane via fermentation into ethanol and subsequent dehydration into ethylene. Source: Koopmans, R.J., 2014. With permission from John Wiley & Sons, Ltd., Chichester, England.

Robertson 2019, History of food packaging

# Wrappers You Can Eat

## WikiPearls / $4 for a pack of two

*Available at select Whole Foods*

Tara Johnson for TIME

“Edible wrapper” sounds like an oxymoron—unless you’re WikiFoods founder David Edwards, who has devised a way to encase yogurt, cheese, ice cream and more in shells strong enough to hold their shape (in water, heat and cold) until you take your first bite. The secret lies in science: Each shell is made of particles of dried fruit or other natural substances that are tiny enough to be electrically attracted to one another; they are combined with calcium and sugar to strengthen the form. Though the frozen-yogurt Pearls—the first WikiFoods product to reach mainstream stores, thanks to deals with Stonyfield and Whole Foods—are still packaged in biodegradable bags of two, Edwards’ ultimate goal is to sell them à la carte, like apples or peanuts, in an effort to reduce the world’s packaging waste.

http://time.com/3594971/the-25-best-inventions-of-2014/?xid=newsletter-brief

After years of research, development and raising funds, the culmination is the WikiPearl, a bite-sized morsel of food that is wrapped in a plastic-free packaging that protects the food, but is also edible and biodegradable. Made of a "protective electrostatic gel formed by harnessing interactions between natural food particles, nutritive ions and a polysaccharide," this skin is water- and oxygen-impenetrable, and is inspired by nature itself, as the creators explain:

Imagine for a second the skin of a grape or a coconut. WikiPearl skins are inspired by the way nature packages fruits and vegetables. These skins are delicious protective coatings against water loss and contaminant entry, and potential carriers of effective and functional nutrition.

The WikiFood technology protects the wrapped food or beverage without exposing it to unnatural materials or chemicals while also delivering benefits of health, convenience and a food experience like nothing else.

https://www.treehugger.com/wikipearls-bite-sized-food-wrapped-edible-packaging-4856813

# Dietary Fibers

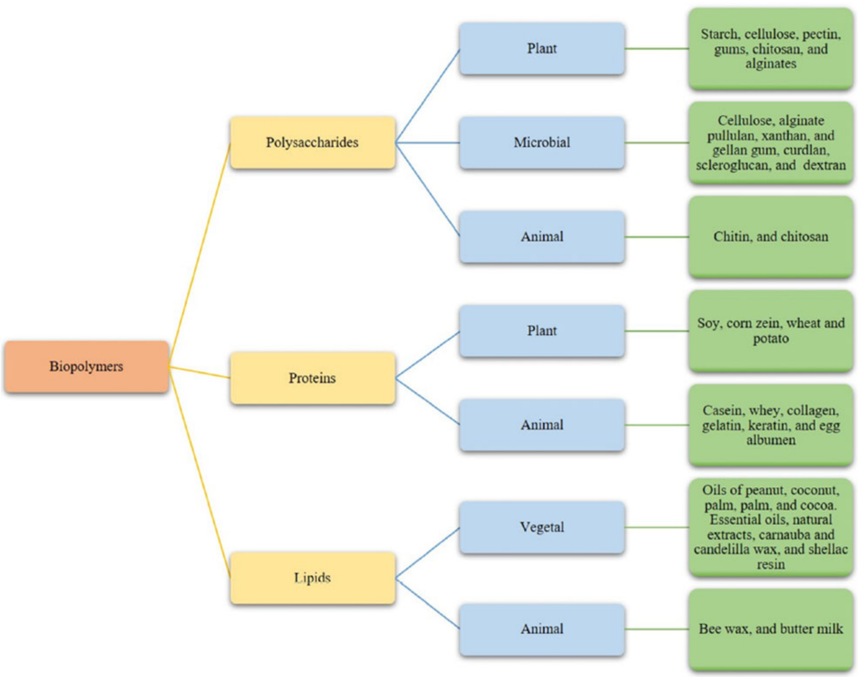



**Figure 1.** Biopolymers used as natural edible films and coatings and their sources.

**Composite coatings**

- Improvement of mechanical, water vapor, barrier, thermal, and antimicrobial properties.
- Improve or reduce water solubility.
- Prevention of dissolving and or swelling.
- Provide antioxidant properties.
- Development of more stable structures.
- Moisture content reduction.
- Protection and extension of activity of bioactive compounds.
- Better retention of organoleptic and nutritional properties of fruits and vegetables.

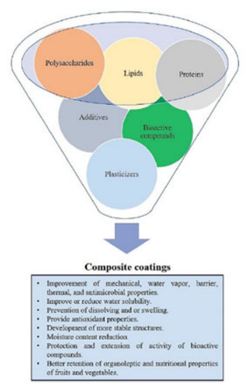



**Figure 2.** Composite coatings and their properties.

Iniguez-Moreno 2021, An extensive review of natural polymers used as coatings for postharvest shelf-life extension

## 9.4 Components of Fruit and Vegetable-Based Film Forming Formulations (FFF)

Vegetable- and fruit-based edible films can be derived from a single plant or more (blends), or even multi-component/composite in nature having a part of conventional polymers or specific additives (binders, plasticizers, flavour enhancers, antioxidants, antimicrobials and essences). Such films can be single layered or multi-layered depending on the target or intended use. Constituents of fruit- and vegetable-based film formulations include various components (Table 9.2) which contribute to different properties of the films.

**Table 9.2** Components of fruit- and vegetable-based FFF with examples

| Binding agents | Plasticizers | Fillers | Functional additives | Other additives |
|---|---|---|---|---|
| Cassava starch | Glycerol<br>Sucrose<br>Inverted sugar<br>Sorbitol | Cellulose nanocrystals (CNCs)<br>Microcrystalline cellulose (MCC)<br>Montmorillonite (MMT) nanoclays<br>Chitosan nanoparticles | Essential oils<br>Tannins<br>Flavonoids<br>Phenolic acid derivatives | Browning inhibitors<br>Cross-linkers |
| Chitosan | | | | |
| Carboxymethylcellulose | | | | |
| Corn starch | | | | |
| Gelatin | | | | |
| High-methoxyl pectin | | | | |
| Hydroxypropyl methylcellulose (HPMC) | | | | |
| Low-methoxyl pectin | | | | |
| Methylcellulose | | | | |
| Phaseolin | | | | |
| Polylactide | | | | |
| Sodium alginate | | | | |
| Soy protein | | | | |

Dhewa 2022, Edible Food Packaging. Applications, Innovations and Sustainability

# Microencapsulated Food Ingredients





# Microencapsulation: Delivering a market advantage

**Microencapsulated ingredients can improve a product's flavor, appearance, shelf-life and nutritional value. An overview of the types of core and coating materials and encapsulation techniques used in the industry gives insights into problem-solving ingredients.**

*Niraj Vasishtha, Contributing Editor*

People love food...its taste, its appearance, its aroma. Besides aesthetics, people purchase prepared foods based on convenience, cost, and perceived value or nutritional content.

Microencapsulation, the science of capturing a core material in a shell or coating for controlled release, can provide the food industry with a distinct market advantage in all these product purchase points. Microencapsulated products can add that extra zing, mask the taste of nutrients, alleviate processing problems, and increase the shelf life of food products.

### Why Encapsulate?

Flavor, taste, and an appetizing appearance are primary factors in a consumer's decision to buy a product. Consider how the mouth-watering aroma of popcorn—microencapsulated for release during preparation—can improve sales. In addition, volatile colorants and aromas can be stabilized and their processing made simpler through microencapsulation.

As consumers become increasingly health conscious, they are looking for more "functional foods"—many of which are augmented with ingredients to promote health. However, simply adding ingredients to food products to improve nutritional value can compromise their taste, color, texture, and aroma. Microencapsulation technology provides viable texture blending, appealing aroma release, and taste-, odor-, and color-masking. The technology enables food companies to incorporate minerals, vitamins, and essential oils, creating foods for the "wellness" market.

Microencapsulation can improve the convenience of food. The shell provides a barrier between reactive components (for instance, delaying the release of leavening agents for fluffier bread products or protecting oxygen-sensitive materials during processing and storage). Microcapsules can help fragile and sensitive materials survive processing and packaging conditions and stabilize the shelf-life of the active ingredient.

In addition, microencapsulation can simplify the food manufacturing process by converting liquids to solid powder, decreasing production costs by allowing batch processing using low-cost, powder-handling equipment. To improve food safety, the technology can be used to indicate product tampering, thermal spoilage, and freeze-thaw cycles.

With such a fascinating range of applications, no single "silver-bullet" microencapsulation process addresses all purposes. The dilemma is further complicated by the choices of shell formulations acceptable for foods, the desired stability and release characteristics and last, but never least, production costs.

Microencapsulation technology is sometimes considered more art than science, as stated by Asajo Kondo in *Microcapsule Processing and Technology*:

*Microencapsulation is like the work of a clothing designer. He selects the pattern, cuts the cloth, and sews the garment in due consideration of the desires and age of his customer, plus the locale and climate where the garment is to be worn. By analogy, in microencapsulation, capsules are designed and prepared to meet all the requirements in due consideration of the core material, intended use of the product, and the environment of storage...*

The challenges in developing a commercially viable product depend on:

- Selecting appropriate shell formulation from FDA-approved, GRAS (generally recognized as safe) materials,
- Selecting the most appropriate process to provide the desired morphology, stability, and release mechanism, and
- Economic feasibility of large-scale production, including capital, operating, and other miscellaneous expenses, such as transportation cost, regulatory cost, and downtime losses.

### Microencapsulation Materials

Typically, microencapsulated products can be divided into five main categories: flavorings, vitamins and minerals, oils and fats (such as omega-3s and 6s), herbs and bioactives (such as creatine and probiotic bacteria), and other food ingredients (such as enzymes, leavening agents, psyllium and yeast).

### Shell Games

A critical step in developing microencapsulated food products is determining the shell formulation that meets the desired stability and release criteria. The GRAS shell material must stabilize the core material, must not react with or deteriorate the active ingredient, and should release under the specific conditions based on the product application.

Shell materials are typically film-forming, pliable, tasteless, non-hydroscopic, soluble in an aqueous media or solvent, and/or exhibit a phase transition, such as melting or gel point.

Most materials approved for food use are natural or derivatives of a natural product. They can be put into roughly six categories as follows; this is not a comprehensive list. The FDA occasionally adds new GRAS materials, allowing researchers to revisit unsolved problems of the past.

- Polysaccharides/hydrocolloids, such as starch, algin/alginate, agar/agarose, pectin/polypectate, carrageenan, and other gums.
- Proteins such as gelatin, casein, zein, soy, and albumin.
- Fats and fatty acids such as mono-, di- and triglycerides, and lauric, capric, palmitic and stearic acid and their salts.
- Cellulosic derivatives such as methyl- and ethyl-cellulose and CMC.
- Hydrophilic and lipophilic waxes such as shellac, PEG (polyethylene glycol), or carnauba wax or beeswax.
- Sugar derivatives.

The variety of shell materials allows food producers to select compounds that work for water- or fat-soluble food ingredients; dissolve, melt or rupture to release core material; and provide textural characteristics to satisfy consumer palates.

### "Captivating" Techniques

The various microencapsulation processes allow product formulators to make capsules from less than a micrometer to several thousand micrometers in size. Each process offers specific attributes, such as high production rates, large production volume, high product yield, and different capital and operating costs. Other process variables include greater flexibility in shell material selection and differences in microcapsule morphology, particle size, and distribution.

Microencapsulation processes include both physical and chemical techniques. Physical methods use commercially available equipment to create and stabilize the capsules. Chemical techniques apply ionic chemistry to create the microspheres in batch reactors.

Of the physical techniques, the spray-drying process typically uses a two-nozzle (internal or external mix) assembly, allowing air from an annular geometry to atomize and implode the issuing liquid stream to form fine particles carrying the microencapsulated product in a dispersed state. With high particle-specific surface areas, heat from the drying chamber flash-evaporates the solvent or aqueous media, rendering powder microcapsules cyclone-collected into a holding chamber. Some spray-drying operations use rotary atomizers that spin at up to 50,000 rpm.

Other physical techniques include the spinning disc and coextrusion processes. The spinning disc method, similar to the spray-drying process, uses an emulsion or suspension containing the food ingredient, prepared with a solution or melt of the coating material. The emulsion or suspension is fed to

# Microencapsulated Food Ingredients



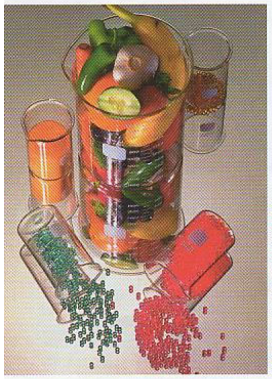


PHOTO COURTESY OF SOUTHWEST RESEARCH INSTITUTE

**Using the various physical and chemical microencapsulation techniques, Southwest Research Institute develops microspheres, ranging in size from half a micrometer to 6,000 micrometers, with various release mechanisms, including mechanical rupture, controlled permeation, digestive dissolution, or sustained, delayed, or targeted release.**

the disc surface and forms a thin wetted layer that, as the disc rotates, breaks up into airborne droplets from surface tension forces that induce thermodynamic instabilities. Resulting capsules are typically spherical. Because the emulsion or suspension is not extruded through orifices, this technique permits use of a higher viscosity shell material and allows higher loading of the food ingredient in the shell. The process also offers a broad range of particle sizes with a controlled distribution.

Coextrusion encapsulation methods, developed at Southwest Research Institute (SwRI), San Antonio, in the 1960s, can create fibers containing the active ingredients within fluid, high-viscosity, glassy sugars and carbohydrates. These fibers can be chopped to create microcylinders. When the viscosity is low and the surface tension of the fluid is high, these extrudates would thermodynamically break up into tiny droplets, creating microcapsules. (This technique is described in the book *Microencapsulation of Food Ingredients;* see Website Resources at end.)

The typical extrusion systems use stationary nozzle coextrusion, centrifugal coextrusion, or submerged nozzle coextrusion. All these processes involve concentric nozzles, which pump the core material through the inner nozzle while the shell formulation is pumped through the annulus, allowing true "core-shell" morphologies, unlike the previously described processes.

As the liquid stream exits the nozzle, local disturbances, such as induced vibration or gravitational, centrifugal, or drag force, control particle size. Typical microcapsules produced by coextrusion range from 100 micrometers to 6 mm, or about the size of a human egg cell to the size of a pencil eraser.

Of the different chemical microencapsulation processes, only phase separation, gelation, and coacervation are widely used in the food industry. All chemical methods are batch processes, although the research community is mounting considerable effort to make them continuous. In phase separation, the food ingredient, such as flavor oil, is emulsified in a polymer solution, and subsequently, an antisolvent is added to induce the precipitation of the polymer around the core. In coacervation, microcapsule shells are formed by ionic interaction between two ionic polymers, typically a polyanion (acacia gum) and a polycation (gelatin). The concept of gelation as a microencapsulation method involves using a technique such as cooling, crosslinking, or a chemical reaction to form gelled microspheres or microcapsules. For example, reacting sodium alginate with calcium chloride forms the insoluble calcium alginate.

**Complex coacervation, phase separation, and gelation are chemical microencapsulation techniques that develop highly stable microcapsules as small as half a micrometer, smaller than some bacteria.**

PHOTO COURTESY OF SOUTHWEST RESEARCH INSTITUTE







## Better Products Through Encapsulation

HeartBar®, manufactured by Unither Pharmaceuticals, Silver Springs, Md., is a line of dietary supplements and medical foods that benefit cardiovascular health. The key ingredient, L-arginine, is a bitter-tasting amino acid. A good-tasting and good-for-you product is achieved by encapsulating this bioactive compound.

Somewhat similarly, encapsulation of nutritional dietary fibers prevents these ingredients from producing an undesirable increase in a product's viscosity. The fibers are then designed to be released once they reach the human digestive tract.

Examples of other foods that rely on encapsulated ingredients include Red Baron's Bake To Rise® pizza from Schwan's Consumer Brands, Bloomington, Minn. There, the action of sodium bicarbonate is delayed until needed in the oven.

www.unitherpharma.com
www.redbaron.com/products_pizzabake.asp

*–Claudia D. O'Donnell, Chief Editor*

Microencapsulation technology remains something of an art, although firmly grounded in science. Combining the right shell materials with the most efficient production process for any given core material and its intended use requires extensive scientific knowledge of all the materials and processes involved and a good feel for how materials behave under various conditions.

As the interest in "wellness" foods or "nutraceuticals" grows, microencapsulation will play a key role in putting the function in functional foods, without sacrificing smell, taste, or convenience. pf

### Website Resources:

www.lfra.co.uk/lfra/lfra/press813.html — Vasishtha and Wade Schlameus describe microencapsulation in the book *Microencapsulation of Food Ingredients,* edited by Per Vilstrup

www.PreparedFoods.com — Type in "microencapsulation" or "encapsulation" in search field

http://ift.confex.com/ift/2002/techprogram/paper_14662.htm — Microencapsulation of probiotics

http://www.doitwithdairy.com/infolib/ingspecsheet/factmicro.htm — Whey protein shell material

*Dr. Niraj Vasishtha is director of the Southwest Research Institute's (SwRI) Microencapsulation, Nanomaterials, and Process Engineering Department within the Chemistry and Chemical Engineering Division. For over 50 years, the non-profit SwRI has been a leader in microencapsulation R&D, and in prototype microcapsule production for the food, pharmaceutical and consumer products industries, among others. Vasishtha specializes in formulations development, encapsulation techniques, and release characterization. For more information see www.swri.com or email niraj.vasishtha@swri.org*

# Keeping Food Fresh

## Keeping Food Fresh: Apeel

Few things are more frustrating than when an unripe avocado turns to mush before you can blink an eye. Some 40% of produce currently goes to waste, often because it goes bad before we can eat it. To cut that waste, Apeel Sciences developed an edible, plant-derived coating for fresh fruits and vegetables that helps them last longer by slowing the ripening process. The company claims the artificial peel can double or even triple the shelf life of a fruit or vegetable.

Apeel introduced its treated avocados to more than 1,000 Kroger locations across the U.S. in September and hopes to expand to other stores and other produce, like limes and asparagus. Soon, consumers may be able to buy things like bananas without worrying they'll go brown in the shopping bag. —Mahita Gajanan


https://time.com/collection/best-inventions-2019/5733137/apeel/

**The Amphiphilic Liquid Coating That Keeps Your Avocados Fresh**

A coating doubles the ripeness window of avocados. How? By supercharging the defenses that evolution crafted on its own.

When plants made the jump from water to land hundreds of millions of years ago, they found themselves to be less, well, wet. Earth's atmosphere has a habit of desiccating things, after all, so plants evolved something called cutin, a waxy barrier against the elements. It's made of fatty acids that link together to form a seal around the plant, helping keep moisture in.

The cutin was such a grand strategy that today you'll find it encapsulating edibles across the plant kingdom, from strawberries to limes to avocados. Not that it's exactly the same solution across the board: A lime can last longer than a strawberry not so much because of the thickness of its skin, but because of the variation of cutin it employs. "It's the same molecular building blocks that are being used in both situations," says James Rogers, CEO of Apeel. "It's just a difference in the arrangement of those molecules on the surface." Call it synergy: A molecule ain't nothin' without its friends. The denser the arrangement, the longer the fruit can resist rot.

Apeel's challenge was first identifying what components of the cutin are water soluble, because they somehow had to apply the stuff to fruits. What they landed on was lipids, which are amphiphilic, meaning they're both water-loving and oil-loving. "Part of it really likes water, and part of it really doesn't like water, which means you can get some limited solubility of that material in water," says Rogers. "Once they dry, then they have the ability to block water." When dissolved in water, the lipid molecules are outnumbered by water molecules. But once that water starts evaporating, those lipid molecules start finding one another, joining into a structure.

As they do so, they build a kind of film that locks in moisture and repels oxygen. So Apeel has developed a substance, which they either spray on fruit or dip the fruit in, that exploits this relationship between lipid molecules you find naturally in fruits. "When we deposit them on a piece of produce and it dries, the result is that we form this special structure, this special barrier, which mimics that structure which is employed by longer shelf life produce," says Rogers. Apeel isn't inventing a newfangled substance. It's using the plant kingdom's own evolved defense against our trifecta of maladies. By coating produce with interacting molecules, they create a microclimate within the fruit to keep good actors in and bad actors out.

https://www.apeel.com/science

# Complex Nanocoating for Protection of Perishable Produce

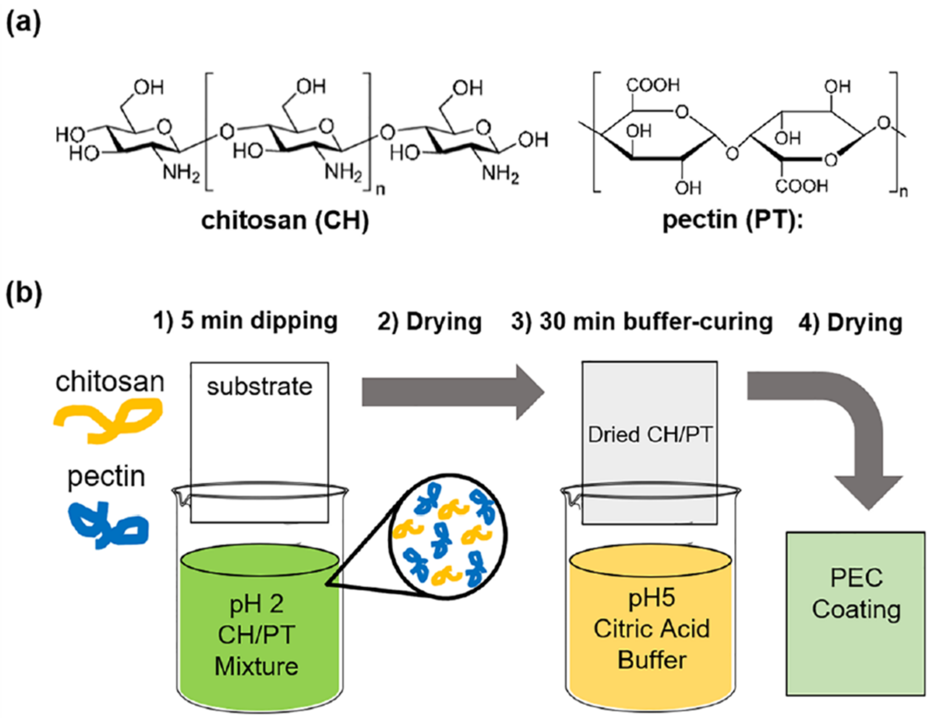



Figure 1. (a) Chemical structures of chitosan (CH) and pectin (PT).
(b) Schematic of the edible polyelectrolyte complex dip-coating process

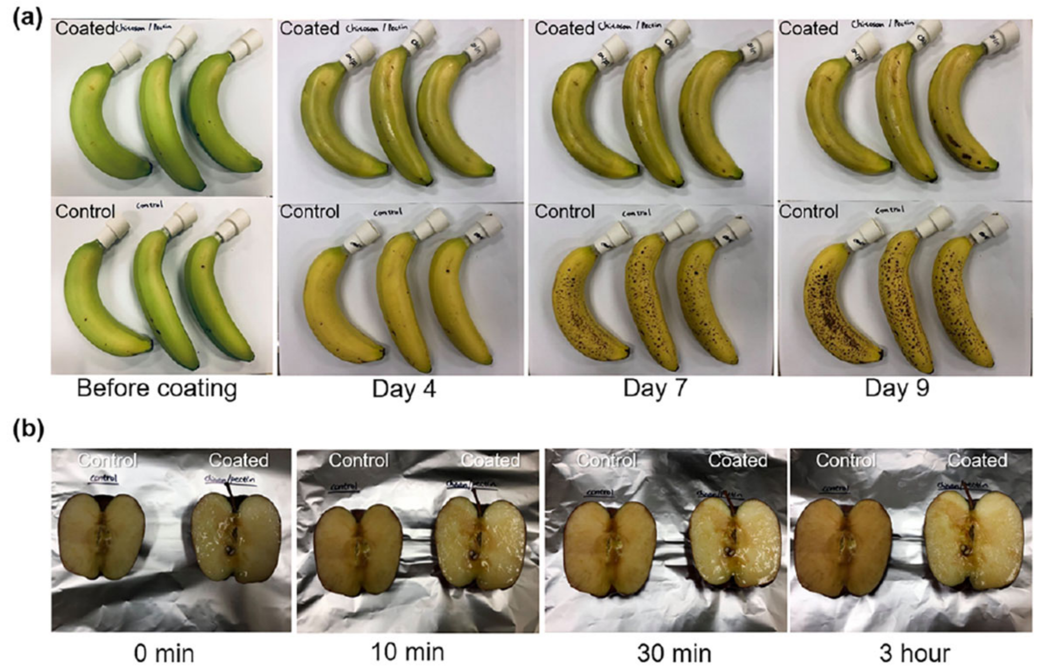



Figure 3. (a) Comparison of CH/PT-coated and uncoated banana ripening as a function of time. Bananas were aged under ambient conditions.
(b) Comparison of CH/PT-coated and uncoated apple browning as a function of time under ambient conditions.

Cheng 2021, Edible polyelectrolyte complex nanocoating for protection of perishable produce

# Boosting Food System Sustainability through Intelligent Packaging

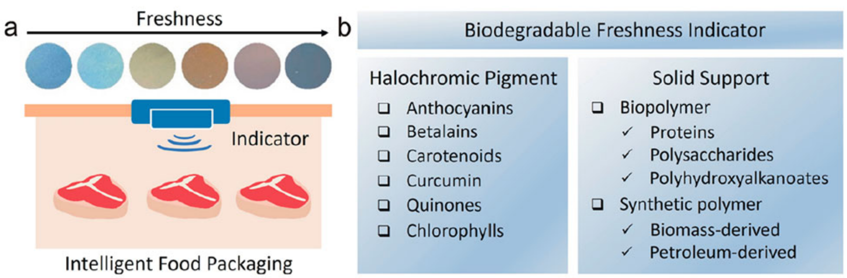



Figure 1. (a) Schematic illustration of intelligent food packaging installed with a freshness indicator. (b) Halochromic pigments and solid supports used for the development of biodegradable freshness indicators.

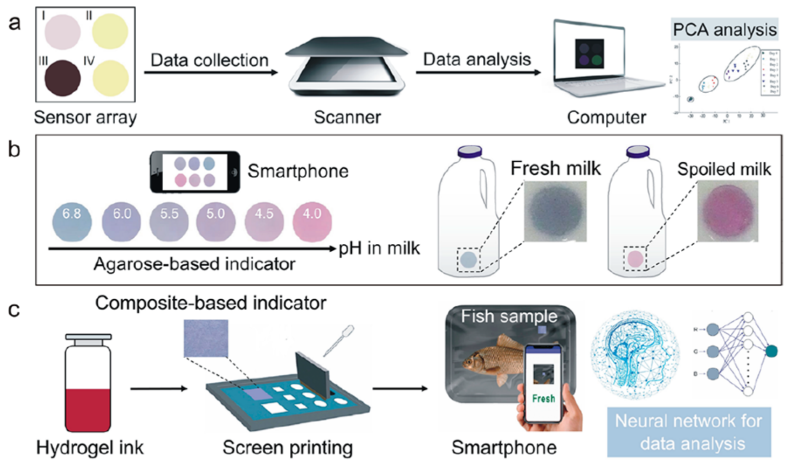



Figure 2. (a) Colorimetric sensor array constructed by printing four natural pigments on a reverse-phase silica gel.52 Pigments were extracted from red radish (I), spinach (II), black rice (III), and winter jasmine (IV). Color signals were analyzed using principal component analysis (PCA). (b) Red cabbage anthocyanin-incorporated agarose film in conjunction with a smartphone for the detection of milk freshness.62 (c) Colorimetric composite-based indicator for smartphone-assisted detection of fish freshness.60 A hydrogel ink containing red cabbage anthocyanins, carboxymethyl chitosan, and oxidized sodium alginate was printed on a cellulose paper to form the indicator.

Table 1. Halochromic Pigments for Use in Biodegradable Freshness Indicators

| Halochromic pigments | | Typical colorimetric response to pH |
|---|---|---|
| Type | Major compounds | |
| Anthocyanins | Cyanidin, Delphinidin, Pelargonidin, Peonidin, Malvidin, Petunidin | pH 2, pH 4, pH 5, pH 7, pH 9, pH 10, pH 12 |
| Betalains | Betacyanin, Betaxanthin | pH 2, pH 4, pH 5, pH 7, pH 9, pH 10, pH 12 |
| Carotenoids | β-Carotene, Lutein, Lycopene | pH <7, pH 7, pH >7 |
| Curcumin | Curcumin | pH 2, pH 4, pH 5, pH 7, pH 9, pH 10, pH 12 |
| Quinones | Alizarin | pH 2, pH 4, pH 5, pH 7, pH 9, pH 10, pH 12 |
| | Shikonin | pH 2, pH 4, pH 5, pH 7, pH 9, pH 10, pH 12 |
| Chlorophylls | Chlorophyll a, b, c1, c2, and d | pH <7, pH 7, pH >7 |

Yu 2023, Boosting food system sustainability through intelligent packaging- application of biodegradable freshness indicators


# Intelligent Food Packaging

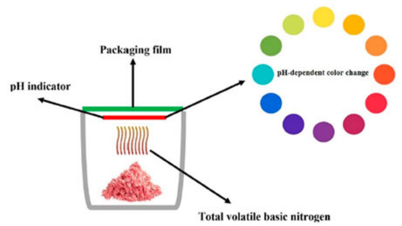



**Figure 1.** Illustration of color changes in the indicator films in response to variation in the food pH due to the production of volatile compounds.

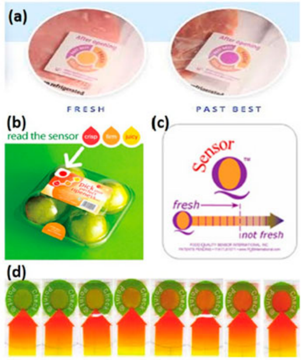



Figure 3. Commercially available colorimetric indicator labels in the market:
(a) Fresh Tag,
(b) RipeSense,
(c) SensorQ, and
(d) CheckPoint.

**Table 1. Application of Natural Colorant Incorporated Biopolymer-Based pH-Sensing Films for Indicating the Freshness of Various Food Products**

| Food | Film base | Natural colorant | Colorant source | Ref |
|---|---|---|---|---|
| Pork | Chitosan | Anthocyanin | Purple sweet potato | 74 |
| Pork | Chitosan/PVA | Anthocyanin | Red cabbage | 75 |
| Chicken | Chitosan/Pectin | Anthocyanin | *Hibiscus rosa-sinensis* | 76 |
| Pork | Chitosan/Starch/PVA | Anthocyanin | Roselle calyx | 77 |
| Sausage | Agar/Tapioca starch | Anthocyanin | Red cabbage | 78 |
| Pork | Agar/Potato starch | Anthocyanin | Purple sweet potato | 79 |
| Pork Lard | κ-carrageenan/Hydroxypropylmethylcellulose | Anthocyanin | *Prunus maackii* juice | 80 |
| Chicken | Cassava starch | Anthocyanin | Blueberry residue | 81 |
| Pork | Cassava starch | Anthocyanin | Grape skin | 82 |
| Pork | Regenerated cellulose | Naphthoquinone | *Arnebia euchroma* | 52 |
| Chicken | Starch/Gelatin | Anthocyanin | Red radish | 83 |
| Pork/Fish | Chitosan | Anthocyanin | *Bauhinia blakeana* Dunn. flower | 84 |
| Pork/Seafood | Cassava starch | Anthocyanin | *Lycium ruthenicum* Murr. | 85 |
| Pork/Fish | PCL/PEO nanofibers | Anthocyanin | Acai (*Eutrepe olereceae*) | 86 |
| Beef/Chicken/Shrimp/Fish | Pectin | Anthocyanin | Red cabbage | 87 |
| Pork/Shrimp | κ-carrageenan | Curcumin | *Curcuma longa* | 88 |
| Shrimp | Chitosan | Curcumin | *Curcuma longa* | 89 |
| Shrimp/Fish | Chitosan | Anthocyanin | Black rice bran | 90 |
| Fish | Chitosan/Corn starch | Anthocyanin | Red cabbage | 91 |
| Fish | PVA | Anthocyanin | Mulberry extract | 92 |
| Fish | Furcellaran Gum | Anthocyanin | Beetroot<br>Elderberry<br>Blueberry<br>Green tea<br>Yerba mate | 93 |
| Fish | Agar | Naphthoquinone | *Arnebia euchroma* root | 53 |
| Fish | Tara gum/Cellulose | Anthocyanin | *Vitis amurensis* husk | 94 |
| Fish | Starch/PVA | Anthocyanin | *Hibiscus sabdariffa* | 95 |
| Fish | Glucomannan/PVA | Betalains | Dragon fruit peel | 56 |
| Fish | Bacterial cellulose nanofiber | Anthocyanin | Black carrot | 41 |
| Fish | Cellulose acetate nanofibers | Alizarin | Roots of Madder family plants | 96 |
| Fish | Chitosan | Alizarin | Roots of Madder family plants | 50 |
| Shrimp | Pectin | Curcumin | *Curcuma longa* | 31 |
| Fish | Starch/Cellulose | Alizarin | Roots of Madder family plants | 27 |
| Shrimp/Milk | κ-carrageenan | Anthocyanins | *Lycium ruthenicum* Murr. | 97 |
| Fish/Milk | Gellan gum/Gelatin | Anthocyanins | Red radish | 98 |
| Milk | Chitosan | Anthocyanin | Purple and black eggplant | 42 |
| Milk | Chitosan/PVA | Anthocyanin | Red cabbage | 99 |
| Milk | Chitosan/cellulose | Anthocyanin | Black carrot | 100 |
| Milk | Tara gum | Anthocyanin | Grape skin | 101 |
| Milk | Starch/PVA | Anthocyanin | Purple sweet potato | 102 |
| Milk | Starch | Anthocyanin | Carrot | 103 |
| Cheese | Polyvinylpyrrolidone/CMC/Bacterial cellulose/Guar gum | Anthocyanin | Red cabbage | 104 |

Priyadarshi 2022, Recent advances in intelligent food packaging applications using natural food colorants

# Naked-Eye Food Freshness

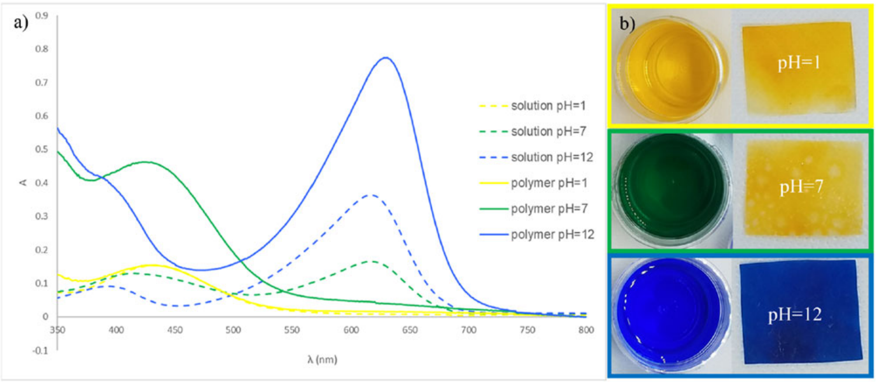



Figure 5. (a) UV−vis spectra and (b) corresponding photographs of a 9.5 μM bromothymol blue (3) solution (dashed lines) and 3-EVOH@ (solid lines) after equilibration at pH 1 (yellow), 7 (green), and 12 (blue).

**Table 2. Onset and Peak Temperatures for the Melting of Functionalized Polymers**

| functionalized polymer | receptor | onset temperature (°C) | peak temperature (°C) |
|---|---|---|---|
| 1-EVOH@ | *m*-cresol purple | 125.69 | 152.17 |
| 2-EVOH@ | *o*-cresol red | 152.00 | 170.16 |
| 3-EVOH@ | bromothymol blue | 147.50 | 170.68 |
| 4-EVOH@ | thymol blue | 137.85 | 160.19 |
| 5-EVOH@ | chlorophenol red | 148.74 | 168.43 |
| 6-EVOH@ | bromophenol blue | 145.59 | 167.97 |

**Polymeric Support of the Array.**
As a polymeric support, ethylene vinyl alcohol copolymers (EVOH), composed of hydrophilic (vinyl alcohol) and hydrophobic (ethylene) segments in a single macromolecule, were selected. These unique copolymers are insoluble in water and have excellent barrier properties, which made them suitable for food packaging films, especially for those foods that are sensitive to certain levels of oxygen or carbon dioxide.31 Moreover, the presence of quite reactive hydroxyl moieties makes EVOH an excellent candidate for our purposes.

Magnaghi 2022, Naked-eye food freshness detection- Innovative polymeric optode for high-protein food spoilage monitoring

# Colorimetric Polymer Sensors and a Smartphone App

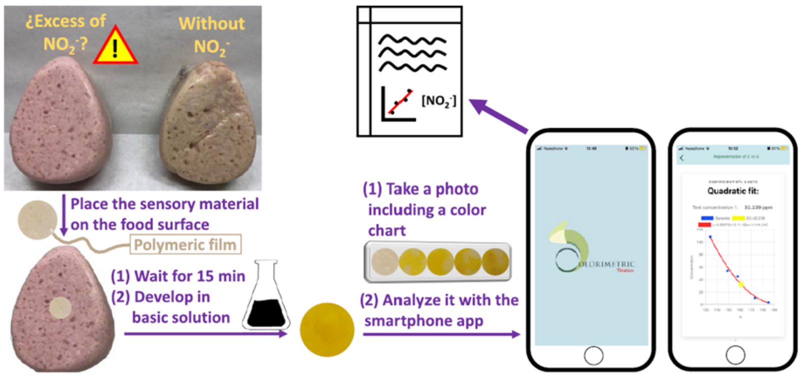



Figure 1. Proposed methodology for the one-pot determination of the nitrite concentration in food samples. The new method is based on a filmshaped polymeric film and is powered by the smartphone application Colorimetric Titration.

Guembe-García 2022, Easy nitrite analysis of processed meat with colorimetric polymer sensors and a smartphone app

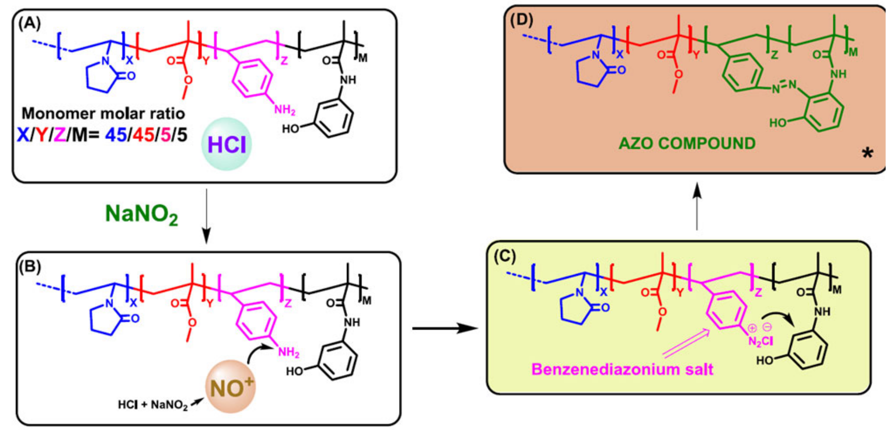



Figure 4. Film-shaped polymeric sensor's (POLYSEN) chemical structures in the different stages of the detection process: (A) starting material, (B) nitrosyl cation formation inside the film, (C) benzenediazonium salt formation, and (D) azo compound formation. *The formation of the azo compound is also possible in the p-OH position, but only the o-OH substitution is shown for clarity.