Ministry of Foreign Affairs

Plant-based & alternative Protein Sector & Midwest Region Analysis

Commissioned by the Netherlands Enterprise Agency

>> *Sustainable. Agricultural. Innovative. International.*

Plant-Based & Alternative Protein Sector & Midwest Region Analysis

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TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

Due to the steady growth of world's population with an expected number of 9 billion people in 2050, demand for the protein will increase significantly. Moreover, current consumption and production patterns of existing protein sources pose a threat to the natural environment by contributing to global warming, resource depletion and the extinction of species (Garnett, 2013).

According to the FAO report 'Livestock's Long Shadow', the global meat and dairy production chains are responsible for approximately 18% of the greenhouse effect and 8% of all water consumption. Given a growing population and an increase in wealth, the demand for food and meat is predicted to increase by around 70% by 2050 for food, and by 2030 for meat (Fiala, 2008; FAO, 2009). The rise in demand and considerations of sustainability aspects faced by the food system, bring about needs to consider alternative solutions in order to prevent some of these effects. In addition, more and more consumers are implementing protein rich diets intro their lives.

Introducing alternative protein sources to the diet is an efficient way to both ensure that the nutritional requirements of consumers are met as well as reduce the negative impact of human behavior on the environment. Alternative protein sources include (i) lab grown or hybrid meat, which is a replacement of meat or dairy products by more sustainable imitations of the product (ii) plant-based commodities (ii) non-traditional sources such as insects.

There are challenges to overcome with this rapidly evolving trend. From the interviews conducted with startups, corporations, and investors, we have identified that the most important challenges to overcome will be providing tasteful products with the least possible environmental impact at affordable pricing levels for consumers to choose. Unfamiliarity with plant or alternative source proteins or at least skepticism around them can be managed with delivery of taste and texture parity, as surveys show. Cost continues to be a challenge as the food systems do not yet properly promote or support the farming for the crops needed, particularly hemp– an opportunity no doubt in the Midwest. If consumer demand continues the trend of today, and global demand for more protein continues to increase, alternative farming practices, particularly in-door agriculture along with other changes in downstream operations will be required to keep up with the demand, particularly in processing.

The other key global challenge may be, however, cooperation and collaboration among regions and markets. Innovative products need to be introduced into new geographies and global retailers need to do a better job of opening up their distribution to international markets. Our global learnings often remain regional for too long. There is a real opportunity to create better nourishment for large populations by sharing of ideas especially among the global corporate and start up communities.

The demand for more protein, particularly alternative protein that may be produced in a more sustainable manner, is real, no doubt. While it is easy to point out environmental challenges that the current protein value chain poses, solutions that will scale to meet this demand need not only consider the consumers expectations, but also the livelihood of all the people involved in, from farm to fork.

2 Introduction

Protein is an essential macronutrient, which every cell in the body needs in order to function properly; it makes up the enzymes that power many chemical reactions and the hemoglobin that carries oxygen in blood.

As consumers become more aware of sustainability and wellbeing, proteins have become an important consideration for many. A study by the Institute of Food Technologists (IFT) in 2015 showed that globally, 59% of consumers globally are actively seeking foods that are high in protein. Due to notions and processes such as global food supply, globalization, impact on third-world countries, health and animal welfare, it is often being asserted that the current system in which animal protein is produced is not sustainable in the long term.

Animal-based foods tend to have higher environmental impact than plant-based foods. Regardless of the production system, livestock are major emitters of greenhouse gases. They represent about 14.5% of all human-induced GHG emissions (which would be roughly equivalent to 7.8 gigatons carbon dioxide equivalent (CO_2e) in 2018) and about 50% of emissions from agriculture.

Although some of these negative consequences could be tackled, for instance, by reducing the contribution of cattle breeding on greenhouse gas emissions and tackling environmental hygiene problems, other effects are of a different nature and require solutions which are different from the classical methods of animal protein production.

As innovation in food technology is accelerating, it is also creating protein production opportunities, such as alternative proteins, with the potential to disrupt the incumbent industry. For intensive animal protein producers, a failure to engage with this innovation at some degree is a risk.

Diversification into producing alternative (i.e., non-animal) proteins is therefore key for both managing the risks of resource-constrained supply chains and for seizing opportunities for market growth. Meat alternatives and broader protein alternatives that can act as substitutes for traditional animal-based food are attracting considerable financial investment.

Consumer demand plays an important role in determining how and what food and agricultural goods are produced. However, a strategy that relies primarily on consumer behavior to drive systemic change neglects other crucial aspects, that is that wide-spread and lasting changes in agriculture are driven by policies, investments, and incentives that facilitate the adoption of agricultural technologies, best practices, and attention to ecosystem services.

Definitions

Alternative proteins' (also known as Novel Protein Foods (NPFs)) is a general term that covers foods which act as a substitute for traditional animal stock. As a whole, proteins can be categorized as animal-sourced, plant-sourced and non-traditional. Alternative proteins do not include animal-sourced category of proteins, which includes meat, eggs, dairy and fish/seafood. This classification (animal-sourced diet) also includes hybrid plant and meat products, which currently dominate the market.

Plant-based Protein is a meaningful food source of protein which is contained in plants. This category can include pulses, tofu, soya, tempeh, seitan, nuts, seeds, certain grains and even peas. Pulses are a large group of plants, which include chickpeas, lentils, beans (such as black, kidney and adzuki beans) and split peas. Plant-sourced protein is the largest source of protein globally (Henchion et al., 2017), particularly in countries such as India with a high percentage of vegetarians.

Protein rich-plants that are used in unprocessed forms to substitute for meat in meals (lentils, for example) through more processed products such as soy-based tofu and wheat-based seiten to recent innovations seeking to make vegetable burgers and other products that are as indistinguishable as possible from real meat. Innovation is occurring across this spectrum from novel recipes and marketing to increase the desirability of the less-processed vegetable alternatives, through advances in food processing involving existing blends and flavors, to biotechnology that combines products from multiple plant sources to create a "mouth-feel" and experience that closely mimics meat. Mycoprotein is another plant-based source of protein, which is typically composed of whole, unprocessed, filamentous fungal biomass, commonly known as mold. It has been around since the 1980s and is produced through fermentation of biological feedstock. Fungi contain approximately 40 percent protein, are high in fiber, have limited carbohydrates, and contain no cholesterol.

Non-traditional Protein includes insects, algae and krill as alternative protein sources. Treats containing various insect species are usually based on the whole larvae of the black-soldier fly, crickets or the yellow mealworm. Each species has a distinct composition, but the protein quality (amino acid composition) and digestibility are generally adequate. Also, insects carry a novel protein which seemingly minimizes the risk of triggering food allergies. Insect-based meat substitutes are potentially more sustainable than animal meat but require more advanced cultivation and technology. Insects have a smaller ecological footprint compared to beef, pork or chicken, but bigger than slaughter by-products, protein meals – which already have a small footprint – or crop production. Whole-cell microalgae can be a feasible alternative to raw materials derived from ocean fish. One of the most popular microalgae in human and pet food is spirulina. This unique ingredient has been proven to offer the pet industry a sustainable, natural source of a highly digestible protein.

Another marine superfood is krill, which is a tiny shrimp-like crustacean. Krill oil or krill meal is an increasingly common functional ingredient in snacks and dental chews. Antarctic krill meal is attracting increasing interest as a source of high-quality protein. Compared to other animal proteins, the advantage is that it is low in fat and a rich source of omega-3 fatty acids. Antioxidant levels in krill are higher than in fish, suggesting benefits against oxidative damage. These sea creatures are caught in the wild. Krill eat algae as their food source, so are free of pollutants and heavy metals.
Innovation in this area includes the discovery and investigation of new insect species of value for food production, and developments in how they may be produced economically at scale. Insects can be consumed in their natural state, although to increase acceptability in cultures where insect consumption is not traditional, there is also research into developing novel products that contain insects in a different form, for instance as flour. However, it is currently cost prohibitive to isolate protein from the flour as the cost of some insects, like crickets, is high, making the process difficult to scale. Food producers are also exploring using grasshoppers as an edible insect source, but development is still in an early stage.

Why now?

Much of the debate about meat production today revolves around its environmental impact, the greenhouse-gas emissions. Impacts vary greatly between livestock types and production systems. Red meat (cow, sheep and goat) production is a particularly large source of greenhouse gases because of methane production in ruminant digestion. Approximately 15% of anthropogenic greenhouse-gas emissions come from livestock production (about 3% is due to dairy production), of which 40% are due to beef and dairy farming. Livestock rearing can also be a source of dispersed and point pollution (including by nitrogen, phosphorous and pathogenic microorganisms), especially where rules on manure and slurry management are lacking or poorly enforced.

The need for grazing land and for arable land to grow animal feed is the single most important driver of deforestation, with consequences for greenhouse-gas emissions and biodiversity. Where livestock are reared on land that cannot be used to grow arable crops, this can contribute to mitigating climate change by helping store carbon in the soil. However, the contributions are relatively small and often undermined by poor land management or overgrazing. It is also important to think of the opportunity cost of using land for livestock rearing that might be used for other environmentally important functions such as carbon sequestration through reforestation. Meat consumption in high-income countries is high, but relatively constant, while consumption is rising rapidly in China and less rapidly in most other regions (excluding India). Overall, global meat consumption is rising with no sign of a plateau. with Asia rapidly converging on "Western" levels of consumption. Shifting towards a diet containing alternative proteins rather than beef can lead to significant reductions in greenhouse-gas emissions, especially for transitions to plant- or insect-based alternatives. While current estimates of emissions from cultured beef suggest only modest reductions, depending on how production of cultured beef is scaled up, there is the possibility of significant emissions reductions as well.

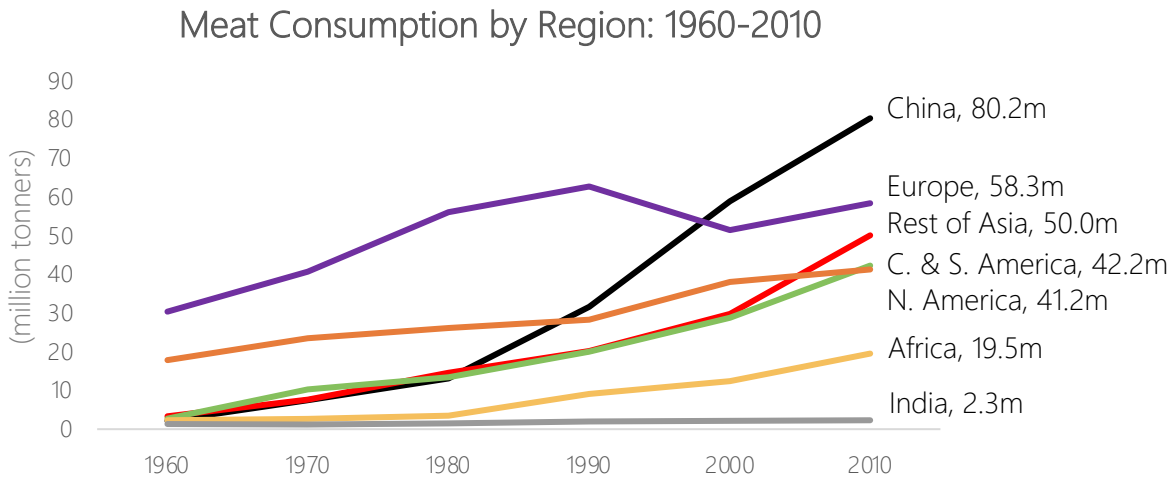


Figure 1: Trends in the consumption of meat, FAOStat

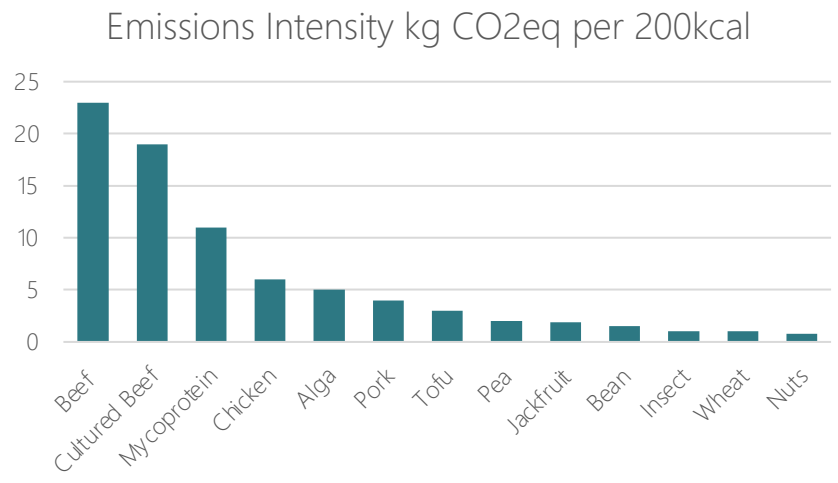


Figure 2:Emission intensities of the different food types, WEF

Land Use

Land use (occupation) is another crucial aspect (besides greenhouse gas emission) because it is very relevant to damage to ecosystem and consequential global loss of biodiversity.
In general, from an analysis of life cycle assessment studies, it can be concluded that food products of animal origin have higher climate- and land use related impacts than vegetable products. Per unit of protein vegetal products, certain types of seafood and poultry products have relatively small carbon footprints. Much land is needed to produce beef protein, although the impact of land use differs strongly between extensively produced beef (demanding mainly grasslands) and pork and poultry (demanding arable land)

Product	Carbon footprint (kg CO_2-eq kg^{-1})	Land use (m^2 y kg^{-1})	Of which grassland (m^2 y kg^{-1})
Beef (15 studies, $n = 26$)	9–129	7–420	2–420
Industrial systems ($n = 11$)	9–42	15–29	2–26
Meadows, suckler herds ($n = 8$)	23–52	33–158	25–140
Extensive pastoral systems ($n = 4$)	12–129	286–420	250–420
Culled dairy cows ($n = 3$)	9–12	7	ca 5
Pork (eight studies, $n = 11$)	4–11	8–15	
Poultry (four studies, $n = 5$)	2–6	5–8	
Eggs (four studies, $n = 5$)	2–6	4–7	
Mutton and Lamb (four studies, $n = 5$)	10–150	20–33	ca 18–30
Milk (12 studies, $n = 14$)	1–2	1–2	ca 1
Cheese*	6–22	6–17	ca 7
Seafood from fisheries (nine studies, $n = 18$)	1–86	**	
Seafood from aquaculture***(seven studies, $n = 11$)	3–15	2–6***	
Meat substitutes containing egg or milk protein (one study, $n = 2$)	3–6	1–3	0–2
Meat substitutes, 100% vegetal (one study, $n = 4$)	1–2	2–3	
Pulses, dry (two studies, $n = 3$)	1–2	3–8	

* Range based on milk range and results from the study by Berlin (2002). For cheese, 6–7 kg of milk is required (Blonk et al., 2008).
** Land use: bottom trawling may have an effect on large areas of the seabed (Davies et al., 2009; Ellingsen and Aanondsen, 2006; Vázquez-Rowe et al., 2011; Ziegler and Valentinsson, 2008).
*** Land use: only land used for vegetal feed component.

Figure 14: Carbon footprint and land use per kilogram of product, D. Nijdam

Comparison Of Various Land Uses

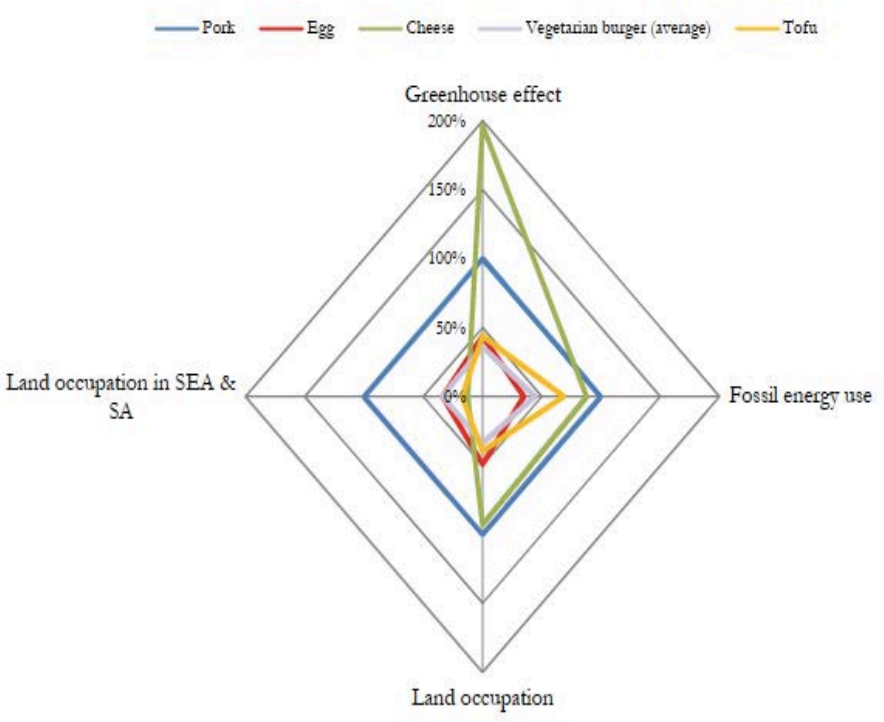


Figure 15: Comparison of proteins by factors

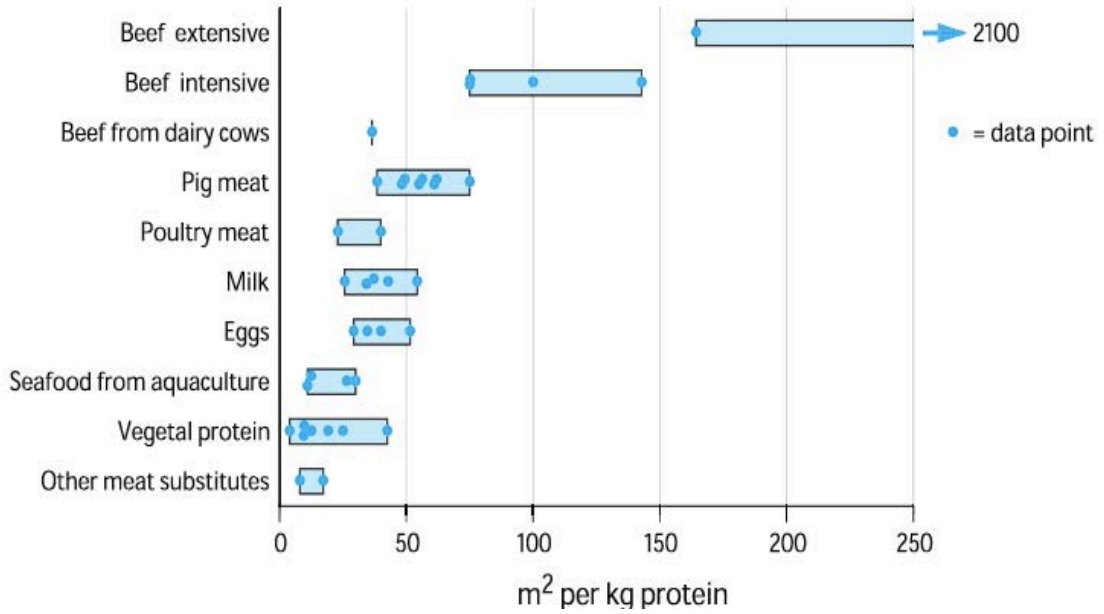


Figure 16: Land use per kilogram of protein

Comparison of Land Requirements

The U.S. Midwest region has little land allocation to crops which are good sources for plant-based protein, because the economics of predominantly chosen grains in Midwest are much higher compared to most protein rich alternatives like peas. Canada's Midwest region, due to its climatic conditions *is best fitted for legumes farming than grains*, and today it is the largest producer of legumes. In the U.S. Dakota, Montana, and Idaho are the primary states where dominant choice of crop is legumes.

Since legumes are limited in production in U.S. and Midwest, the total harvest capacity is far from meeting the demand of the industry. Currently total harvest capacity is roughly 91M tons globally and only 10-15% is serving plant-based protein ingredient markets.

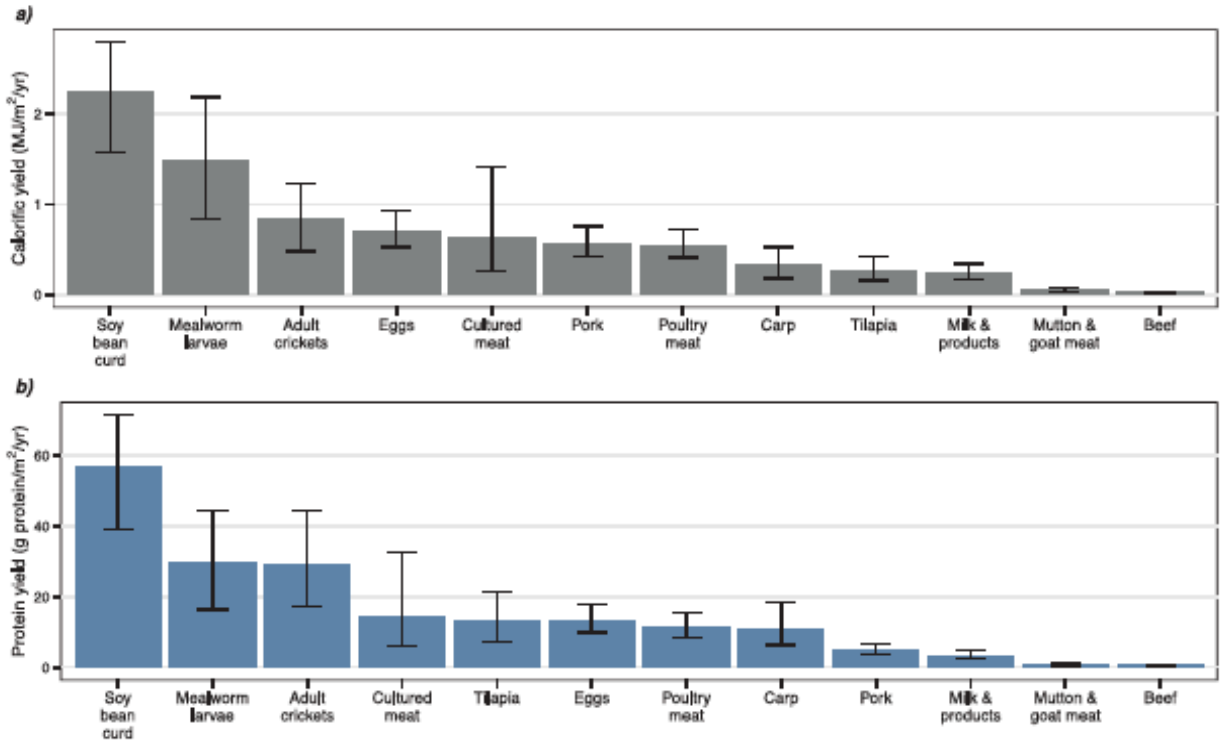
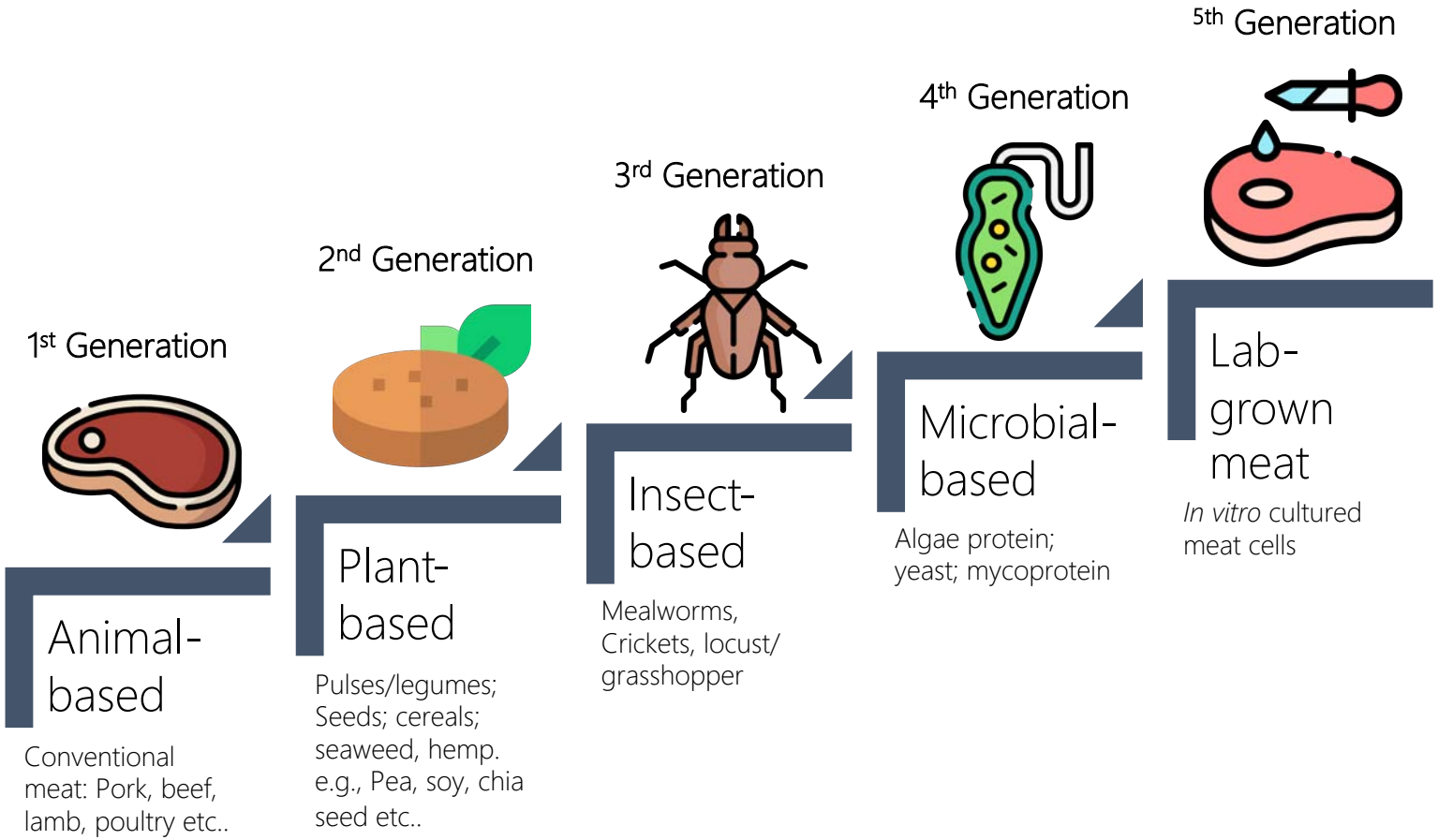


Figure 15: Energy and protein per unit are of agricultural land, P. Alexander

3 Applications: Overview



Availability, price and protein quality all influence the choices processors make when choosing raw materials for protein extraction and manufacturing.

The protein taken out of a plant, whether it's soy or pea, might be 25 percent, and the rest starch or oil, for example. Therefore, it is the isolation and production of co-products from the side streams that adds to profitability in this industry – which of course also reduces wastage.

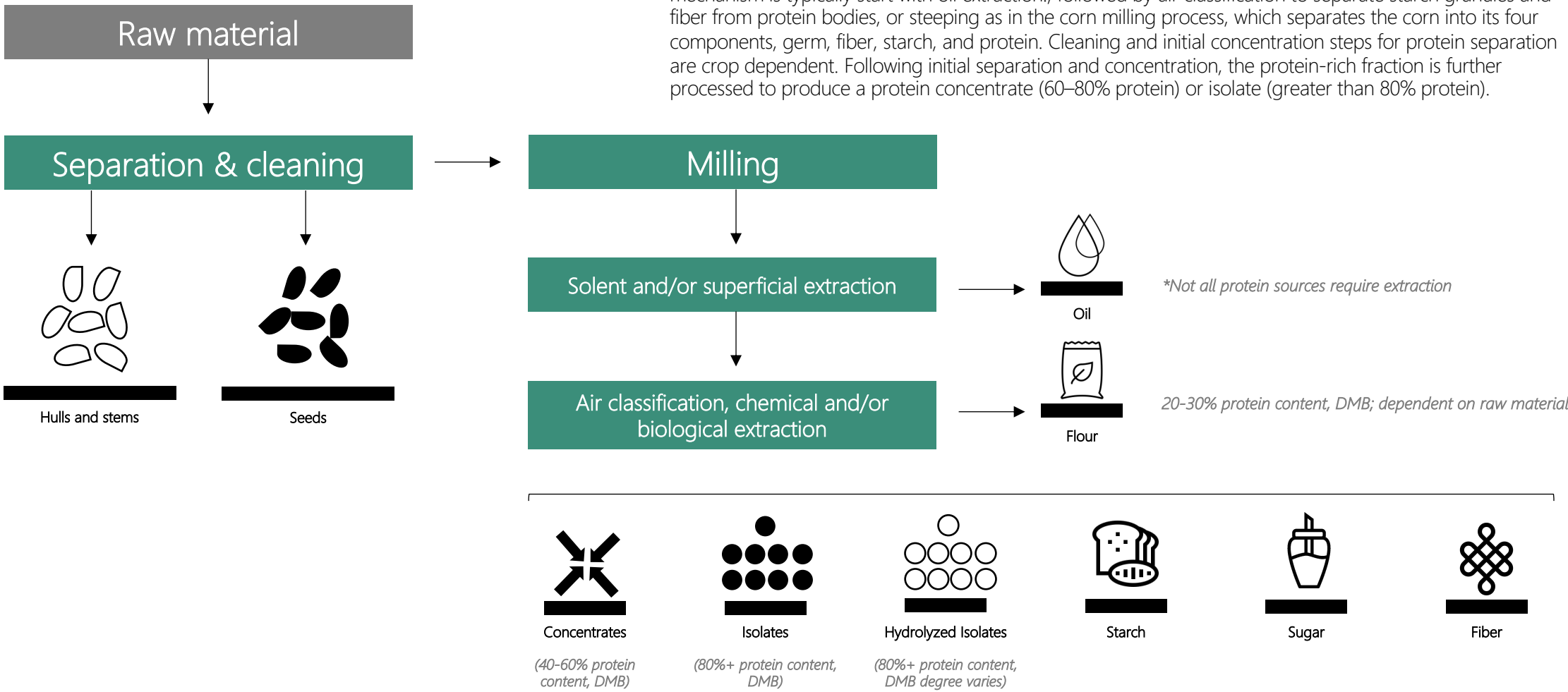
Each raw material has its own unique composition and properties, requiring a tailored process to separate each efficiently into its individual ingredients. This challenge forces producers rethink whether the protein being recovered the primary product or a co-product and whether the raw product being utilized to its fullest extent.

Especially in plant protein production, some of the most common processing scenarios are:

a) protein production with starch as co-product (peas, barley or wheat)
b) protein production with oil as co-product (soybeans, rape seed or sunflower seed)
c) starch production with protein as co-product (potatoes, corn or rice)

Processing & Applications Scheme

The chart exhibits an allegorical description of plant protein extraction and purification processes. The mechanism is typically start with oil extraction., followed by air classification to separate starch granules and fiber from protein bodies, or steeping as in the corn milling process, which separates the corn into its four components, germ, fiber, starch, and protein. Cleaning and initial concentration steps for protein separation are crop dependent. Following initial separation and concentration, the protein-rich fraction is further processed to produce a protein concentrate (60–80% protein) or isolate (greater than 80% protein).



Functionality

Proteins are often expected to have useful attributes:

- Dispersibility
- Solubility
- Viscosity
- Gelation
- Emulsification
- Foaming
- Water holding
- Oil holding

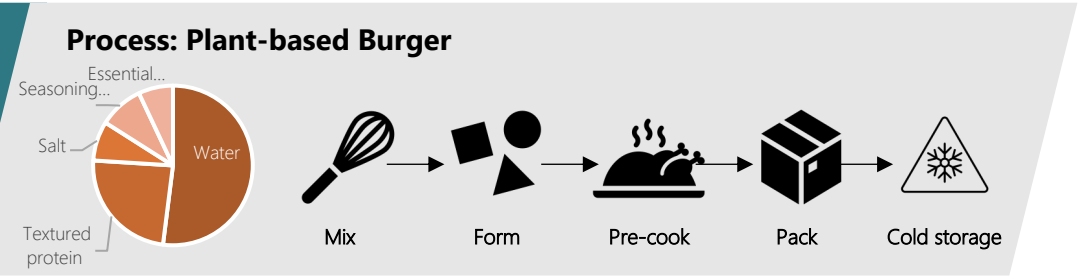
These functions may be dependent on:

- Solvent (e.g. pH, salt, Aw)
- Temperature
- Time
- Pressure
- Shear
- Concentration

The following production profiles cover major plant-based product categories—plant-based meat & fish, milk, yogurt, cheese, and eggs. Each of the profiles contains details on composition, expectations, consumption, and areas of opportunity, as well as an example process diagram for a major product in the category alongside an example composition at-a-glance .

Plant-Based Meat & Fish

Plant-Based Meat & Fish



Composition

- Textured base protein, fast, binder, flavor, salt, preservative, color

Expectation

- Characteristic flavor, texture & appearance
- Provides protein, fat, iron

Composition

- Center of plate
- Comminuted: burgers, sausage, nuggets
- Intact muscle: steaks, slices, breasts, wings

Areas of Opportunity

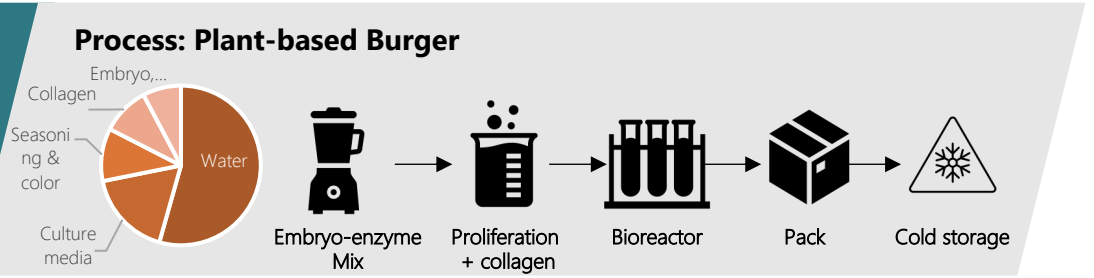
Functionality	Intact muscle, fat retention, seafood
Flavor	Base off-flavor, exact matches, subtle flavors, precursor ingredients
Variety	Goat, lamb, organ meats
Experience	Raw feel, recipe resilience, color change on cooking
Cost	Scale, automation
Health	Alt. proteins, clean label, salt & saturated fat reduction

Watchlist

Ripple | Elmhurst 1925 | Eden Foods | Califia Farms

Cultured Meat & Fish

Cell-Based Meat & Fish



Composition

- Textured base protein, fast, binder, flavor, salt, preservative, color

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- Characteristic flavor, texture & appearance
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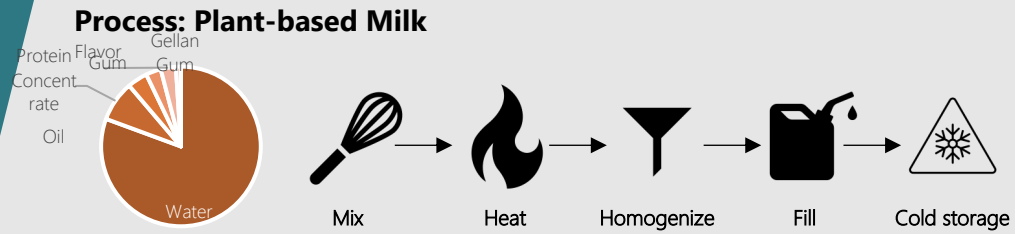
Watchlist

Mosa Meat | Memphis Meats | Aleph Farms | Higher Steaks

Plant-Based Milk

Plant-Based Milk



Composition

- Water, base plant protein source, vitamins (antioxidant), minerals (pH reg), salt, sweetener, flavor, texturizer, oil, emulsifier

Expectation

- Smooth, low viscosity, neutral mild dairy flavor & sweetness, white, protein & calcium

Composition

- Cold drink & coffee/tea/cacao
- Breakfast cereal/bowl
- Desserts
- Sauces

Areas of Opportunity

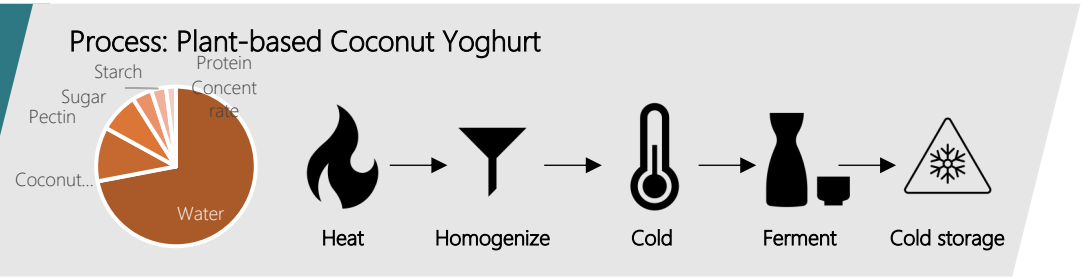
Functionality	Combining individual products with positive attributes
Flavor	Dairy flavor, no off-notes
Experience	Creamy texture
Applications	Acid & heat tolerance (barista style)
Cost	Parity
Clean Label	Clean label stabilization

Watchlist

Ripple | Elmhurst 1925 | Eden Foods | Califia Farms

Plant-Based Yoghurt

Plant-Based Yoghurt



Composition

- Water, base plant protein source, texturizer, culture, often sweetener, pH regulator, vitamin, flavor

Expectation

- Creamy, smooth, viscous weak gel, lactic acid, mildly sweet, white, provides probiotics, protein, calcium

Composition

- Cold, sweetened with fruit paste
- Cold, sauce for savory dish, often with spice, cucumber

Areas of Opportunity

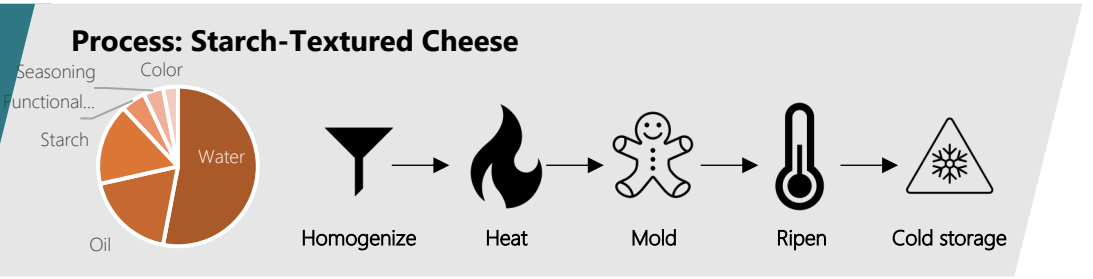
Functionality	Combining individual products with positive attributes
Flavor	Creamy flavor, no off-notes
Experience	Creamy, non-grainy mouthfeel
Clean Label	Clean-label texture & stabilization
Nutrition	Nutritional equivalence
Allergenicity	Allergen-free

Watchlist

Forager Project | Nancy's | Kite Hill | Lavva

Plant-Based Cheese

Plant-Based Cheese



Composition

- Nut-based; cashews, starch/gums, seasoning
- Cultured emulsions, coconut oil, starch/gums, seasoning, acid, color, preservatives

Expectation

- Yellow/white, fatty/creamy, lactic acid, indulgent, provides protein & calcium

Areas of Opportunity

Flavor	Dairy flavor, reduce base off-notes
Variety	Camembert, parmesan, Roquefort, etc..
Performance	Improved melting, browning, grating
Cost	Cost parity, scale, automation
Nutrition	Dairy cheese equivalence, protein, calcium, alternative proteins, saturated fat reduction

Composition

- Melt: grateable, hot viscosity, browning, stretch
- Spread: soft paste-like high-viscosity
- Slice: textures/flavors to replicate original (cheddar, camembert, feta)

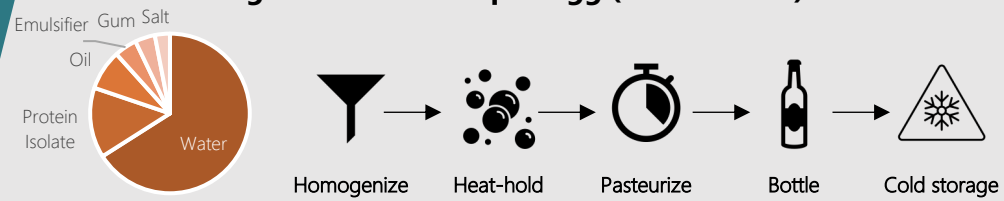
Watchlist

UPrise Foods | Violife | Daiya | Siete

Plant-Based Egg

Plant-Based Egg

Process: Mung Bean Protein Liquid Egg (for scramble)



Composition

- Varies widely depending on the egg-like functionality required and the application

Expectation

- Heat-included gelation, foaming, emulsification, protein, mild sulfurous flavor, color

Composition

- As a whole food (boiled, scrambled)
- For functionality (baked goods, dressing)
- Whites, yolks or whole

Areas of Opportunity

Functionality	One size, fits all solution
Applications	Application-specific solutions
Performance	Matching cook time and texture
Clean Label	Clean label & authentic

Watchlist

JUST Egg

Key Attributes of Most Common Sources

Protein	Protein Concentration	PDCAAS	Allergen Risk	Commercial Stage	Flavor	Functionality	Cost (/kg protein)	Global Crop Volume (MMT)
Soy								
Pea								
Wheat								
Canola								
Chickpea								
Fava Bean								
Lentil								
Lupin								
Mung Bean								
Navy Bean								
Peanut								
Sunflower								
Almond								
Corn								
Oat								
Potato								
Quinoa								
Rice								
Sorghum								

Note: For some proteins, certain metrics are not available

Hemp: An Emerging Alternative Source

Hemp seed is an undervalued co-product resulting from the cultivation of industrial hemp. This plant resource has significant contents in protein and oil of nutritional value, that may help to meet the challenges of sustainable food. Extraction yields generally vary from 34% to 51%, and the protein purity of the resulting protein isolates from 87% to 94%. Many authors have highlighted that hemp protein hydrolysates possess a wide range of health biological activities such as antioxidant properties, metal chelation, antihypertensive, hypoglycemic properties. Despite limited solubility, hemp protein ingredients represent an *alternative to current cereal and legume protein materials* in human diet in the future.

In terms of *nutrition* hemp seed is rich in vitamin E, minerals, antioxidants, and fiber, omega-3 and omega-6 fatty acids. The B vitamin content is not much different from that of other grains. However, what makes hemp seeds different is the quality and proportion of the protein and fatty acids, respectively. Hemp seed protein is composed of 65% high quality protein, the most potent protein of any plant source, with the remaining 35% provided by albumin protein and essential amino acids. Hemp seeds contain all 9 essential amino acids (AAs), with a high concentration of sulfur-containing AAs (methionine and cysteine), which are usually low in vegetable proteins.

According to a Mintel study, From January 2008 to November 2017, there were 452 launches of products containing hemp around the world. Most of these occurred in the *food* category. North America had the second-largest launches of hemp-containing products with a total of 148 products. The top five subcategories of food were: **snacks (48%), sauces and seasonings (20%), bakery (13%), desserts and ice cream (10%), dairy (9%).**
The top claims hemp-containing products revolve around having no additives/preservatives, followed by reduced sugar, gluten free, vegan, and organic.

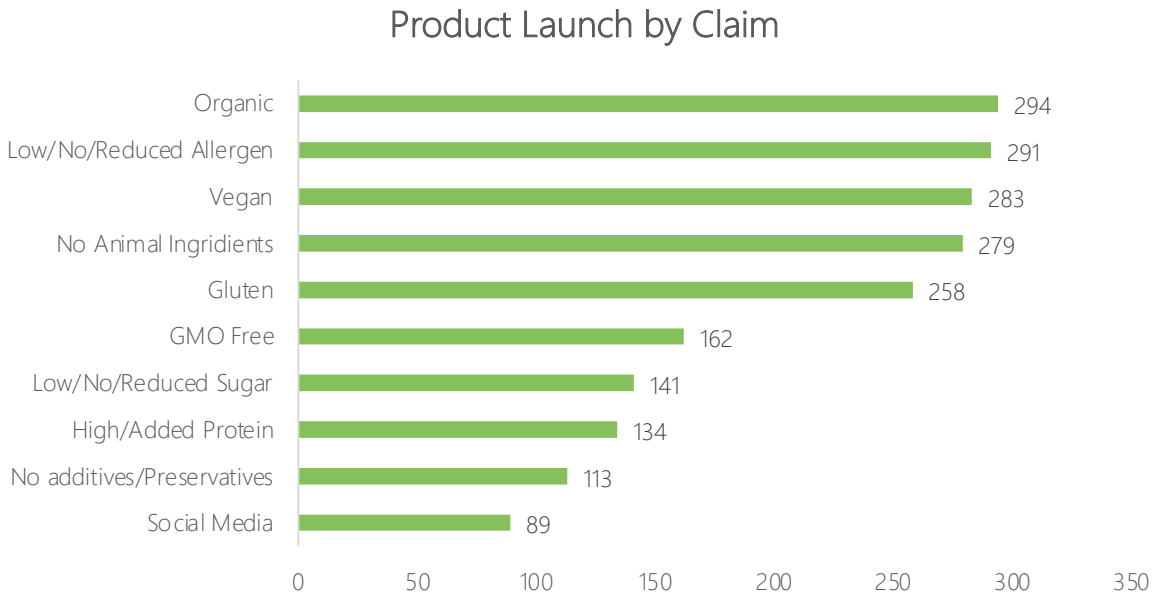


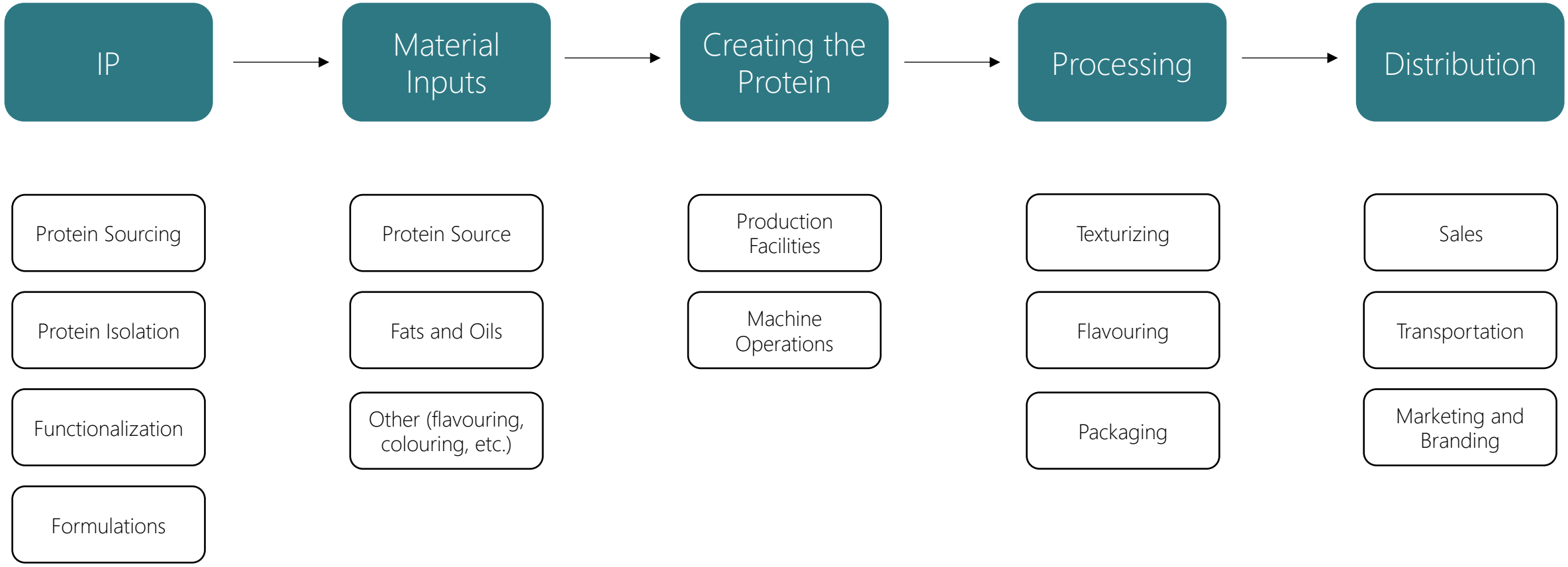
Figure 10. Product launch by claim, Mintel, 2017

Ingredient	Number of Products
Hemp Protein	247
Hemp Seed Oil	111
Hemp Flour	43
Hemp Juice	18
Dogbane	13
Hemp Seed Milk	12
Hemp Seed Extract	11
Hemp Tofu	3

Figure 11. Hemp ingredients used in products launched in the world, from 2008 to 2017, Mintel, 2017

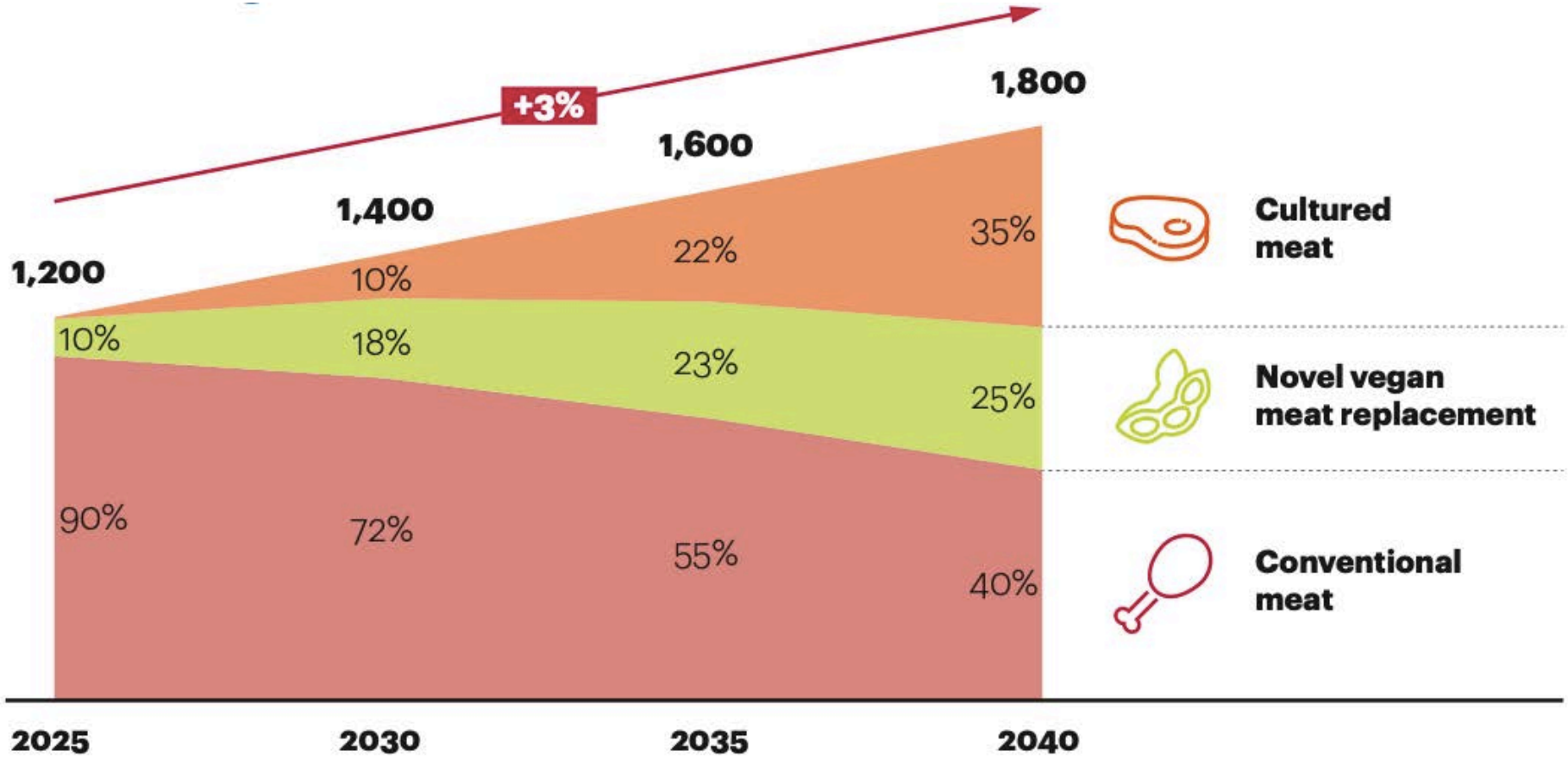
4. Industry Overview: Value Chain

Alternative protein value chain, at a high-level, is composed of several critical elements that vary by the protein origin as well as geography and brands' choice of protein alternative in consumer applications. This not only creates significant opportunities for startups but also challenges for the industry to scale at the pace it is envisioned.

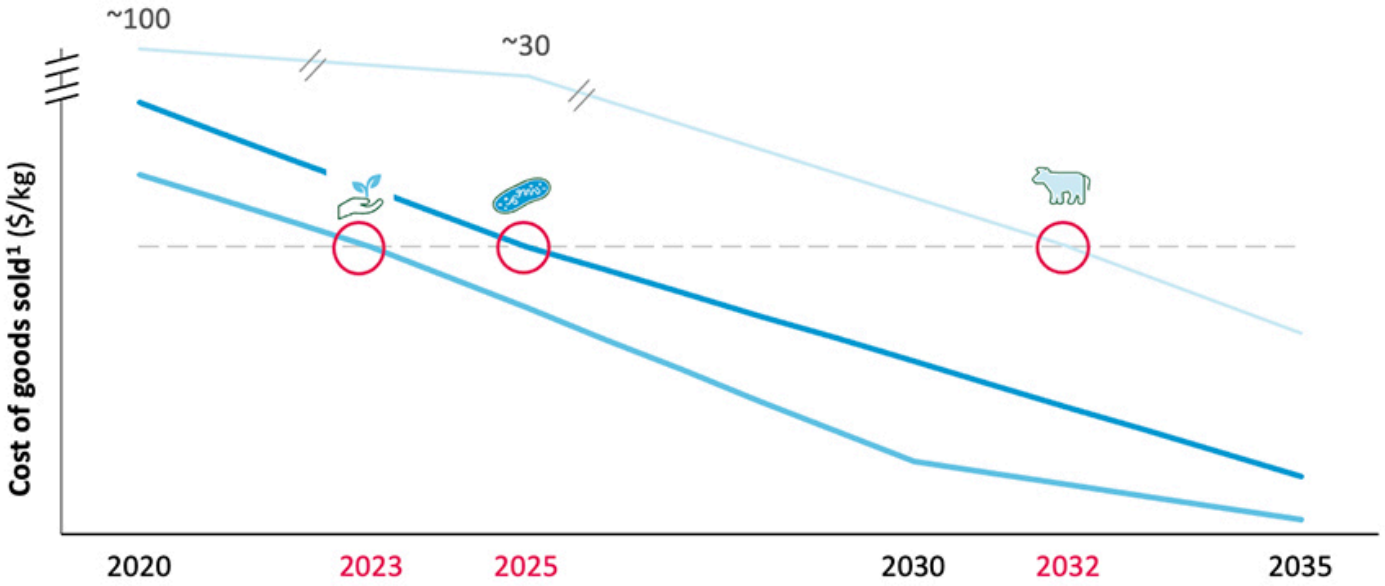


Source: Plant Based Meat Value Chain, Robert Yaman

Global Meat Market Forecast (in $ bn, global)



Alternative proteins will reach cost parity with animal-based protein soon.

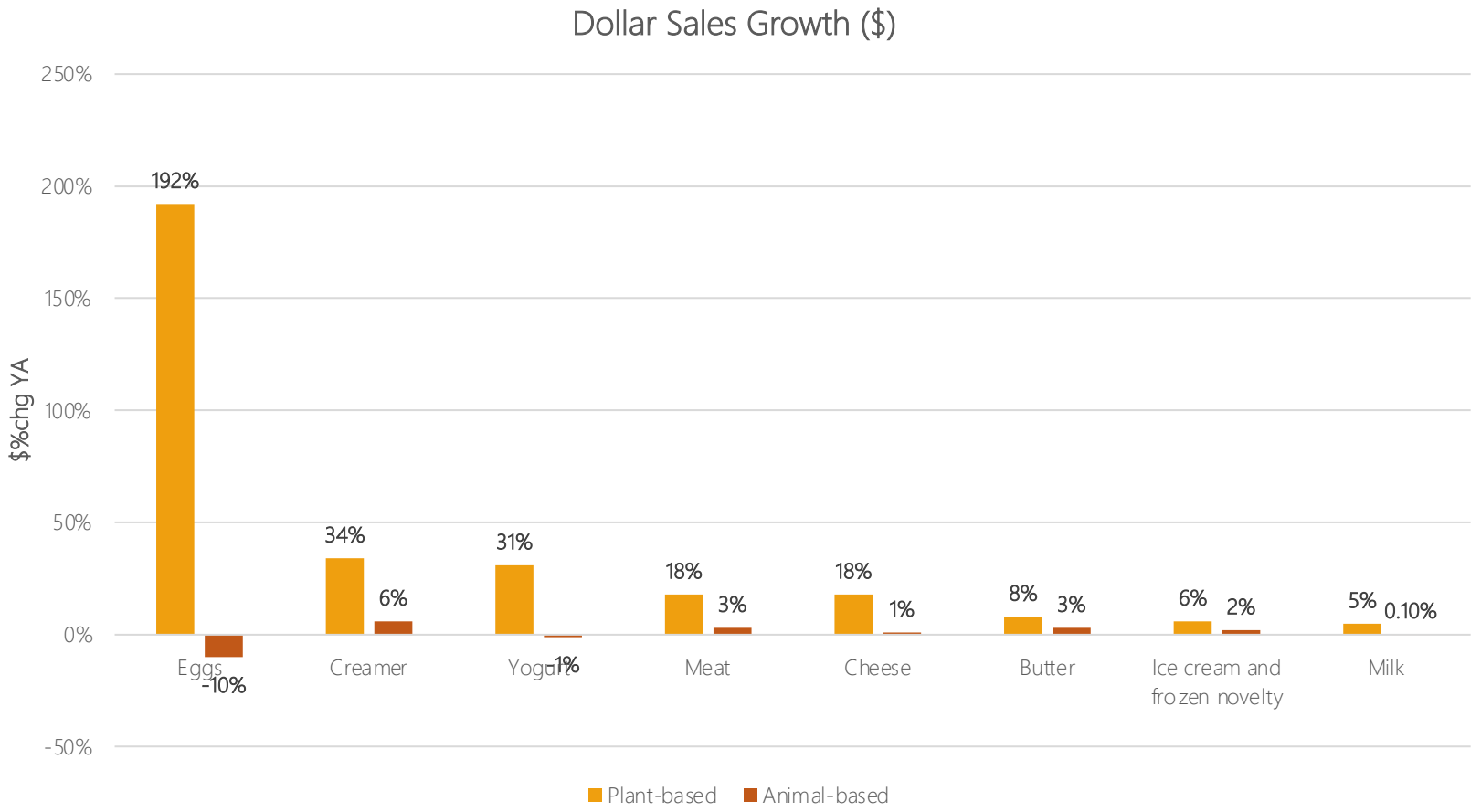


Conventional animal-based
Plant-based
Microorganism-based
Animal cell-based

Timing of parity:
A substitute with realistic taste and texture reaches the same price as conventional protein

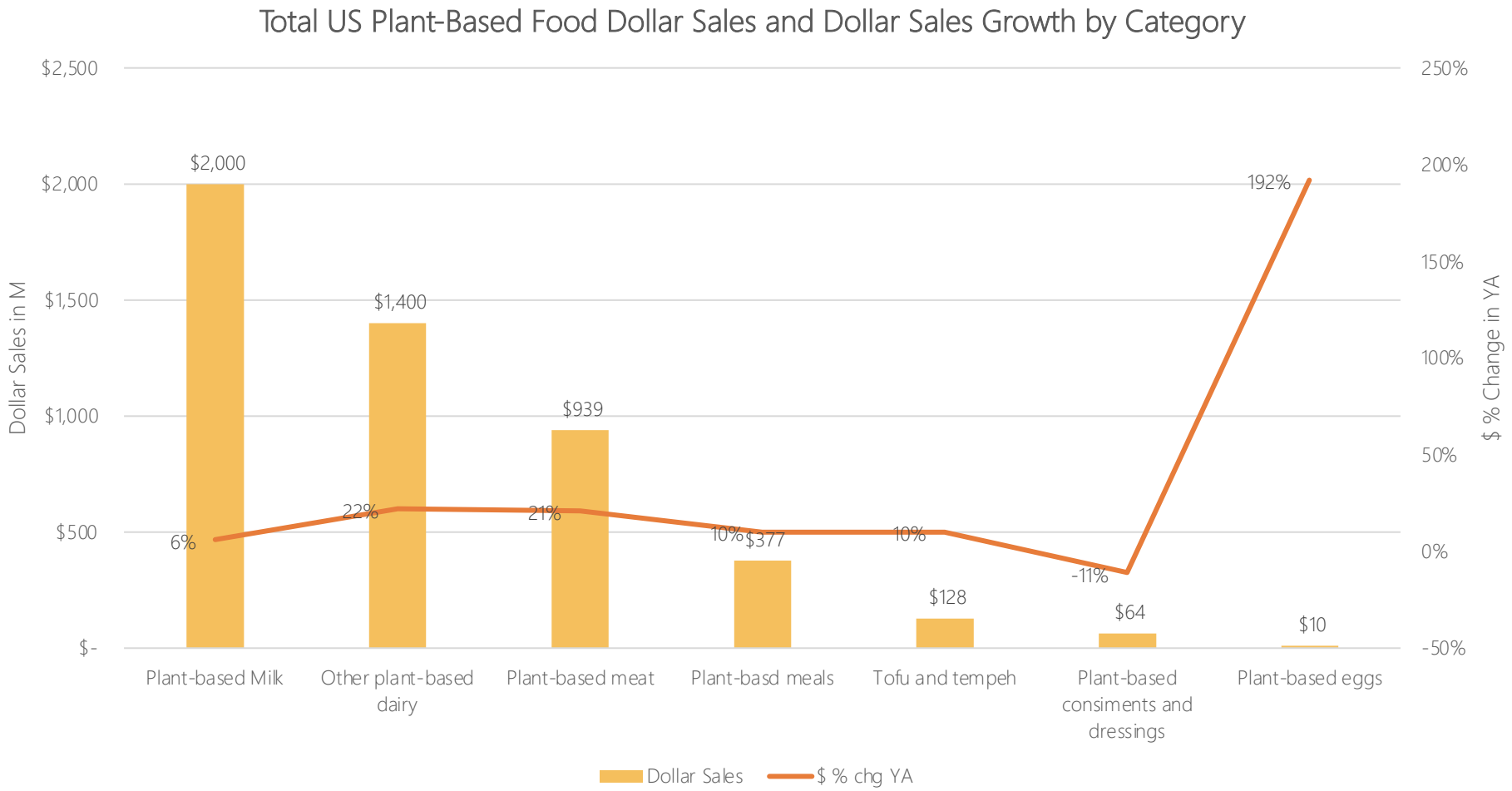
1. Illustrative data for US and EU – variations by product group and geography omitted for clarity
Source: Expert interviews; industry reports; Blue Horizon & BCG

US Market Overview: Animal-Based and Plant-based Products Comparison



Source: Market Overview, GFI

US Market Overview – Plant-based



Source: Market Overview, GFI

US Market Overview: Plant-based Market By category (2019)

Category	2017 Sales (values in 000's)	2018 Sales (values in 000's)	2019 Sales (values in 000's)	$ Sales Growth (2018-2019)	$ Sales Growth (2017-2019)
Plant-based milk	$1,765,971	$1,920,579	$2,016,540	5.0%	14.2%
Plant-based meat	$681,763	$793,614	$939,459	18.4%	37.8%
Plant-based meals	$300,464	$348,102	$376,972	8.3%	25.5%
Plant-based ice cream and frozen novelty	$250,513	$317,575	$334,549	5.7%	33.9%
Plant-based creamer	$148,809	$213,381	$286,662	34.3%	92.6%
Plant-based yogurt	$144,906	$215,156	$282,502	31.3%	95.0%
Plant-based butter	$173,053	$183,017	$198,359	8.4%	14.6%
Plant-based cheese	$125,377	$159,783	$189,099	18.3%	50.8%
Tofu and tempeh	$111,823	$118,807	$127,856	7.8%	14.6%
Plant-based ready-to-drink beverages	$87,862	$103,242	$122,276	18.4%	39.2%
Plant-based condiments, dressings and mayo	$62,841	$71,465	$63,696	10.9%	1.4%
Plant-based dairy spreads, dips, sour cream and sauces	$12,543	$19,206	$29,513	53.7%	135.3%
Plant-based eggs	$3,001	$3,377	$9,851	191.7%	228.2%
Grand Total	**$3,868,925**	**$4,467,358**	**$4,978,587**	**11.4%**	**28.7%**

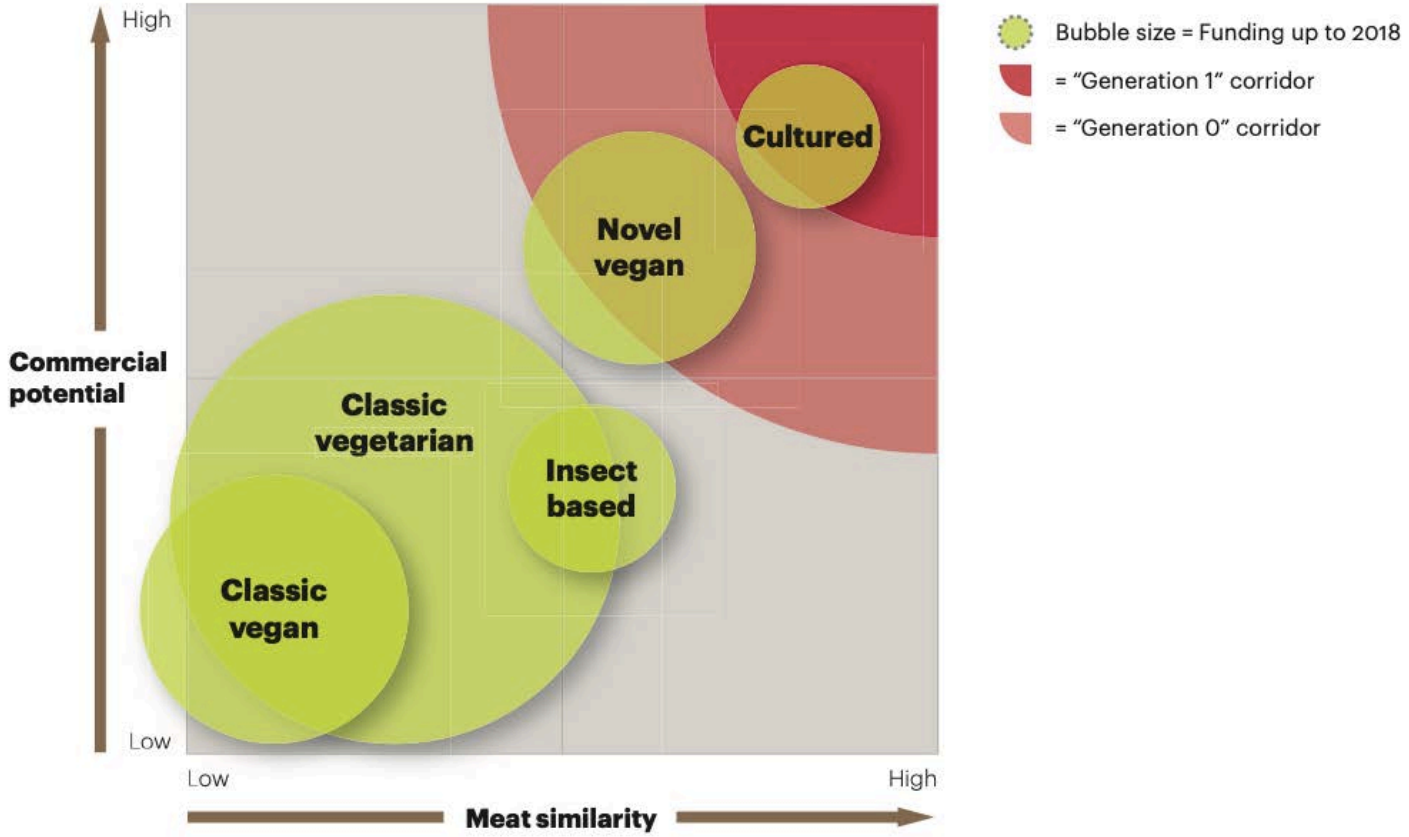
Source: Market Overview, GFI

Industry Overview: Plant-based

- *Investments:*
  - Investment in alternative protein companies in Q1 2020 has surpassed 2019 full-year totals, with **$824 million** invested in 2019 and **$930 million already invested in Q1 2020**
  - U.S. plant-based meat, egg, and dairy companies have received **$2.7 billion** in venture capital investments in the past decade (Q2 2010–Q1 2020), 45 percent or $1.2 billion of which was raised in 2019 and Q1 2020 alone
- *Products*:
  - In 2019 ***15%*** *of Food and Beverage* dollars come from products that meet a plant-based diet, up 1.3% from prior year
  - Foods with protein base of **YEAST** grew **45%** with annual sales of **$46M**
  - Foods with protein base of **PEA** grew **8%** with annual sales of **$1.3B**
  - Foods with protein base of **SOY** grew **3%** with annual sales of **$2.9B**
- *Corporates*:
  - Two in five global food giants with combined annual revenues of $459 billion now have dedicated teams to develop and sell plant-based alternatives to meat and dairy; with Tesco and Unilever ranked top
  - 10% of all Nestlé's R&D employees are now dedicated solely to the development of plant-based products, and it is to build a $100m plant-based center in China.
  - Unilever have built a $94m innovation center in the Netherlands as "protein transition" goes mainstream, also has invested $94 million in a new innovation center housing 500 employees with a focus on plant-based innovation for brands like Knorr and Hellmann's.
- *R&D Priorities*
  - Breeding & engineering for higher protein yields and functionality
  - Protein fractionation and functionalization
  - Improved plant fat profiles
  - Novel methods for texturizing and structuring plant-based proteins

Industry Overview: Cell-based

- Global cultivated meat companies raised $77 million in 2019, which is 63 percent more than in 2018 and more than double the capital raised in 2016 and 2017 combined
- Q1 2020 brought cultivated meat companies $189 million in additional investments, more than the amount invested in the industry's prior history
- Out of 10 largest US meat producers, 2 entered in collaboration with cultured meat companies
- R&D Priorities:
- Bioreactors capable of supporting high-density, large-volume cell cultures
- Cell growth surfaces
- Characterized volatile compounds
- Meat science expertise
- Research & monitoring tools



Industry Overview: Fermentation

- *Investments:*
  - $274 million was invested in 2019 and $435 million was invested in the first seven months of 2020 alone. Combined, that amounts to 85 percent of all-time funding for this technology sector, which is commanding an increasing share of all alternative protein investments.
- *R&D Priorities*:
  - Increased titers and yields
  - Strain engineering
  - Safety studies and genetic tools for more microbes
  - Lipid production
- *Corporates*:
  - Acknowledge the growing importance of this application area and are developing novel solutions accordingly
- The majority of B2B companies using fermentation for alternative protein products position themselves as ingredient suppliers that empower B2C companies to improve their branded products.
  - MycoTechnology and 3F Bio produce natural microbe-derived flavoring solutions or bulk proteins for use in consumer-facing products,
  - Companies like Clara Foods, Fybraworks Foods, and Geltor leverage biotechnology to produce genuine animal proteins in microbial or mycelial hosts for such products.
  - Scale, cost, and functionality are these companies' core drivers for differentiation and adding value to the alternative protein ecosystem.
- An additional layer of B2B activity exists in the fermentation sector: companies positioning themselves as service providers and technology development partners for B2B or B2C fermentation companies.
  - Culture Biosciences is an example of a process optimization service provider that has supported many fermentation companies, including Geltor, Clara Foods, Modern Meadow, and C16 Biosciences, to accelerate their process development and cost curve progression while reducing their capital expenditure for in-house R&D.

Top U.S. Meat & Poultry Producers

As shown in the list below, most of the fifteen largest meat producers in the U.S. have either bought existing plant-based food brands, launched their own, or entered into collaborations with plant-based and/or cultured meat companies.

Company	HQs	Operations	Plant-based Activities	Cellular Agriculture Activities	Fermentation
JBS USA Holdings	Greeley, CO, USA	Beef Slaughter, Boxed Beef, Beef Further Processing, Ground Beef, Pork Slaughter, Fresh Pork, Poultry Slaughter, Poultry Further Processing, Lamb, Prepared Foods, Case-Ready, Private Labeling, Export, Natural/Organic	Launched a line of plant-based burgers—the "Incredible Burger"—in Brazil under the Seara brand in May 2019. In 2020 entered the US plant-based market area via a new subsidiary, Boulder, CO-based Planterra Foods, with various plant-based products under the OZO brand.	Not found	Uses MycoTechnology's pea and rice protein fermented by Shiitake mycelia (the roots of Shiitake mushrooms) for the OZO products
Tyson Foods Inc	Springdale, AK, USA	Beef Slaughter, Boxed Beef, Beef Further Processing, Ground Beef, Pork Slaughter, Fresh Pork, Fresh Sausage, Cured Sausage, Ham, Deli Meat, Bacon, Poultry Slaughter, Poultry Further Processing, Prepared Foods, Portion Control, Case-Ready, Private Labeling, Export, Natural/Organic	The company has invested in several plant-based companies since 2016. In 2019 launched meat-free nuggets and blended meat-plant products under the Raised & Rooted and Aidells Whole Blends brands. In 2021 it brings plant the based meats to its Jimmy Dean brand.	In 2016 snapped up a five percent stake in Beyond Meat. In 2018 it has invested in Memphis Meat; Tyson Foods investment represents a minority stake in the business.	Invested into MycoTechnology in 2020
Cargill	Wichita, KA, USA	Beef Slaughter, Boxed Beef, Beef Further Processing, Ground Beef, Fresh Pork, Fresh Sausage, Cured Sausage, Ham, Deli Meat, Poultry Slaughter, Poultry Further Processing, Portion Control, Case-Ready, Private Labeling, Export, Natural/Organic	This complements investments in plant-based protein like PURIS, North America's largest producer of pea protein. Also make specialty sweeteners and texturizers for plant-based dairy alternatives.	In 2017 and 2020 made investments in Memphis Meats, a U.S.-based leader in cultured protein products. In 2019 we also invested in Aleph Farms, an Israel-based cell-cultured protein company focused on growing complex meat varieties like steak	One of the largest suppliers of products to bioindustry manufacturers worldwide, with offerings spanning the whole fermentation process
Sysco	Houston, TX, USA	Boxed Beef, Beef Further Processing, Ground Beef, Fresh Pork, Fresh Sausage, Cured Sausage, Ham, Deli Meat, Bacon, Poultry Further Processing, Veal, Lamb, Seafood, Portion Control, Natural/Organic	In 2020 the company announced the launch of its Sysco Simply™ Plant-Based Meatless Burger Patty, a Sysco brand exclusive product. This innovative burger is now available to the company's customers in the majority of its U.S. markets.	Not found	Not found

Top U.S. Meat & Poultry Producers (continued)

Company	HQs	Operations	Plant-based Activities	Cellular Agriculture Activities	Fermentation
Smithfield Foods	Smithfield, VA, USA	Pork Slaughter, Fresh Pork, Fresh Sausage, Cured Sausage, Ham, Deli Meat, Bacon, Poultry Slaughter, Poultry Further Processing, Seafood, Prepared Foods, Portion Control, Case-ready, Private Labeling, Export, Natural/Organic	In August 2019 launched the Pure Farmland brand with eight initial products, including plant-based burgers, meatballs, breakfast patties, and vegan cheese	Not found	Not found
Hormel Foods	Austin, MN, USA	Beef Further Processing, Pork Slaughter, Fresh Pork, Fresh Sausage, Cured Sausage, Ham, Deli Meat, Bacon, Poultry Slaughter, Poultry Further Processing, Prepared Foods, Portion Control, Case-Ready, Private Labeling, Export, Natural/Organic	In March 2019, its Applegate brand launched a blended burger product, made from meat and mushrooms. In September 2019 Hormel launched the Happy Little Plants brand under its Cultivated Foods umbrella. The flagship product at this point is a ground meat alternative. In 2020 it introduced Protein Puffs, the gluten-free snacks are made with soy protein, rice flour, tapioca starch, sugar and calcium carbonate, which are available for purchase on Amazon	Not found	Not found
National Beef Packing	Kansas City, MO, USA.	Beef Slaughter, Boxed Beef, Beef Further Processing, Ground Beef, Case-Ready, Export, Natural/Organic	Not found	Not found	Not found
Perdue Farms	Salisbury, MD, USA	Poultry Slaughter, Poultry Further Processing, Prepared Foods, Portion Control, Export, Natural/Organic	In June 2019 launched Chicken Plus, a line of "vegetable-enhanced" foods including chicken nuggets.	Not found	Not found
OSI Group	Aurora, IL, USA	Beef Slaughter, Beef Further Processing, Ground Beef, Cured Sausage, Ham, Deli Meat, Bacon, Poultry Slaughter, Poultry Further Processing, Seafood, Prepared Foods, Portion Control, Case-Ready, Private Labeling, Export, Natural/Organic	In 2019 Impossible Foods has added manufacturing capacity to process the Impossible Burger by entering into a co-manufacturing agreement with OSI Industries	Not found	Not found

Top U.S. Meat & Poultry Producers (continued)

Company	HQs	Operations	Plant-based Activities	Cellular Agriculture Activities	Fermentation
ConAgra Foods	*Omaha, NB, USA.*	Fresh Sausage, Cured Sausage, Prepared Foods	Gardein, a brand of Conagra which was acquired in 2018, is expanding its line of meat-free dishes, including new items that feature pea and wheat protein.	Not found	Sells probiotic supplements under its Culturelle brand
Sanderson Farms	*Laurel, MS, USA*	Poultry Slaughter, Poultry Further Processing, Case-Ready, Private Labeling, Export, Natural/Organic	'Will not engage' in the trend	Not found	Not found
American Foods Group	*Green Bay, WI, USA.*	Beef Slaughter, Boxed Beef, Beef Further Processing, Ground Beef, Prepared Foods, Portion Control, Case-Ready, Export	Not found	Not found	Not found
Koch Foods	*Pack Ridge, IL, USA*	Poultry Slaughter, Poultry Further Processing, Prepared Foods, Portion Control, Export	Not found	Not found	Not found
Oscar Mayer	*Chicago, IL, USA*	Cured Sausage, Deli Meat, Bacon, Prepared Foods, Natural/Organic	In 2020 Oscar Mayer has announced that it is acquiring the David Wood Foods' factory in Flint, UK to produce meat alternative foods.	Not found	Not found

Companies involved in Fermentation

Company	HQs	Operations	Plant-based Activities	Cellular Agriculture Activities	Fermentation
DuPont	*Wilmington, DE, US*	Consumer Products, Fabrics, Fibers & Nonwovens, Home Garden & Car Care, etc.	Offers food and beverage manufacturers ingredients for plant-based product development in the industry, in 2020 expanded its SURPO Soy products with Cocoa range	Not found	Opened a $100 million state-of-the-art probiotics fermentation facility in Rochester, New York. The plant will produce probiotics for the food and beverage industries and for dietary supplements
Kerry Group	*Tralee, Ireland*	Development of taste and nutrition solutions for the food, beverage and pharmaceutical markets	Acquired Probiotic supplier Ganeden Biotech Inc. (Cleveland) in 2017. In 2020 launched 13 new plant-based ingredients	Not found	Significant producer, in 2018 expanded fermentation facility in the US
ADM	*Chicago, IL, US*	Manufacturer of biodiesel, ethanol, soybean oil and meal, corn sweeteners, flour and other value-added food and feed ingredients	Has a broad portfolio of plant-based ingredients. In 2020 created PlantPlus Foods as a joint venture with beef producer Marfrig	Not found	In 2021 invested in Air Protein, a US start-up making meat from mineral nutrients
Perfect Day	*San Francisco, CA, US*	Food Technology startup producing milk proteins via microbial fermentation	n/a	n/a	The company has signed an agreement with Singapore's Agency of Science, Technology, and Research (A*Star) to build out a R&D lab in the city-state. The facility, slated to open in April 2021, will be used to further develop Perfect Day's processes for its flora-based dairy products that are made via yeast-fermentation and include items like ice cream, cheese, and milk.
Myco Technology	*Aurora, CO, US*	Food ingredients	Delivers plant-based protein	n/a	The ClearTaste, is derived from an extract of fungal mycelium cultivation and in the context of the alternative protein industry, its primary use is as a bitter blocker for undesirable off-flavors in some plant proteins. The PureTaste, uses shiitake mycelium fermentation of a pea and rice protein feedstock to improve the flavor, aroma, and functional properties of the feedstock.

Companies involved in Fermentation

Company	HQs	Operations	Plant-based Activities	Cellular Agriculture Activities	Fermentation
Clara Foods	*Chicago, IL, USA*	Yeast engineering and fermentation technologies to selectively cultivate the perfect strain of yeast	n/a	n/a	It is the first fermentation-based egg protein company. The company uses yeast to produce egg albumen proteins (the major constituents of egg whites) as an ingredient for cooking and baking. In April 2019, Clara Foods announced a joint development and distribution partnership with global ingredient supplier Ingredion to fast-track the commercialization of the world's first animal-free egg proteins.
Noblegen	Peterborough, ON, Canada	Nutritional and functional plant-based food and ingredients	n/a	n/a	Instead of using synthetic biology for microbial fermentation, uses Euglena Gracilis (a protist which could be also classified as algae) which can produce cost-effective vegan replacements for palm oil, beta-glucan and complete proteins offering the same nutrition and functionality as ones from an animal *without* using genetic engineering.
Nature's Fynd (Sustainable Bioproduct)	Chicago, IL, USA	Developer of microbe-based proteins for meat substitutes	n/a	Instead of using synthetic biology, it is working with "extremophiles" – fungal strains that can survive in extreme environments such as the volcanic springs at Yellowstone National Park - that naturally produce high levels of complete protein when grown in a controlled environment.	
Motif FoodWorks	*Boston, MA, USA*	Yeast engineering and fermentation technologies to selectively cultivate the perfect strain of yeast.	In 2019, synthetic biology leader Ginkgo Bioworks announced the spin out of Motif—seeded with $90 million. Motif was specifically created to expand the capabilities of Ginkgo's biological foundry toward applications in meat, egg, and dairy replacements. Ginkgo serves as a technology development partner for strain and biosynthetic pathway development, while Motif is tasked with identifying target molecules and manufacturing them as flavoring and functionality solutions for the plant-based sector. Established a partnership with researchers at the University of Queensland in Australia to develop high-throughput methods for assessing texture, which is currently handled by expensive, variable, and time-intensive sensory expert panels.		

Top U.S. Plant-based Meat & Poultry Brands

Company/Brand	Founded	HQs	Revenue	Protein Source				
				Soy	Wheat	Mycoprotein	Pea	Other
Beyond Meat	2009	Los Angeles, CA, USA	$407 M				✓	✓
Boca Burger	1993	Chicago,IL, USA	$40 M	✓	✓			
Dr. Praeger's	1994	Elmwood Park, NJ, USA	$98 M	✓			✓	✓
Field Roast	1997	Seattle, WA, USA	$38 M		✓			
Gardein	2003	Richmond, BC, Canada	$12 M	✓	✓			
Impossible Foods	2011	Redwood City, CA, USA	$114 M	✓				
Lightlife	1979	Turner Falls, MA, USA	$81 M	✓	✓		✓	
Morningstar	1975	Battle Creek, MI, USA	$210 M	✓	✓			✓
Quorn	1985	Stokesley, United Kingdom	$134 M			✓		
Tofurky	1980	Hood River, OR, USA	$48 M	✓	✓			

Investment in Plant-Based Protein

Plant Protein Sources Index

	Protein Concentration	PDCAAS	Allergen Risk	Commercial Stage	Flavor	Functionality	Cost (/kg protein)	Global Crop Volume (MMT)
Excellent	>30%	>0.80	Usually mild	Commodity	Flavorless	Low conc. effect	<$2	>100
Good	20-30%	0.60-0.79	↕	Large	↕	↕	$2-4	10-99
OK	10-20%	0.40-0.59	↕	Small	Acceptable	↕	$5-9	1-9
Low	5-10%	0.20-0.39	↕	Start-up	↕	↕	$10-19	0.1-0.9
Poor	<5%	<0.20	Severe	R&D	Objectionable	Water insoluble	>$20	<0.1

The plant protein profiles represent the most widely available sources. Each of the profiles contains a color-coded comparison on select metrics, and details about sourcing, properties, nutrition, applications, a breakdown of dry composition, and product examples. The below key categorizes performance on each metric. Soy, pea, and wheat are featured first as major benchmark proteins, followed by profiles organized by protein type (legume / pulse / oilseed; vegetable / fruit / nut / cereal).

Note: PDCAAS is a method of evaluating the quality of a protein and was adopted by US FDA & FAO/WHO in 1993. Capped at 1.0

Regulatory Environment

Regulatory environment can be considered favorable to the sector. In March 2019, the United States Department of Agriculture (USDA) and the U.S. Food and Drug Administration (FDA) released a formal agreement outlining their respective regulatory roles for livestock and poultry meat: FDA will oversee the earlier stages of cultivated meat production and USDA will ensure safety in the later stages. Since then, USDA and FDA have formed three interagency working groups on cultivated meat and have also held a joint webinar. Additionally, since FDA has sole regulatory authority over most cultivated seafood, they have released a request for information seeking input on cultivated seafood labeling.

In a *Loyola University Chicago Law Journal* article, Steph Tai of the University of Wisconsin Law School argues that the battle between livestock-based proteins and emerging protein alternatives is playing out in labeling laws.

For instance, in 2018, the Missouri legislature passed a bill known as the "Missouri Meat Advertising Law." The Missouri Department of Agriculture issued a public statement describing the state as "the first state to take steps to prevent misrepresentation of products as meat that are not derived from livestock or poultry." To prevent "misrepresentation," non-livestock-derived products must "must include a prominent statement on the front of the package, immediately before or immediately after the product name, that the product is 'plant-based,' 'veggie,' 'lab-grown,' 'lab-created' or a comparable qualifier." Moreover, "products must include a prominent statement on the package that the product is 'made from plants,' 'grown in a lab,' or a comparable disclosure."

As for the insect-based protein, In the United States, edible insects fall under current legislation, since they fit the definition for food as described under US Code Title 21, Subchapter II: Definitions. This means that they must be wholesome, labeled appropriately to declare origin, species and allergen content, toxin-free, and produced under sanitary conditions. There is, however, no specific regulation.

5 Protein Highway

The Protein Highway is an international initiative to reinforce cross-border alliance among entrepreneurs, researchers, corporations and investors across the Canadian Prairies and Upper Midwest/Great Plains region while sparking economic growth and affluence in innovative agricultural technology solutions to meet the ever-growing global demand for plant-derived protein sources.

Key activities of the Protein Highway include:

- Constructing an innovation focal point that expedites collaboration among prominent researchers to develop novel, value-added products from regional protein crops;
- Connecting ideas with entrepreneurs;
- Enabling companies for scale-up; and
- Showcasing regional opportunities to premier investors in agricultural innovation.

The US-Midwest/Great Plains and Canadian Prairies region is well positioned to be a key player in the development of value-added plant proteins for domestic and global markets. The region possesses strong capabilities in producing and processing a number of crops that are ideal feedstocks for processing into value-added protein products for human consumption, pet foods and aquaculture. Technologies for economical extraction of value-added proteins have been scaled by companies in the region, which is also known for its high-quality agricultural production, innovative human and capital resources and proximity to business, population, transportation and education centers.

Through collaborative promotion, research, business development and investment, the Protein Highway is designated to become globally recognized region of choice for secure and sustainable production of high-quality plant proteins.

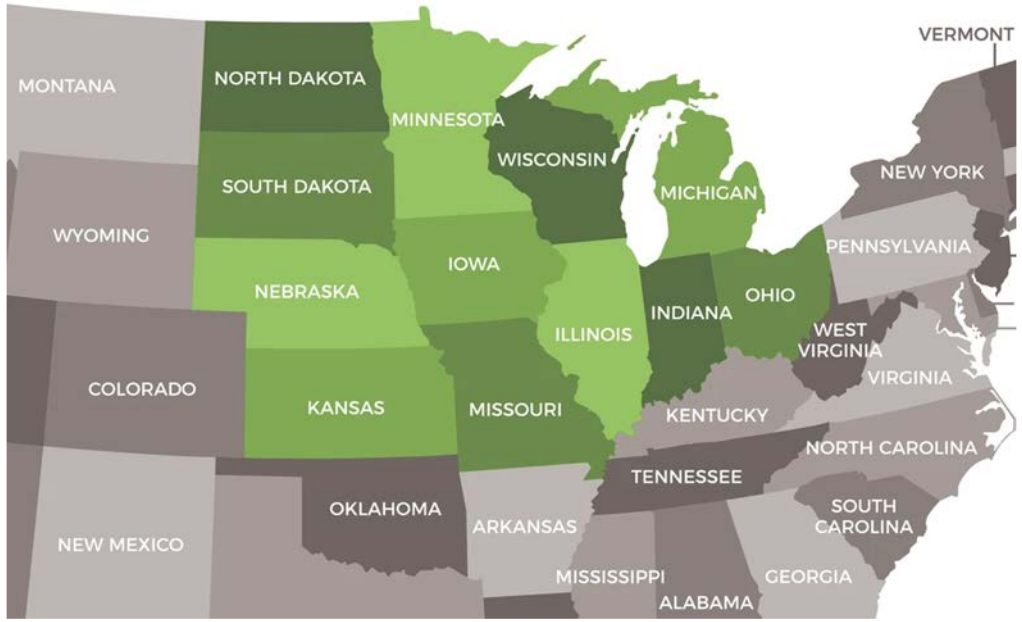
Major Players – Partner Organizations

Name	HQ	Founded	About
Innovation, Science and Economic Development Canada	Surrey, BC, Canada	1993	Innovation, Science and Economic Development Canada, is the department of the Government of Canada with a mandate of fostering a growing, competitive, and knowledge-based Canadian economy. Founded in 1993, the department is led by Simon Kennedy to strengthen Canada's Prairie Provinces' involvement in the future of alternative proteins while driving trade with the US.
Pulse Canada	Winnipeg, MB Canada	1997	Pulse Canada is the national association of growers, traders and processors of Canadian pulses, also known as lentils, dry peas, beans and chickpeas. Pulses are an essential part of a healthy and sustainable diet. Pulses and pulse ingredients can help food manufacturers improve the nutritional and functional quality of food products.
Agriculture and Agri-Food Canada	Ottawa, ON, Canada	1868	The Department of Agriculture and Agri-Food, also referred to as Agriculture and Agri-Food Canada, is the department of the Government of Canada with responsibility for policies governing the production, processing, and marketing of all farm, food, and agri-based products.
United States Department of Agriculture	Washington, DC, United States	1862	Founded by Abraham Lincoln in 1862, The United States Department of Agriculture, also known as the Agriculture Department, is the U.S. federal executive department responsible for developing and executing federal laws related to farming, forestry, rural economic development, and food.

US State Profiles

The Midwest Region is defined by the U.S. Census Bureau as these 12 states:

- Illinois: Old Northwest, Mississippi River (Missouri River joins near the state border), Ohio River, and Great Lakes state
- Indiana: Old Northwest, Ohio River, and Great Lakes state
- Iowa: Louisiana Purchase, Mississippi River, and Missouri River state
- Kansas: Louisiana Purchase, Great Plains, and Missouri River state
- Michigan: Old Northwest and Great Lakes state
- Minnesota: Old Northwest, Louisiana Purchase, Mississippi River, part of Red River Colony before 1818, Great Lakes state
- Missouri: Louisiana Purchase, Mississippi River (Ohio River joins near the state border), Missouri River, and border state
- Nebraska: Louisiana Purchase, Great Plains, and Missouri River state
- North Dakota: Louisiana Purchase, part of Red River Colony before 1818, Great Plains, and Missouri River state
- Ohio: Old Northwest (Historic Connecticut Western Reserve), Ohio River, and Great Lakes state. The southeastern part of the state is part of northern Appalachia
- South Dakota: Louisiana Purchase, Great Plains, and Missouri River state
- Wisconsin: Old Northwest, Mississippi River, and Great Lakes state



Indiana

Overview	
Capital	Indianapolis
Largest city	Indianapolis
Area	
• Total	94,321 km^2
• Land	92,897 km^2
• Water	1,424 km^2 (1.5%)
Elevation	700 ft (210 m)
Population	6,732,214 (17th)
Med. Household Income	$54,181 (35th)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
Indiana State Department of Agriculture	Indiana Biosciences Research Institute		Indiana Soybean Alliance (ISA)	Indiana University	ADM
Indiana Department of Education				IU Food Institute	AmeriQual Group
				IU-Bloomington Lewis Lab	Flagship Food Group
				Purdue University	Frito Lay
				Purdue Agriculture & Food Science	Geary's Foods Inc.
					Gunthorp Farms
					Indiana Packers Corporation
					International Bakers Services Inc.
					Kerry Ingredients Inc.
					Maple Leaf Farms
					Miller Poultry
					Mimi's Gourmet Pasta Sauce
					Red Gold
					Sander Processing
					Troyer Farms Potato Chips

Illinois

Overview	
Capital	Chicago
Largest city	Chicago
Area	
• Total	149,997 km^2
• Land	143,969 km^2
• Water	5,981 km^2 (4.0%)
Elevation	1600 ft (180 m)
Population	12,671,821 (6th)
Med. Household Income	$65,030 (13th)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
Illinois Department of Agriculture	Center for Nutrition Research (CNR)		Illinois Soybean Association	University of Illinois	Barilla America Inc.
Indiana Department of Education			Illinois Agricultural Association	UI The Protein Sciences Facility (PSF)	Burgess & Burgess Inc
			Illinois Corn Growers Association	IU Carl R. Woese Institute for Genomic Biology	Earthgrains Refrigerated Dough Products, Inc.
				IU Department of Food Science and Human Nutrition	General Mills, Inc.
				Northwestern Unniversity	Hearthside USA, LLC
				NU Rocklin Lab	Insight Beverages, Inc.
				University of Chicago	Kellogg Company
				UC Staley Lab	Kraft Heinz Foods Company
					Lightlife Foods, Inc.
					Mars Chocolate North America, LLC
					Mondelez International, Inc.
					Mullins Food Products, Inc.
					Nation Pizza Products, L.P.
					Nestle Prepared Foods Company
					Newly Weds Foods, Inc.
					OSI Group, LLC
					Preferred Meal Systems, Inc.
					Proven Partners Group, LLC
					Rich Products Corporation
					Rose Packing Company, Inc.
					Sokol and Company
					Th Foods, Inc.
					The Hillshire Brands Company
					The Jel Sert Co
					The Tootsie Roll Company Inc
					Wm. Wrigley Jr. Company

Iowa

Overview	
Capital	Des Moines
Largest city	Des Moines
Area	
• Total	145,744 km^2
• Land	142,378 km^2
• Water	3,366 km^2 (2.3%)
Elevation	1,100 ft (340 m)
Population	3,155,070 (31st)
Med. Household Income	$59.955 (26th)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
Iowa Department of Agriculture and Land Stewardship	Iowa Soybean Assocation	USDA-National Labrotory for Agriculture and the Environment	Nnorth Central Soybean Research Program	Iowa State University	A to Z Drying
	Soybean Meal Info Center	USDA-National Institute of Food and Agriculture		ISU Agriculture and Home Econnomics Experiments Station	ADM
				IS BioCentury Research Farm	Ag Logic (Yield Igniter)
				ISU BioSafety Institute for Genetically-Modified Agri Products	Algae Protein Powder
				ISU Center for Agricultural and Rural Development	Beaver Creek R&D
				ISU Center for Crops Utilization	Cardiostrong
				ISU Center for Designing Foods to Imprive Nutrition	Cargill
				ISU Center for Plant Responses to Environmental Stresses	Devannsoy
				ISU Department of Food Science and Human Nutrition	Diamond V
				ISU Experiment Research Stations	DuPont
				ISU Nutrition and Wellness Research Center	DupPont Pioneer Johnston Innovation Center
				ISU Raymond F. Baker Cennter for Plant Breeding	Embria
				ISU Seed Science Center	Grain Processing Corporation
				ISU Technnology Transfer Office	Harvest Innovations
				ISE The Protein Facility of the Office of Biotechnology	Horan Bio Production
				WM Keck Metabolomics Research Laboratory	John Deere Intelligent Solutions Group Development
				University of Iowa	Kemin Technologies
					Kerry Ingredients
					Metabolic Technologies
					Monsanto
					Naturally Recycled Protein
					Nutrient (Kerry)
					Proliant Inc.
					Roquette America Inc.
					The Scoular Company

Michigan

Overview	
Capital	Lansing
Largest city	Detroit
Area	
• Total	250,493 km^2
• Land	726 km^2
• Water	103,767 km^2 (41.5%)
Elevation	900 ft (270 m)
Population	12,671,821 (6th)
Med. Household Income	$54,909 (34th)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
Michigan Department of Agriculture and Rural Development	Proteos	USA-AFRI Food Access in Michgan (FAIM)	Michigan Food Processors Association (MFPA)	Michigan State University	Agridient
	Michigan Organic Food and Farm Alliance		Michigan Soybean Committee	MUS Department of Food Science and Human Nutrition	Better Made Snack Foods Inc.
	Michigan Food Hub Learning and Innovation Network		Michigan Agri-Business Association	University of Michigan	Chelsea Milling Co.
			Michigan Farmers Union	UM Yang Zhang Lab	Co.Operative Elevator Co.
			Michigan Farm Bureau	UM Protein Assembly Lab	Eden Foods, Inc.
			Michigan Farmers Market Association	UM Weizmann Institute of Science	Kellogg NA Co.
			Michigan Corn Growers Association		King Milling Company
			Michigan Bean Commission		Koegel Meats, Inc
			Michigan Wheat Program		Kowalski Kowality
					Michigan Milk Producers
					Monitor Sugar Company
					Proteos
					Star Of The West Milling Co.
					Wolverine Packaging Co.

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Minnesota

Overview	
Capital	Saint Paul
Largest city	Minneapolis
Area	
• Total	225,163 km^2
• Land	206,232 km^2
• Water	18,930 km^2 (8.4%)
Elevation	1,200 ft (370 m)
Population	5,639,632 (22nd)
Med. Household Income	$68,388 (10th)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
	Agricultural Utilizations Research Institute		Dry Edible Bean Research & Promotion Council	University of Minnesota	ADM
				UoM Applied Plant Sciences	Ag Motion
				UoM Center for International & Agricultural Policy	Batory Foods
				UoM Food Industry Center	Burley Foods
				UoM Healthy Foods, Healthy Lives Institute	Cargill
				UoM Institute of the Environment	CHS
				Institute on the Environment	Dow AgroSciences
				Minnesota Institute for sustainable Agriculture	Fiberich
				Office of Commercialization	General Mills
				Stakman-Borlaug Center for Sustainable Plant Health	Grain Millers Innc.
					Great River Milling
					Homestead Mills
					InHarvest
					Innovative Food Products
					Kraft Food Ingredients
					Lea Bean & Seed Inc
					Marathon Foods
					Meadowland Soy
					Natural Way Mills Inc.
					PGP International
					Schafer Seed Co
					Scoular Company
					SK Food Speciality Processing
					Slauson Tradinng Co
					Summit Brewing co
					World Food Processing

Missouri

Overview	
Capital	Jefferson City
Largest city	Kansas City
Area	
• Total	180,560 km^2
• Land	179,015 km^2
• Water	1,545 km^2 (<0.1%)
Elevation	800 ft (244 m)
Population	6,6151,548 (18th)
Med. Household Income	$53,578 (37th)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
Missouri Department of Agriculture	Food and Agricultural Policy Research Institute	Missouri Food Research & Action Center	Missouri Association of Meat Processors	University of Missouri	AB Mauri
Missouri Department of Health and Senior Services (DHSS)	Missouri Food and Nutrition Information Center	Institute of Food and Agriculture (NIFA)	Association of Nutrition & Foodservice Professionals	UM College of Agriculture, Food, and Natural Resources	ADM Milling
			Missouri Soybean Association		Anheuser-Busch
			MFA Incorporated		Beyond Meat
			Missouri Corn Growers Association		Bissinger's
					Boulevard Brewing Company
					Bunge North America
					Daily's Premium Meats
					Danisco Food Ingredient Solutions
					Farmland Foods
					Frick's Meat Products
					Gilster-Mary Lee
					Hostess Brands
					ICL Performance Products
					International Dehydrated Foods
					International Food Products Corporation
					Jasper Products
					Kraft Foods Group
					Lifeline Foods
					Martin Rice Company
					Mid Missouri Protein Manufacturers
					Post Holdings
					Quaker Oats
					Reliv
					Tyson Foods
					Unilever

Montana

Overview	
Capital	Helena
Largest city	Billings
Area	
• Total	380,800 km^2
• Land	376,980 km^2
• Water	3,862 km^2 (1.0%)
Elevation	3,400 ft (1,040 m)
Population	1,068,778 (43rd)
Med. Household Income	$53,386 (38th)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
Beartooth RC&D Food & Agricultural Development Center		USDA-Agricultural Systems Research		Montana State University	Columbia Grain
Food & Ag Development Center Network		USDA-Northern Plains Agricultural Research Labratory		MSU Agriculture Experimental Research Centers	GTC Nutrition (Ingredion)
Mission Mountain Food Enterprise Center				MSU Barley &Plant Biotech Lab	Montana Milling
Montana Department of Agriculture				MSU Department of Chemistry and Biochemistry	Montana Speciality Mills
				MSU Functional Genomics Coore Facility	Timeless Foods
				MSU Plant Growth Center	
				MSU Plant Science & Pathology	
				MSU Proteomics and Biological Mass Spectrometer Facility	
				MSU Schutter Diagnostic Lab	
				MSU Technology Transfer Office	

Nebraska

Overview	
Capital	Lincoln
Largest city	Omaha
Area	
• Total	200,356 km^2
• Land	199,099 km^2
• Water	1,247 km^2 (0.7%)
Elevation	2,600 ft (790 m)
Population	1,934,408 (37th)
Med. Household Income	$59,970 (22nd)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
Nebraska Department of Agriculture		USDA-ARS	Core for Applied Genomics and Ecology (CAGE)	University of Nebraska	ADM
			Food Allergy Research & Resource program (FAARP)	UoN Agricultural Research Division	Bunge
				UoN Center for Biotechnology	Cargill
				UoN Center for Plant Science Innovation	Columbian Grain
				UoN Crop Watch	Con Agra
				UoN Deparment of Agronomy & Horticulture	Crop Production Services
				UoN Department of Plant Pathology	DuPont Pioneer
				UoN Food Innocation Center	Farmers Cooperative
				UoN Industrial Agriculture Products Center	Frenchman Valley Farmers
				UoN Institute of Agricultural & Natural Resources	International Nutrition
				UoN Plant Sciences Program	Kelley Bean Co.
				UoN Plant Transformation Core Research Facility	Kellogg
				UoNn Technology Transfer Office	Koch Industries
					Louis Dreyfus
					Michael Foods
					Monke Brothers
					Nature's Variety Inc.
					Sensory Effects Cereal Systems
					Syngenta Foods

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North Dakota

Overview	
Capital	Bismarck
Largest city	Fargo
Area	
• Total	183,123 km^2
• Land	178,694 km^2
• Water	4,429 km^2 (2.5%)
Elevation	1,900 ft (580 m)
Population	762,062 (47th)
Med. Household Income	$61,843 (19th)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
North Dakota Department of Agriculture	Northern Pulse Growers Associations (NPGA)	USDA-ARS-GFHNRC		North Dakota State University	ADM Edible Bean Specialities
		USDA-ARS-Natural Resource Management Center		NDSU Animal Nutrition & Physiology Center	AGT Food and Ingredients
		USDA-ARS-Red River Valley Agricultural Research Center		NDSU Carrinngton Research Extension Center	AGT Foods
		USDA-ARS-PMC-Natural Resources Conservationn Service		NDSU College of Agriculture, Food Systems, and natural Resources	Archer Daniels Midland Co. (ADM)
				NDSU Department of Agriculture and Biosystems Engineering	Cargill
				NDSU NCI Feed Mill	Central Valley Bean Cooperative
				NDSU North Dakota Agricultural Experiment Station (AES)	Centrol Ag Consultinng
				NDSU norther Crops Institute (NCI)	Dakota Dry Beans
				NDSU Technology Transfer Office	Dakota Speciality Milling
				University of North Dakota (UND)	Dupont
					Great Northern Ag
					Heartland Flax
					Hurdsfield Grain Inc.
					J.R. Simplot Company
					JM Grain
					Johnstown Bean Company
					Legume Logic
					Legume Matrix
					Mehl's Flour Company
					Meridian Seeds
					Northern Praire Envirofuels
					Premium Gold Flax Products
					Pulse USA
					Red River Commodities
					Safflower Technologies International
					Sanford Health

South Dakota

Overview	
Capital	Pierre
Largest city	Sioux Falls
Area	
• Total	199,729 km^2
• Land	196,350 km^2
• Water	3,379 km^2 (1.7%)
Elevation	2,200 ft (670 m)
Population	884,659 (46th)
Med. Household Income	$56,521 (30th)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
South Dakota Department of Agriculture		USDA-ARS-North Central Agricultural Research Lab	SD Crop Improvement Association	South Dakota State University	Bel Brands
South Dakota Department of Game, Fish and Parks		USGS EROS Data Center	SD Oilseeds Council	SDSU Agriculutral Experiment Stations	Dakota Mill & Grain
			South Dakota Pulse Growers	SDSU Dakota Lakes Research Station	DuPont
			South Dakota Soybean Association (SDSA)	SDSU Northeast Research Station	Frontier Mills Inc.
			South Dakota Soybean Processors	SDSU Southeast Experiment Station	Gabby's Roasted Garbanzos (Dakota Valley)
			South Dakota Soybean Research and Promotion Council (SDSRPC)	SDSU Extension Service	Glanbia Nutritionals
				SDSU iGrow	Heintzman Farms
				SDSU Research Park	Hesco
				SD Technology Transfer Office	Hesco Dakota Organic Products
				University of South Dakota	Huubard Feeds
					J&R Distributing
					Mustang Seeds
					POET Dakota Gold
					Prairie AquaTech
					Pride Grain
					Purina Animal Nutrition
					Purity Seeds
					Sanford Health
					SD Innovation Partners
					Sexauer Discount Farm Services
					SmartLic Supplements
					South Dakota Pulse Processors

Wisconsin

Overview	
Capital	Madison
Largest city	Milwaukee
Area	
• Total	169,640 km^2
• Land	140,663 km^2
• Water	28,977 km^2 (17.0%)
Elevation	1,050 ft (320 m)
Population	5,822,9434 (20th)
Med. Household Income	$59,305 (23rd)

State Government	Applied Research Associations	Federal Government Research Labs	Specialty Organizations	Academic Research Institutions	Corporations
Wisconsin Dept. of Agriculture, Trade and Consumer Protection	Wisconsin Soybean Assocation	U.S. Dairy Forage Research Center	Wisconsin Lab Assocation	University of Wisconsin	American Foods Group
	Food Research Institute (FRI)		Wisconsin Soybean Marketing Board	UW Applied Food Safety Laboratory	Connoils LLC
	The Wisconsin Youth Institute		Scientific Protein Laboratories	UW Kucharik Lab	DCI Cheese Company
				UW-Madison Food Research Institute	Eagle Food Centers
				UW-Madison Department of Food Science	Eagle Food Centers
				UW-River Falls Animal and Food Science	Eurofins USA
				UW Technnology Transfer Office	Jack Link's Beef Jerky
				Wisconsin Alumni Research Foundation (WARF)	Johnsonville Foods
					Masterson Foods
					Mikana Foods
					Organic Valley
					Pure Choice Whey
					Sensient Technologies
					Uplands Cheese Company
					Wisconsin Specialty Protein
					Wisconsin Whey Protein

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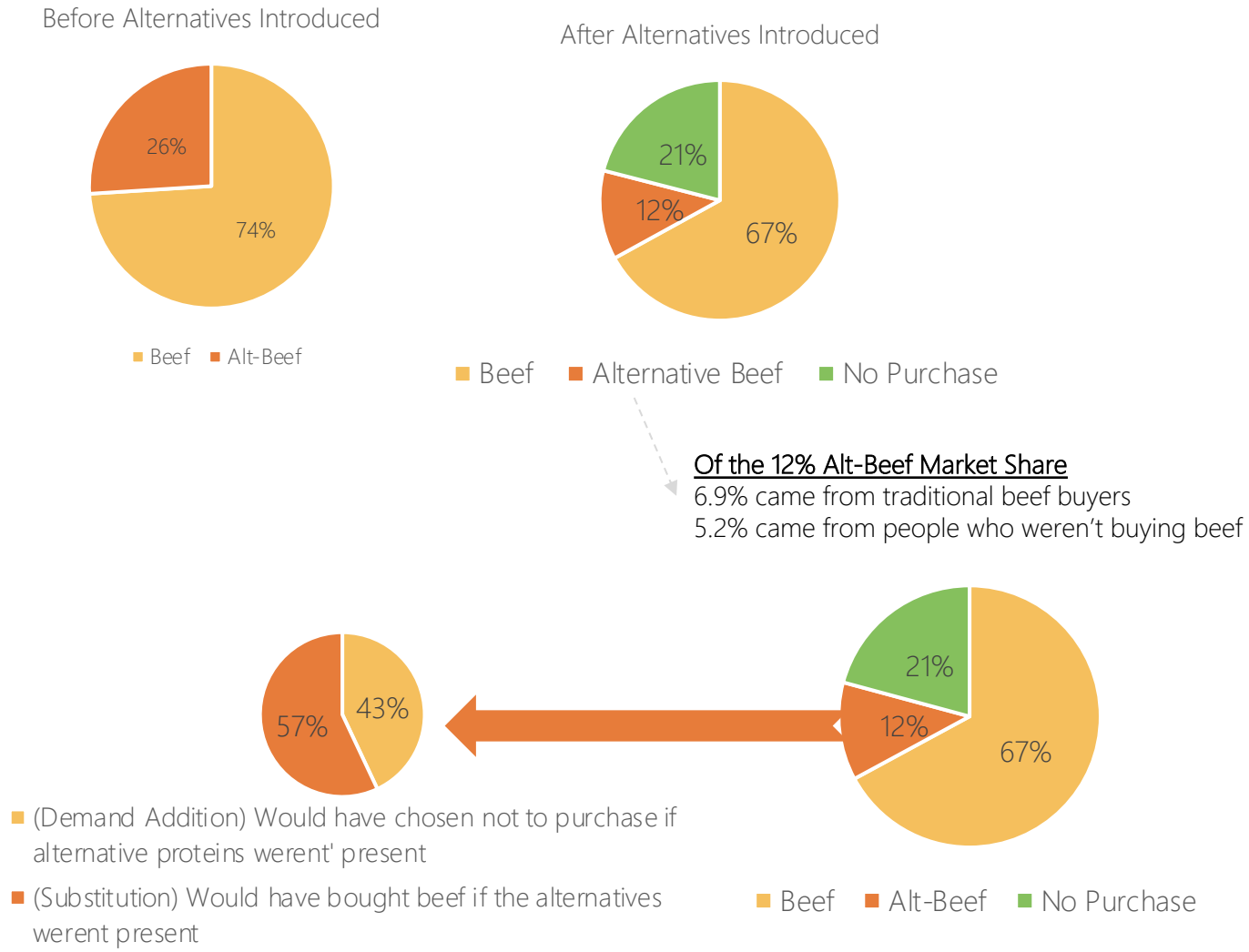
6 Consumer Preferences

In the study entitled 'Consumer preferences for farm-raised meat, lab-grown meat, and plant-based meat alternatives: Does information or brand matter?' (Van Loo et al., 2020) nationwide survey of more than 1800 U.S. consumers who completed a choice experiment in which they selected among conventional beef and three alternative burger patties was conducted. Respondents were randomly allocated to treatments that varied in the presence/absence of brands and information about the competing alternatives.

It was projected that before any alternatives are introduced about 73% of consumers would buy ground beef on a grocery shopping trip (assuming the price is $5/lb.) and 27% would refrain from buying ground beef.

After the alternatives are introduced (at an assumed price of $9/lb.), **it is projected about 12% of shoppers would buy one of the beef alternatives**. Thus, of the buyers of the new alternatives, researchers project about 57% (6.9/12.1) would have instead bought conventional ground beef whereas the remaining 43% (5.2/12.1) wouldn't have bought beef in the first place. Thus, of the buyers of the new alternatives, researchers project about 57% (6.9/12.1) would have instead bought conventional ground beef whereas the remaining 43% (5.2/12.1) wouldn't have bought beef in the first place.



Source: :Consumer preferences for meat, J. Lusk

Consumer Food Values

The key drivers behind consumers' food and beverage purchases have been largely unchanged for years.

According to a research done by Jason Lusk, **taste** still reigns supreme, which is followed by **safety**, **nutrition** and **price**. Hence, we will evaluate Alternative Protein products and its derivatives with respect to these four predictors

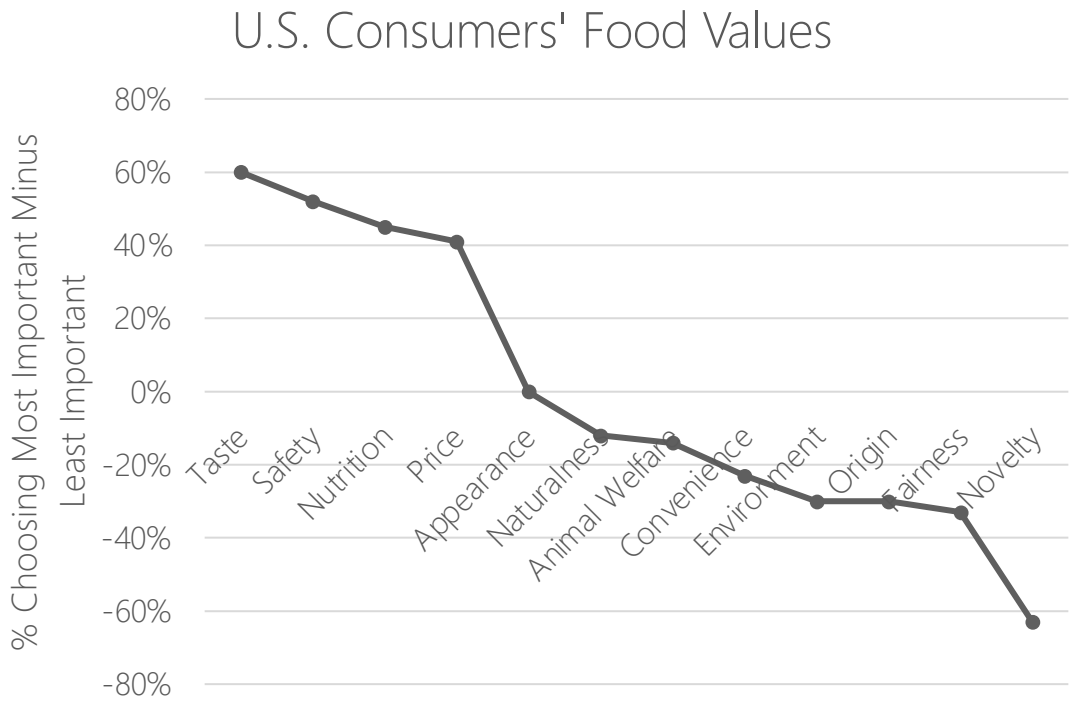


Figure 6:Consumer food values, J. Lusk

Consumer Food Values: Taste

As a leading parameter for food evaluation *taste* should be a key focus during product development and a key criteria in the decision to launch the product commercially, and it is the most important re-purchase driver.

When it comes to the Alternative Protein Market, two barriers to the uptake of animal-free alternatives, particularly among meat eaters, are a lack of familiarity and negative perception of their sensory properties. Building a narrative that promises the same taste, appearance and overall eating experience as conventional animal foods has consequently been a central goal of those supportive of alternative protein developers.

- Plant based Protein:

In 2019 NPD found that 16 percent of Americans say they "regularly" use plant-based alternatives to meat and dairy products, such as almond milk and meat substitutes. More unexpected, though, is that 89 percent of the people eating all of these tell NPD that they're not vegetarian or vegan — they just like variety in their diets.

A research done by Mintel reveals that *taste* is the top reason US adults who eat plant-based proteins do so (52 percent), outranking concerns over diet (10 percent), animal protection (11 percent), the environment (13 percent) and even health (39 percent)

- Lab Grown Meat

Some research suggests that consumers have relatively low expectations for the taste of cultured meat, tending to view it as not fresh, lacking in taste, and worse than conventional meat. Moreover, it was found that 'expected taste strongly predicted purchase intent, demonstrating a need to reassure consumers of the sensory experience of cultured meat as a central feature of messaging'.

New research by the University of Sydney and Curtin University published in Frontiers in Nutrition, found that, despite having a great concern for the environment and animal welfare, 72 percent of Generation Z were not ready to accept cultured meat – defined in the survey as a lab-grown meat alternative produced by in-vitro cell cultures of animal cells, instead of from slaughtered animals. 35 percent rejected cultured meat and edible insects but accepted plant-based alternatives because they "sounded more natural" and are "normal".

Consumer Food Values: Insect Protein

Despite a promising way which insects offer to address the problem of food, a strong rejection of insects as food is considered to be the major impediment to large scale increases of insect consumption.

In a study done by M.B. Ruby 'Determinants of willingness to eat insects in the USA and India' it was found that a substantial minority in each country was willing to try food containing whole insects, and a clear majority was willing to consume a food with very low levels of insect flour. Overall, men were more willing than were women. Acceptability of insect flour or whole insects did not depend much on a particular food in which it was presented. Ants were consistently among the least offensive insects, and cockroaches the most offensive, either whole or as insect flour.

In the same study a stepwise linear regression predicting willingness to try insect flour and whole insects was conducted. **The best predictors of insect acceptance were found to be disgust at the thought of eating insects, beliefs about the benefits of eating insects, sensation seeking, and the enjoyment of telling others about consumption of unusual foods.**

Beliefs/Attitudes	Flour (β)	Food (β)	Demographics/Traits	Flour (β)	Food (β)
Insect Disgust	-0.35***	-0.51***	Food Neophobia		-0.28***
Disease Risk	-0.21**		Tell others	0.29***	0.25***
Environmental benefits		0.25***	Gender (male)	0.22**	0.22***
			Risk tolerance	0.21**	0.19**

US Sample with n=176
Figure 8:Predictos regarding willingness to try insect food, M.B.Ruby

	Rank
Form	
Flour	1.66 (0.94)
Puree	2.41 (0.98)
Chopped	2.53 (0.81)
Whole	3.40 (1.00)
Plain Insect	
Ant	2.25 (1.63)
Cricket/Grasshopper	3.06 (1.81)
Beetle	4.01 (1.54)
Mealworm	4.20 (1.86)
Caterpillar	4.22 (1.58)
Fly	4.35 (1.68)
Cockroach	5.91 (1.80)
Insect Flour	
Ant	2.47 (1.78)
Cricket/Grasshopper	3.22 (1.89)
Beetle	4.08 (1.50)
Mealworm	4.07 (1.94)
Caterpillar	4.01 (1.54)
Fly	4.30 (1.83)
Cockroach	5.85 (1.78)

US Sample with n = 177
Figure 7:Preferred forms and species of insect food, M.B.Ruby

Consumer Food Values: Insect Protein and Lab Grown Meat

In another study named 'Factors Predicting the Intention of Eating an Insect-Based Product', similar influences were found. In addition, as a part of this study, a seminar was carried out to explore how the provision of information (ecological, gastronomic, etc..) would affect consumer beliefs regarding insects as food. In the table below it can be asserted that after the seminar the scores of all items improved, indicating a more positive outlook (i.e., lower rejection).

In another recent study conducted by Ryan Ardoin and Witoon Prinyawiwatkul, two online surveys (N = 1005 U.S. consumers) identified the most appropriate products, from a list of 30, for insect protein powder incorporation by evaluating willingness to try (WTT). Consumers reported perceived risks for negative WTT, and the effect of entomophagy benefit information (EBI) on WTT was measured.

Overall, 72% of consumers were willing to consume at least one insect-containing product. The three most appropriate products were protein/energy bars, chips/snack crackers and protein shakes. Bakery/cereal products garnered positive WTT by >54% of consumers, followed by snacks/candy (53%). Unfamiliarity with insects as food was the most cited risk. EBI presentation significantly increased (α < 0.05, McNemar's test) positive WTT for all products. Once unfamiliarity is overcome through *trial*, negative emotions and concerns about sensory quality can be addressed.

As for the lab grown meat The industry is new and the exact production process and inputs needed for large-scale, lab cultured "meat" production are unknown (or not being disclosed by the companies). It is the responsibility of both FDA and USDA to ensure that all inputs used in production and the final product are safe for human and animal consumption. These agencies must ensure that lab-cultured "meat" is labeled appropriately, including if any of the product ingredients are genetically modified or if the ingredients are produced using unmodified cells from animals. These agencies must also ensure that this product doesn't introduce new allergens into the food supply, that any hormones or antibiotics used are not found at unsafe levels in the final product, and that the product doesn't contain any compounds or oncogenic (cancer-causing) cells that have not been approved for use in food. In 2020 the USDA announced that it will start the process of developing regulations for these new kinds of 'meat'.

Items	Before, Mean (sd)	After, Mean (sd)	Mean Difference	95% CI	p
The idea of eating insects provokes my disgust	4.80 (1.83)	4.09 (1.79)	0.71	(0.461,0.957)	0.000
I fear that insect-based foods have negative texture properties	4.61 (1.7)	4.19 (1.61)	0.42	(0.184, 0.653)	0.001
I fear that insect-based foods have negative taste properties	3.99 (1.55)	3.84 (1.59)	0.15	(-0.062, 0.365)	0.164
I fear that insect-based food implies a poor hygiene	3.30 (1.62)	2.99 (1.6)	0.31	(0.065, 0.542)	0.013
I believe that eating insects is not part of our diet	2.91 (1.66)	2.55 (1.44)	0.36	(0.152, 0.575)	0.001
Eating insects is not socially acceptable	2.52 (1.43)	2.27 (1.38)	0.25	(0.042, 0.467)	0.019

Respondents indicated their opinion on a seven-point scale ranging from 1 ("do not agree at all") to 7 ("totally agree")

Source: Mean values and CI for the insect food rejection items, before and after seminar, S. Mancini

Consumer Food Values: Safety and Price

In the studies it was shown that in the USA, the most common perceived risk of eating insects was microbes/disease (51%). Food safety aspects of edible insects are largely unknown, but their widespread consumption worldwide supports the possibility of their consumption. The EFSA scientific committee, compiled a report that assessed "potential biological and chemical hazards, as well as allergenicity and environmental hazards, associated with farmed insects used in food and feed taking into account the entire chain, from farming to the final product". It concluded that for biological and chemical hazards of using farmed insects for human consumption and in animal feed, the risks were dependent upon the form of husbandry being employed. It observed: "The specific production methods, the substrate used, the stage of harvest, the insect species, as well as the methods used for further processing will all have an impact on the possible presence of biological and chemical contaminants in insect food and feed products."

While taste tops the list of reasons to eat plant-based proteins, perceived health benefits are on consumers' minds, as nearly half (46 percent) of Americans agree that plant-based proteins are better for you than animal-based options, and *three quarters (76 percent) say plant-based foods are healthy*. Whether a desire to avoid processed foods (39 percent), manage weight (31 percent) or promote muscle growth (16 percent), many plant-based protein consumers are motivated by maintaining or improving their health and well-being.

When it comes to making decisions in the grocery aisle, taste (65 percent) is the driving factor for those who eat plant-based proteins, followed by health-centric attributes. These consumers are more likely to seek plant-based protein products with no artificial ingredients (41 percent), that are high in protein (35 percent) and fiber (28 percent), and those that are non-GMO (28 percent). Non-GMO claims, in particular, are driving innovation in the category, as US launches of foods and beverages with plant-based proteins with a non-GMO claim grew from 3.8 percent in 2012 to 19.6 percent in 2017, according to Mintel Global New Products Database (GNPD).

According to Parry and Mitchell's (2019) findings on consumer preferences for plant-based protein sources, while almost half (47%) of participants reported willingness to consume all types of plant proteins, the remaining participants reported *avoiding* certain plant proteins at varying rates: *soy protein (29%), fava bean protein (25%), pea protein (20%), chickpea protein (19%), lentil protein (18%), and wheat protein (18%)* .

Elzerman et al. (2013) has found price to be a reported negative aspect of plant-based meat and thus a major barrier to its consumption.

Recent nationally representative results from Neff et al. (2018) reveal that the high price of conventional meat in the U.S. is one reason that consumers are reducing their meat consumption. However, it should be noted that meat reduction can be accomplished in a number of ways and does not necessarily indicate that a consumer is replacing conventional meat with plant-based meat. Price should be considered a barrier to consumer adoption of plant-based meat.

In Feb. 2021 Impossible Foods noted that it would cut the prices of its faux meat patties by 20% at U.S. grocery stores as the plant-based protein maker ramps up production with a larger plan to eventually undercut ground beef prices. The suggested retail prices for Impossible Burger would drop to $5.49 in about 17,000 U.S. grocery stores, the company said in a statement, adding that it will introduce similar price cuts at retail stores in Canada and Asia.

Demographics of Alternative Meat Consumers

Characteristic	Beef Buyers (N=1360)	Alt-Beef Buyers (N=470)	Difference
% Vegetarian	1.9%	25.5%	-23.6%
% with children under 12	25.8%	36.8%	-11.0%
% with BS degree or higher	33.4%	40.0%	-6.6%
% Female	47.1%	46.2%	0.9%
% with Household Income < $40,000	19.5%	18.1%	1.4%
% with Household Income between $40,000 and $80,000	33.5%	31.9%	1.5%
% with Household Income between $80,000 and $120,000	13.5%	15.3%	-1.9%
% with Household Income > $120,000	8.2%	12.3%	-4.1%
Average age in years	48.0	40.3	7.7
% younger than 30 years	18.6%	37.2%	-18.6%
# people in Household	2.49	2.57	-0.07
% residing in Northeast	17.7%	21.3%	-3.6%
% residing in Midwest	22.9%	17.4%	5.4%
% residing in South	38.6%	38.1%	0.5%
% residing in West	20.8%	23.2%	-2.4%

Source: Alternative Beef buyers Demographics, J. Lusk

Alternative Protein: Cultured Meat

Surveys, as the most common method of quantifying public views, were conducted to study consumer acceptance rates:

- Bryant et al. (2019) with n=1185 adults in the US Census balanced, found out that 66.4%would try; 48.9% would aet regularly; 55.2% would eat instead of conventional meat
- Bryant & Dillard (2019) with n=480 adults in the US, 64.4% would try; 24.5% would buy regularly; 48.5% would eat instead of conventional meat

In general, higher rates of cultured meat acceptance were observed in the US than Europe.

Typically, people perceive the benefits of lab-grown meat with that of the society, but the risks accruing to themselves. However, in an experimental setup, Rolland et al. found that a message about the personal benefits of the lab-grown meat led to the largest increase in its acceptance. That is, health claims could drive acceptance, hence, pro-cultured meat messaging strategies related to personal benefits can be considered a significant matter in this regard.

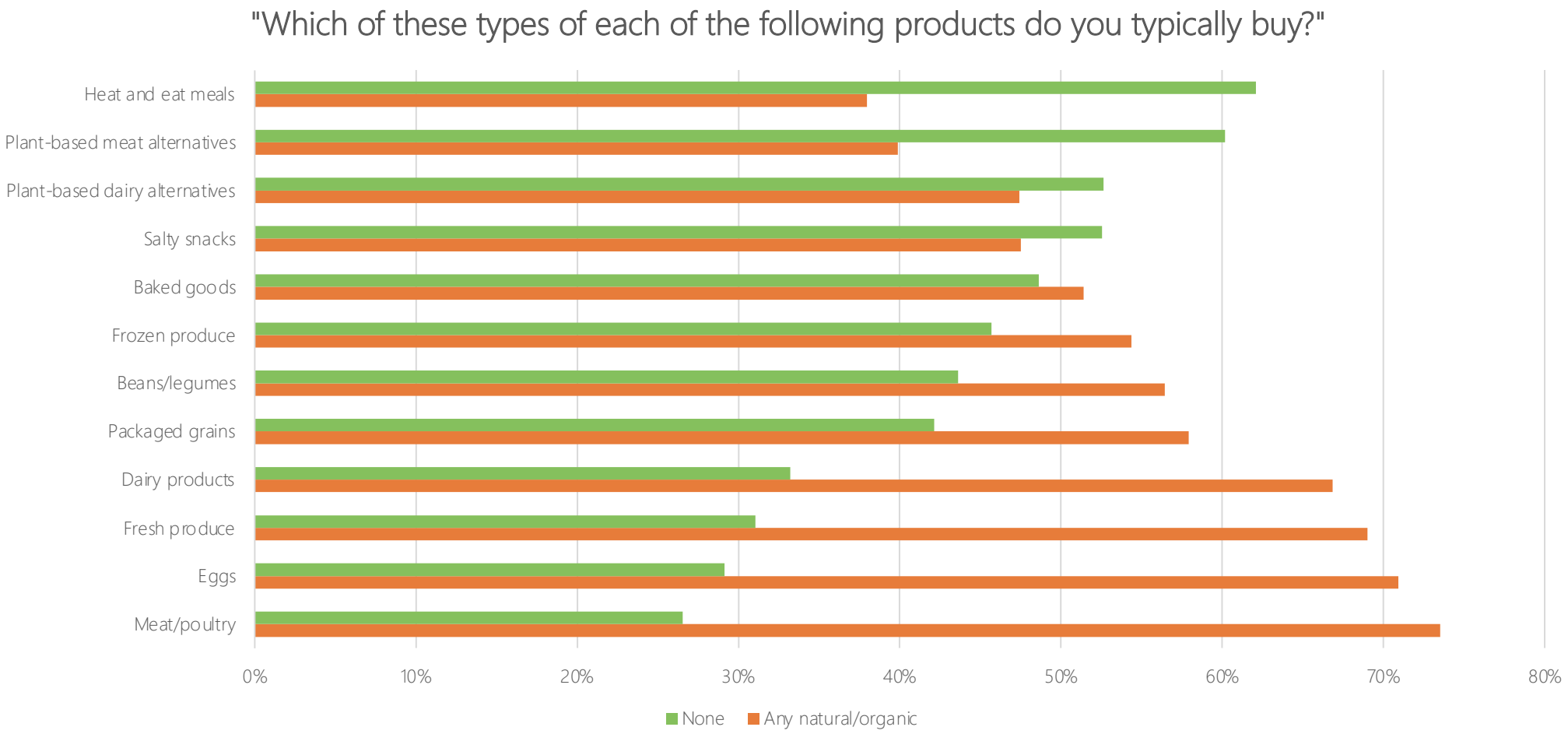
The other barriers to acceptance include:

- *Unnaturalness*, which is often the basis for feelings of disguise and safety concerns. It is a more fundamental objection when it comes to consumers' reasons to avoid lab-grown meat
- *Neophobia*, which was also identified as a key predictor of cultured meat rejection across different countries, including the US
- *Economic Anxieties*, which are related to affordability of it as well as the impact on farming and rural communities

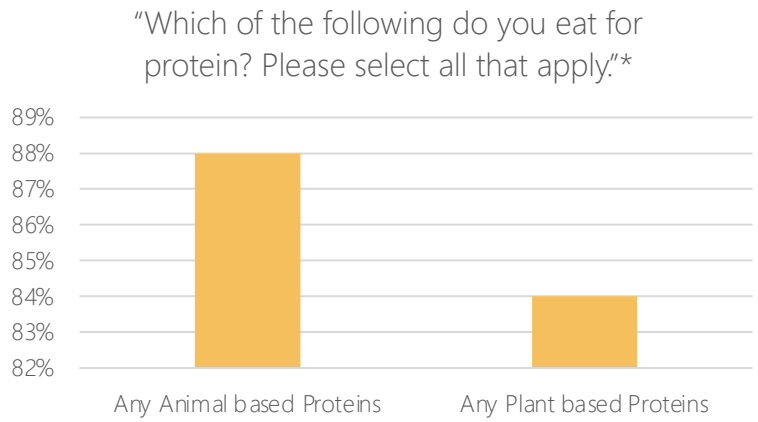
In the same study done by Roland et al., it was found that additional information regarding various benefits of lab-grown as well as tasting increased the acceptance rate. The authors tested three types of information (societal benefits, personal ones, meat quality and taste). And while all of the above led to further acceptance, information related to personal benefits has the higher impact on acceptability.

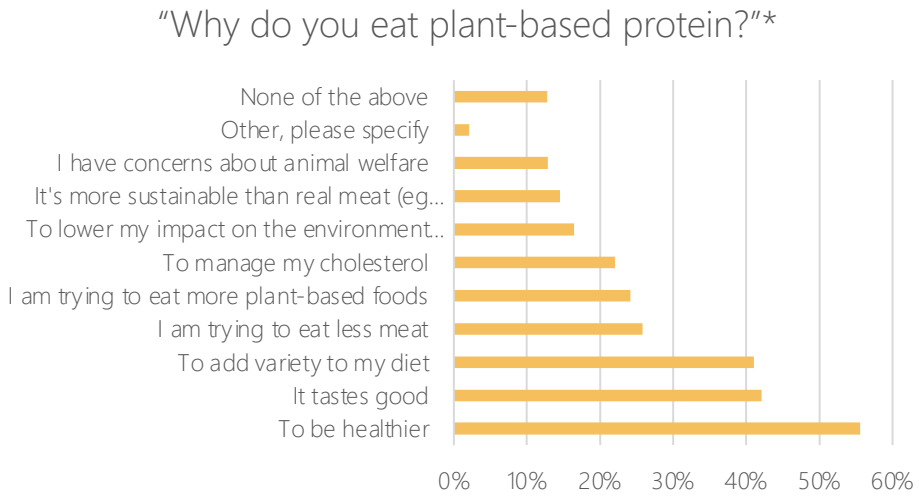
In addition, cultured meat is usually perceived as more acceptable than GM foods and insect-based protein. Research shows that while it is not as broadly accepted as plant-based protein, a certain consumer group is expected to emerge. Factors which were mentioned earlier, such as taste and price will play a key role in willingness to consume cultured meat, hence, determining market success of the product.

Natural/Organic: Survey Across Products



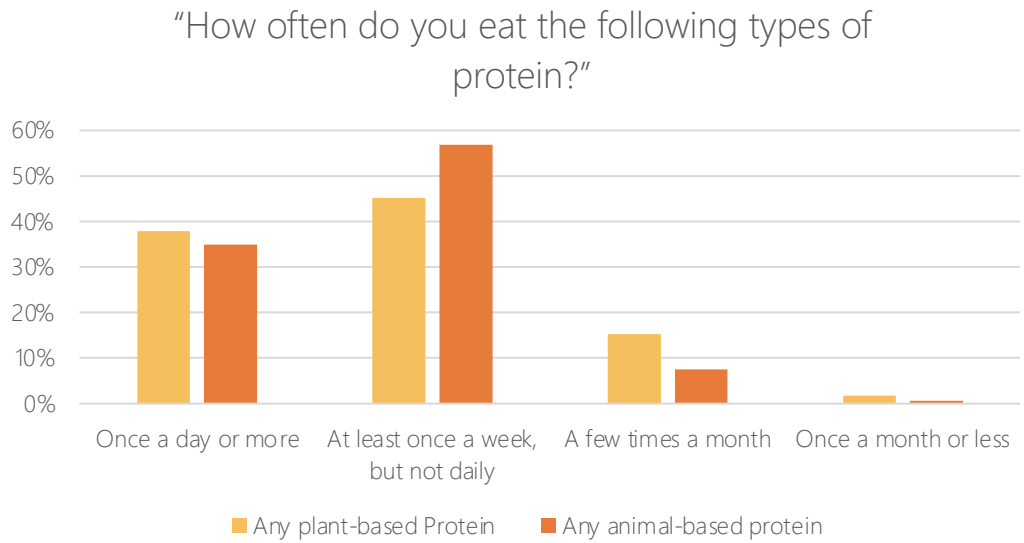
Alternative Protein: Survey





*Base: 2,000 internet users aged 18+

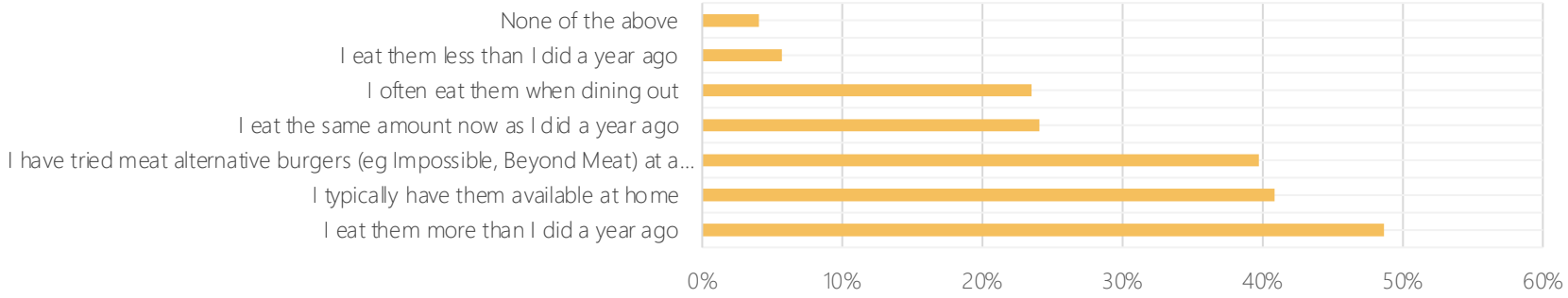
Frequency of protein consumption among stratified consumer segments [1,2]



1: internet users aged 18+ who eat only Animal based Proteins
2: internet users aged 18+ who eat only Plant based Proteins

Alternative Protein: Survey

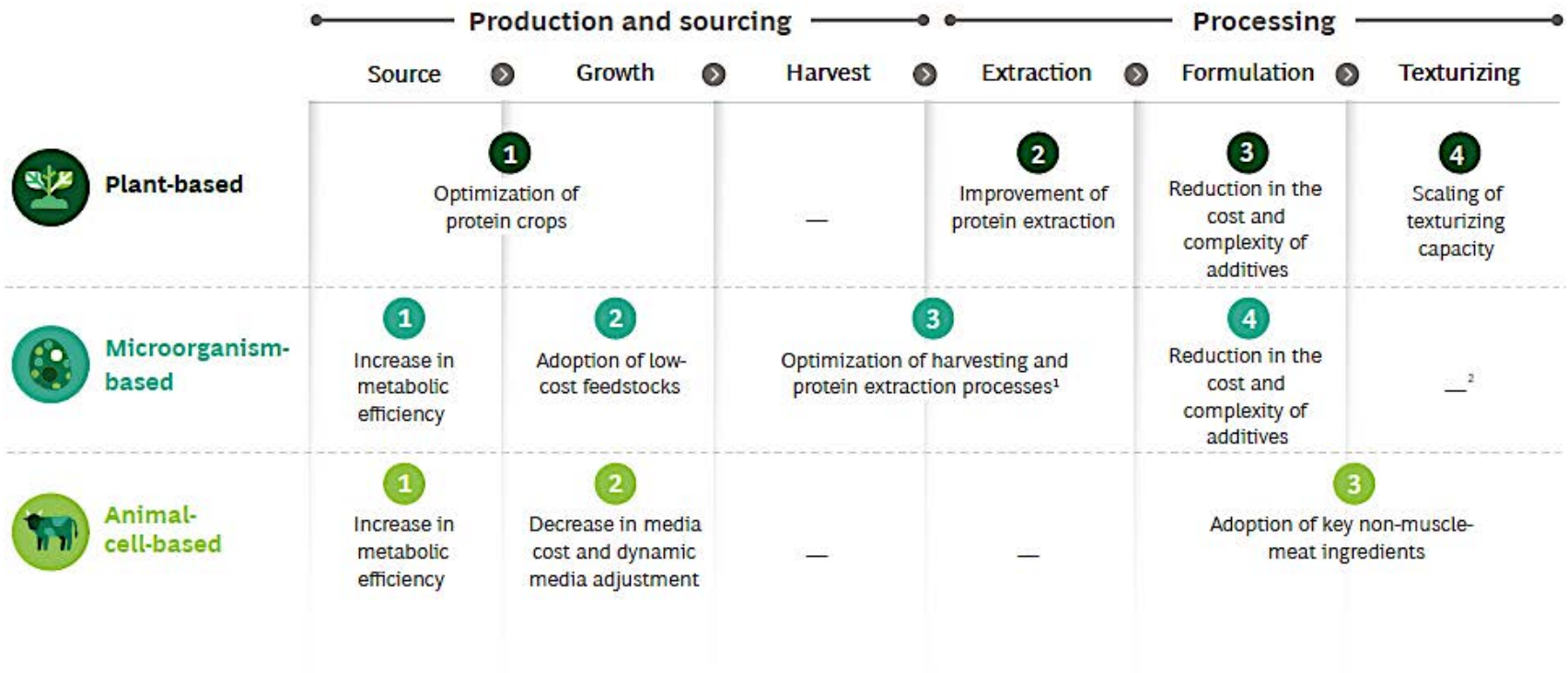
"Which of the following statements about plant-based meat substitutes do you agree with?"



"Why don't you eat plant-based meat substitutes?"

7 Opportunities

The plant-based and cultured meat industries are novel and present an attractive and perspective market opportunity for various innovators, from startups to established industry players. The graph below provides an overview of some of the areas for potential opportunities within these growing sectors.



Sources: Blue Horizon and BCG analysis.

Note: The list of measures is not exhaustive, focusing only on the measures with the greatest impact.

[1]Applicable only to precision fermentation.

[2]Additional texturizing may be needed when using precision fermentation; the challenges are similar to texturizing plant-based proteins.

Each opportunity on the lists over the next slides in this section, represents an unsatisfied demand that will require unique skills and resources to address. As a result, some of these demands might be best fulfilled by startups, while others might be better suited for established players in various industries. Anyhow, businesses should perform their own feasibility analysis of their ideas to determine commercialization potential.

Opportunities in Plant-based and Cultured Meat

- Protein Farming and Breeding

Objective	Need	Situation	Opportunity
Improving Underutilized Crops	Crops with better functionality for plant-based meat applications.	Crops such as soy, wheat, and corn have been optimized for increased yield, robustness, and disease resistance, though few other plant varieties have achieved the same.	Utilization of genetic engineering and/or high-throughput breeding approaches to improve underutilized plant protein crops for plant-based meat applications. • Increasing yield, robustness, and resistance to biotic/abiotic stress to decrease costs • Adapting tolerance to new climates (temperature, drought, salinity) for expanded growing opportunity and thus increased availability/supply • Altering protein content for improved functionality • Altering nutritional profile to increase content and/or bioavailability of macronutrients and micronutrients • Improving flavor profile by removing off-flavors or enhancing desirable flavors
Remove off-flavors from plant-based proteins	Better tasting plant-based proteins for plant-based meat applications.	Soy, pea, and other proteins used in plant-based meat applications tend to have off-flavors (e.g., beany, grassy) due to the presence of compounds such as saponins, isoflavones, and lipoxygenases that must be removed or masked to ensure product quality of plant-based meats.	Developing a mechanism to remove or mask off-flavours in plant-based proteins, which could be used to sell ingredients B2B or develop better-tasting consumer products. • Genetic engineering and/or high-throughput breeding approaches to remove or alter the gene that encodes the undesirable compound (see Improve underutilized crops idea). Note that this strategy may not be feasible for compounds that are important for the biological functions of the plant. • Developing additives to block or neutralize undesirable flavours, ideally without compromising clean label standards (e.g., MycoTechnology's ClearTaste protein) • Utilizing biological (e.g., microbial fermentation) chemical (e.g., incubation with an enzyme like ALDH) or physical (e.g., heating and cooling) means to remove or neutralize undesirable compounds • Using bioprocessing methods (e.g., salting-out or β-Cyclodextrin-mediated methods of off-flavour removal from soy protein)

Opportunities in Plant-based and Cultured Meat (continued)

- Protein and Ingredient Processing

Objective	Need	Situation	Opportunity
Textured proteins for plant-based meat applications	Greater variety and availability of textured plant-based proteins for the production of plant-based meat.	Rather than starting from powdered protein isolates or concentrates and using an extruder to create a fibrous structure, plant-based meat manufacturers might choose to use pre-extruded textured proteins to formulate their products. This method is often more economical for manufacturers since it does not require extrusion equipment, which is expensive to purchase and operate. Currently, there are many types of textured soy and wheat protein on the market, and textured pea proteins are just starting to become available in the US. However, other varieties remain unavailable.	Opportunity: Develop novel textured proteins to be sold B2B to plant-based meat manufacturers. Opportunities include: • Using novel plant sources to create textured proteins from on-trend ingredients like chickpeas. • Creating different shapes and particle sizes. • Creating desirable flavor profiles that remove off-flavors and actually taste like meat. A similar but distinct opportunity is to develop plant-based meats to be sold B2B for incorporation into value-added products or meals. For example, Improved Nature sells plant-based chicken strips that can be finished into chicken tenders, used as a pizza topping, etc.., but there may be opportunities to develop additional products for different applications.
Non-textured proteins for plant-based meat applications	Greater variety, availability, and functionality of powdered plant-based proteins for the production of plant-based meat.	Currently, ~60% of the plant-based proteins on the market are soy-based and another ~10% are wheat-based. Consumers are seeking more on-trend protein sources, but few companies (e.g., purePlants) supply unique plant-based proteins, and even fewer can supply these proteins in the volume that plant-based meat manufacturers would need. Furthermore, B2B plant-based protein suppliers often have little to no data on the extrusion properties of the plant-based proteins they sell, nor have they optimized for such properties.	Develop novel powdered proteins to be sold B2B to plant-based meat manufacturers. Opportunities include: • Using novel plant sources to create plant-based proteins • Developing novel milling and extraction techniques to create more cost effective and scalable plant-based proteins • Optimizing plant-based proteins for functional properties such as solubility, foaming, emulsifying, gelation, etc. • Characterizing and optimizing plant-based proteins for performance during extrusion processing and other forms of texturization

Opportunities in Plant-based and Cultured Meat (continued)

- Protein and Ingredient Processing

Objective	Need	Situation	Opportunity
Characterization of plant-based proteins and other raw materials	Tools and metrics for more thorough characterization of plant-based proteins and other raw materials.	Plant-based meat manufacturers routinely struggle with supplier-to-supplier or even lot-to-lot inconsistency in their raw materials. This can lead to delays as they adjust manufacturing parameters to compensate or even lost batches of product if the raw materials perform poorly enough that the resulting product does not pass quality control. Plant protein concentrates and isolates (and even whole plant flours) are sold to meet target specifications for a given SKU. These specifications may include percentages of fat, protein, and moisture; solubility at certain pH ranges; particle or granule size; and color. For hydrolyzed proteins, the specifications may also include a degree of hydrolysis, but this provides little insight into the nature of the hydrolyzed protein fragments (for example, the average molecular weight). These attributes are not sufficient to predict performance in some applications such as high moisture extrusion for plant-based meat manufacturing. Product manufacturers must typically test samples of each lot of raw material for its performance in their actual manufacturing platform, rather than buying raw materials to specifications that ensure they will achieve consistent performance.	Develop new methods for more detailed characterization of these processed raw materials to capture the attributes that contribute to performance in applications like plant-based meat. With more detailed specifications, manufacturers of these end products can rely on more consistent performance between different suppliers and lots. These methods could be monetized as diagnostic kits to enable plant ingredient suppliers to characterize and validate their products for clients for whom these specifications are critical, or for sale to plant based product manufacturers themselves to allow them to test samples of various suppliers' products before making a bulk ingredient purchase. Alternatively, any IP pertaining to these methods could be licensed to the plant ingredient suppliers so that they can incorporate this methodology directly into their existing QC protocols.

Opportunities in Plant-based and Cultured Meat (continued)

- Protein and Ingredient Processing

Objective	Need	Situation	Opportunity
Plant-based fats	Plant-based fats that can replicate or improve the taste, functionality, and nutritional profile of plant-based and clean meat.	DSM/Martek and ADM have created plant and algal sources of omega-3s like DHA and EPA. Dow and Cargill have pursued projects to develop canola plants that produce higher levels of omega-3s. However, outside of omega-3s, very few companies have attempted to replicate animal-based fats using plant, fungal, or algal sources..	Produce plant-based fats that mimic animal fats to be sold B2B or incorporated into consumer products. There is opportunity to make a broader range of fats other than omega-3s, including fat profiles more similar to animal fats with respect to degree of saturation, chain length, etc., for more convincing function and taste when incorporated into plant-based products. Techniques for creating novel plant-based fats might include: • Selective breeding or genetic engineering of crops. • Developing novel extraction techniques. • Using underutilized crops as a fat source. • Using techniques like fractionation and interesterification to alter fat composition. • Producing plant-based fats from waste streams of bio-based lipid production industries, for example, by combining waste glycerol from the biodiesel industry with fatty acids in desirable ways to recapitulate fat content either of animal origin, or of plant origin with limited or controversial supply (e.g., palm oil).
Fat encapsulation	Encapsulated plant-based fats for improved mouthfeel of plant-based and clean meat.	Plant-based meats do not have the same mouthfeel as animal-based meats since fat is not retained and released in the same way. Fats like canola or coconut oil are usually added to plant-based meat in a liquid or solid form and are not encapsulated within a membrane. In contrast, animal-based fats in meat are contained within the cell walls of adipocytes. Unencapsulated fats tend to leak out of plant based meat during the cooking process and do not provide the same "burst" when bitten into.	Develop encapsulated plant-based fats for plant-based meat applications to be incorporated into products or sold B2B. Forming micelles around fats using compounds with naturally hydrophilic and hydrophobic regions (e.g., saponins) is one way to encapsulate fat within a hydrophilic medium. Encapsulated fats can be used in solution, as an emulsion, or spray-dried for use as a shelf-stable additive.

Opportunities in Plant-based and Cultured Meat (continued)

- Protein and Ingredient Processing

Objective	Need	Situation	Opportunity
Fermented ingredient supply	B2B supply of ingredients (proteins or other components) that enhance the sensory or functional profile of plant-based meats.	Some companies are exploring the possibility of adding in small amounts of molecules (proteins or other biomolecules)— sometimes ones originally found in animal products— to enhance the sensory profile or functionality of plant-based alternatives. The most famous example is Impossible Foods' leghemoglobin protein. However, there is no dedicated supplier of these ingredients that have already been identified (they are currently being made in-house).	Search for fermentation-based methods of producing a greater variety of these molecules or proteins to supply B2B. For non-protein ingredients, biosynthetic pathway insight and engineering may be required to produce these efficiently through a fermentation-based platform. Deep knowledge of fermentation-based recombinant protein and other biomolecule expression can facilitate more efficient production of these key ingredients to improve the fidelity of plant-based meat. This can ultimately bring down costs for plant-based meat manufacturers by allowing them to outsource production of these components. Beyond simply contracted production of already-identified components, expanded R&D in this area can generate novel ingredients that can be made available to all plant-based meat companies to improve the quality of their products.

Opportunities in Plant-based and Cultured Meat (continued)

- Product Formulation

Objective	Need	Situation	Opportunity
Price-competitive plant-based meat	Price-competitive plant-based meats for price-sensitive markets such as K 12 school foodservice.	Plant-based meat is currently more expensive than animal-based meat, which makes it less appealing to consumers in most markets, and outright inaccessible in price-sensitive markets like K-12 foodservice. In these price-sensitive markets, the stringency for fidelity with animal-based meat is lower.	Develop plant-based meat products such chicken nuggets and sausages that can compete with animal-based products in price-sensitive markets such as K-12 school foodservice. The goal would not be to perfectly replicate animal-based products, but create products that appeal to consumers (especially kids) and are inexpensive to produce at scale. Formulating products using pre-extruded textured protein might help reduce production costs compared to using powdered protein concentrates or isolates that must be extruded.
Refrigerated plant-based prepared foods	Refrigerated plant based entrees/ prepared foods to be sold in retail, foodservice, and grocerant settings.	According to Nielsen data, the majority of sales of plant-based meals and meats are frozen, in spite of evidence that consumers are increasingly choosing fresh, prepared foods. Packaged Facts estimates the overall sales of refrigerated meals and meat will be $31 billion by 2018, and grocerants serving prepared foods within a retail setting are becoming increasingly popular. Wicked Kitchen's Tesco line is an example of a company that has taken advantage of this trend in the UK, but few US companies have done the same.	Develop refrigerated prepared meals to be sold in retail, foodservice, or grocerant settings. This opportunity might involve product development of novel plant-based meats for inclusion in meals or the incorporation of existing plant-based meats into refrigerated meals.

Opportunities in Plant-based and Cultured Meat (continued)

- Product Formulation

Objective	Need	Situation	Opportunity
Clean label plant-based meat	Price-competitive Clean label and/or allergen-free plant-based meat products.	Consumers are increasingly seeking clean label products, but few plant-based meat products are clean label, and even fewer are primarily composed of whole foods.	Develop plant-based meats and meals that are centered around whole food ingredients like mushrooms and jackfruit that naturally resemble (but do not exactly replicate) meat's taste and/or texture. Another idea is to use novel protein sources (e.g., chickpea protein) which consumers may perceive as cleaner label and more desirable than soy and wheat proteins.
Blended meat products	Blended animal- and plant-based meat products that consumers might choose in lieu of 100% meat products..	The taste, texture, and mouthfeel of meat products can often be preserved and even enhanced by replacing some of the meat with plant- or fungal based ingredients. Not only can blended products taste better than 100% meat products, but they also offer a nutritional profile that is lower in calories, saturated fat, and cholesterol, and higher in fiber and other nutrients. While blended products are popular in low-price point markets (fast food, K-12 school foodservice) in which plant-based ingredients are essentially used as fillers (e.g., Taco Bell's sawdust controversy), there is an opportunity to produce and market blended products as a desirable, value-added product. Value-added blended products have shown potential within retail and foodservice markets.	Develop blended products for sale in retail or foodservice markets. There are a number of ways to formulate blended products. A manufacturer might create products that blend animal-based meat with pre-extruded, textured proteins such as textured soy flour or a product like Lika Plus or Meatless BV. Alternatively, a manufacturer might blend meat with whole plant-based ingredients such as mushrooms, pulses, vegetables, and spices, or use a combination of these approaches. While most blended products have been beef or pork-based burgers or sausages, there may be opportunities to develop blended poultry or seafood products as well. Another company idea is to develop a novel plant-based meat replacer or extender for use in blended products to be sold B2B.

Opportunities in Plant-based and Cultured Meat (continued)

- Manufacturing

Objective	Need	Situation	Opportunity
Sensors for plant-based meat production	Sensors for monitoring production and ensuring consistent product quality of plant-based meats.	During extrusion of plant-based meat, various physical inputs (e.g., water, raw materials) and conditions (e.g., temperature, pressure, stress) can affect product quality (e.g., fibrousness, consistency, morphology). These attributes should be monitored in real-time to inform product development and to ensure consistent production throughout the manufacturing process.	Develop sensors for fibrousness, moisture content, and stress profiles to help manufacturers better predict the precise parameters of their plant-based meat manufacturing process. These sensors could be advantageous to raising production quality and quantity of plant-based meat while lowering costs by reducing product waste due to inconsistent manufacturing. There are several examples of the sensor developed in academia for detecting quality of plant-based meats including the neutron scattering for fibrousness and quality evaluation developed to show fiber development in materials processed via the Couette Cell. There are also a number of sensors in the plastics extrusion industry that could be modified to assist with higher quality or consistency of plant-based meats. Note: This technology may be best developed within or in close co-development with an extruder company so that it directly integrates into the existing equipment and its read-out can be tied to adjustable parameters of the process.

Opportunities in Plant-based and Cultured Meat (continued)

- Manufacturing

Objective	Need	Situation	Opportunity
Texturization technologies	Lower cost, higher quality, and more accessible methods for creating fibrousness in plant-based meat products..	Most plant-based proteins must be texturized in order to replicate the structural and functional properties of meat. Currently, plant-based meat manufacturers usually either 1) Purchase powdered protein concentrates or isolates and use high moisture twin screw extrusion to create fibrous structures, or 2) purchase pre-extruded textured proteins so further extrusion is not required. Each method has its limitations: for the first method, extruders are expensive to purchase, and few co-packing facilities exist. Furthermore, extruders can only create tissue of a limited thickness. For the second method, pre-extruded proteins can generally only be used to create ground meat products (e.g., chicken nuggets) as opposed to whole tissues (e.g., chicken strips), and limited varieties are available.	Opportunities include: • Develop extruders that are more affordable, compact, and/or easy to operate compared to commercially available models. • Develop alternatives to extrusion through the design of novel equipment like the Couette cell, which was developed at Wageningen University and is being commercialized by a consortium of companies. • Adapt technologies from other fields (e.g., 3D printing) for plant-based meat production. • Utilize mechanical techniques such as stretching, kneading, press forming, folding, and layering or explore non-mechanical processes that may promote protein texturization, such as temperature variation, biochemical manipulation, or enzymatic treatment.
Plant-based meat co-packing	Co-packing facilities for plant-based meat production.	Co-packing (also known as co-manufacturing) is an essential service for food manufacturers who are looking to scale up production beyond pilot-scale but are not yet ready to purchase their own equipment and facility. However, there are very few co-packing facilities that have high-moisture twin screw extruders or other equipment that is suitable for plant-based meat production.	Create a co-packing facility for plant-based meat, including manufacturing equipment such as extruders, as well as packaging and storage equipment for a variety of temperatures.

Opportunities in Fermentation Domain

Objective	Need	Situation	Opportunity
Fermentation	Efficiency of current industrial food production and outcompeting animal agriculture as a form of food production, not just in cost, but in capabilities, speed, and volume	As fermentation space for alternative protein applications is growing, it is expected that an increased number of both established and emerging companies to target fermentation businesses as their core clientele	More and more companies are using engineered microorganisms capable of producing everything from collagen to egg proteins, Precision fermentation as a process that enables programming of micro-organisms to produce almost any complex organic molecule is considered to be on the cusp of outcompeting animal agriculture as a form of food production, not just in cost, but in capabilities, speed, and volume. The end result will be an improvement in the efficiency of current industrial food production by an order of magnitude.

8 – Conclusion - Key Takeaways

There are **many potential commercial sources**—wheat and soy are leaders, with pea rapidly Growing, and hemp emerging.

Commercial proteins are complex mixtures, and **viability** often requires value from **non-protein components** (e.g. oil, starch).

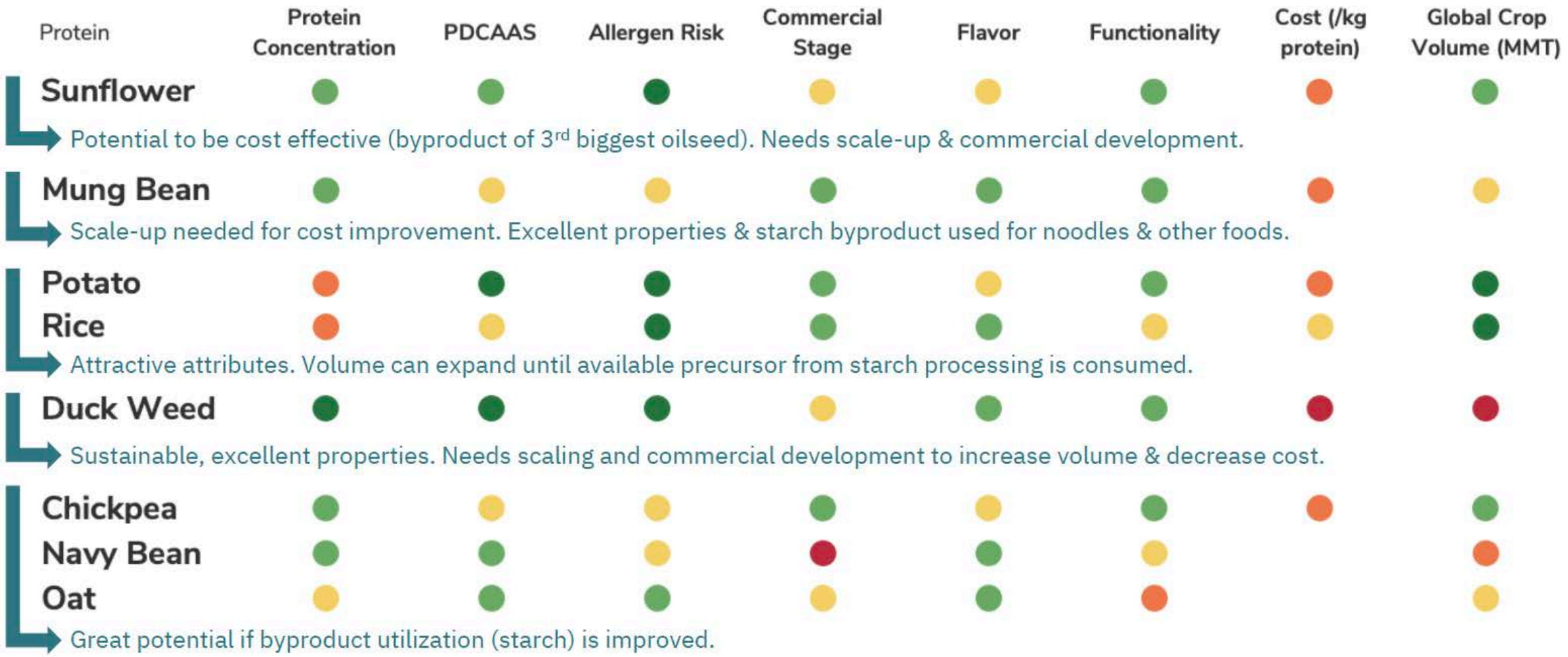
Properties depend on **plant source** and **process**, and formulations often benefit from **protein synergies**.

Process influences **purity, extracted fractions,** and **structural changes**.

There is a lack of systematic data to **objectively compare functionality**.

Optimizing protein selection is dependent on many factors, including **function**, **cost**, and **perception**.

Plant-based specific opportunity areas.



In Summary

In the alternative protein space, for the US consumers, plant-based protein continues to be the major alternative source of proteins, with majority stating that the reason for it is *taste*. Unsurprisingly, taste is ranked to be first when it comes to overall American food values, according to the research of Jason Lusk. Hence, this parameter should be fundamental when new products are introduced to the US market. According to BCG, by 2035 alternative proteins will cover 11% of the $872 billion global protein market.

In the context of Midwest, it should be noted that the region has very little land allocation to crops which are ideal for alternative proteins, partly because the economics of predominantly chosen grains in Midwest are much higher compared to most protein rich alternatives like peas. The region is best fitted for legumes farming than grains. However, since legumes are limited in production in U.S. and Midwest, the total harvest capacity is far from meeting the demand of the industry at its current pace of growth. Today total harvest capacity is roughly 91M tons globally and only 10-15% is serving plant-based protein ingredient markets. This limited raw material availability prevents broader and faster adoption and therefore prevents affordability for larger population.

Cultured meat has shown significant growth in recent years, although some challenges remain. First, as it was stated previously, price is one of the top values of American consumers; in the context of the cultured meat, the major production expense is the growth medium which can cost around 400$ per litre, and in application a conventional bioreactor requires up to 600 litres to produce 1 kg of meat, which overall requires 240K. Companies are investing heavily in the R&D but problems remain.

For the insect-based food, the major obstacle is the feeling of insect disgust and disease risk; however, in another research it was found out that educational seminar decreases negative attitudes and beliefs towards insects and its derivative in foods, hence improving some prospects of the consumer behaviour. It was found that flour was the commodity which customers were most willing to buy, and in terms of demographics men were more likely to consume these foods.

In general, plant-based alternatives are the most popular ones, both among producers and the customers. In our analysis of the top fifteen meat and poultry producers in the US, ten were involved in plant-based activities (production and/or investments), while only three in that of cellular agriculture. Interestingly, the US market analysis suggest that the products such as plant-based eggs, yogurt and creamer experience profound sales growth, i.e., 192%, 34%, 31%, respectively, surpassing that of plant-based meat (18%). In addition, hemp is viewed as an alternative protein source, with the States having a high capacity for its production.

Fermentation domain presents another opportunity in the industry, with large investments made in the last years. Precision fermentation, that is a process of programming of micro-organisms to produce complex organic molecules, such as proteins, is gaining attention due to its potential to produce value-added, highly functional, and nutritious ingredients.

Overall, the current market conditions and trends present ample opportunities for innovators and startups targeting the Midwest, and as an extension of it the broader U.S. market. Most important success factor will be to find the right partners across the value to expedite the commercial success. Given the highly active startup ecosystem, it also offers significant investment opportunities for investors focused in this domain. The recent plant-based technology IPOs like Beyond Meat, has shown that there is an actual exit market. This accelerated the investment flow into the space.

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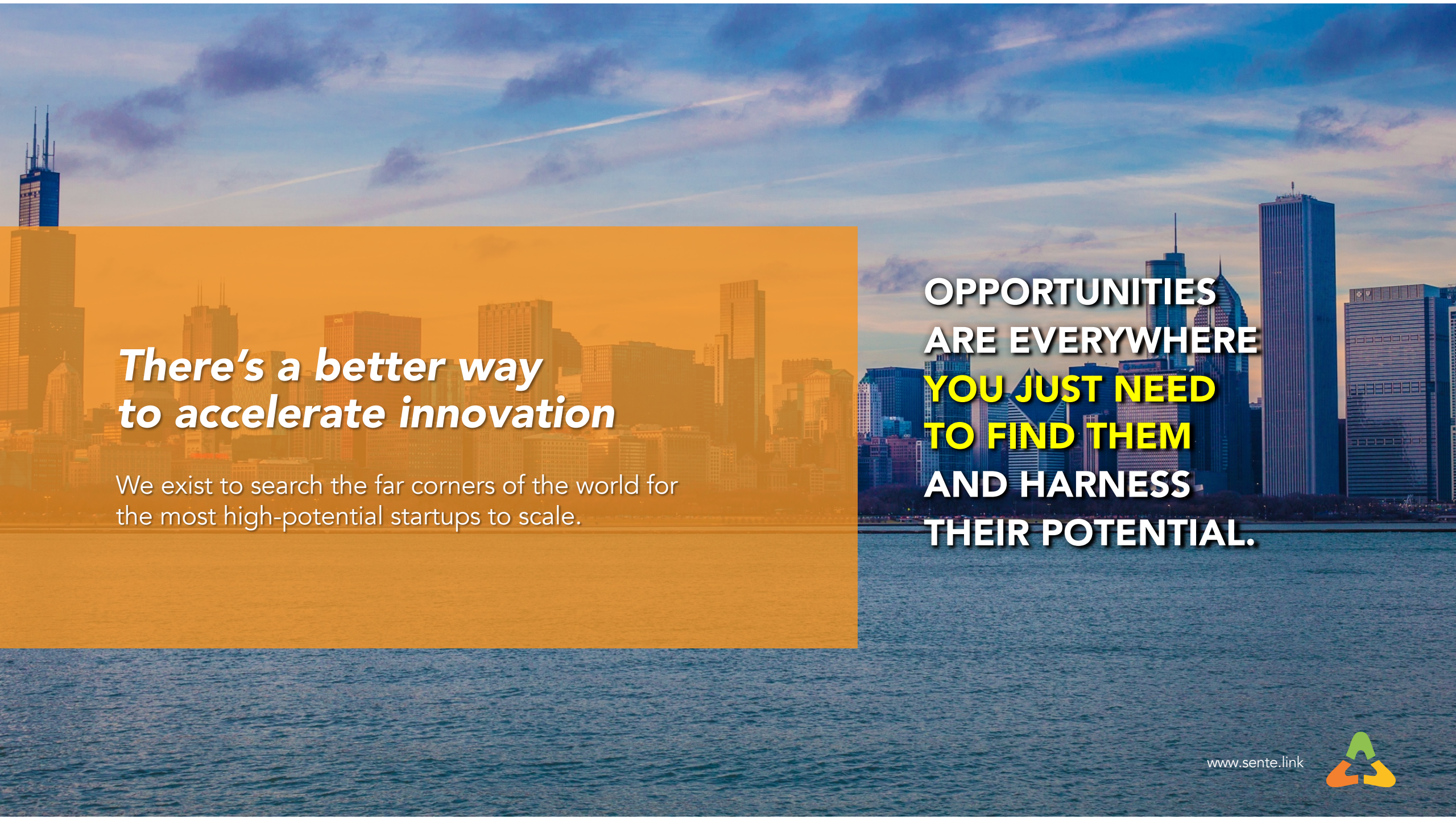
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