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# PROMISEANG

Alternative PROteins from MIcrobial fermentation of non-conventional SEA sources for Next-Generation food, feed and non-food bio-based applications

# D2.5

## Alternative proteins market study v2.1

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## PROJECT INFORMATION

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| 3 | MOA BIOTECH SL | MOA | ES |
| 4 | INSTYTUT BIOTECHNOLOGII PRZEMYSLU ROLNO-SPOZYWCZEGO IM PROF WACLAWA DABROWSKIEGO - PANSTWOWY INSTYTUT BADAWCZY | IBPRS | PL |
| 5 | CONTACTICA SL | CTA | ES |
| 6 | CENTIV GMBH | CENTIV | DE |
| 7 | AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS | CSIC | ES |
| 8 | BIOZOON GMBH | BZN | DE |
| 9 | LABORATORIO IBERICO INTERNACIONAL DE NANOTECNOLOGIA LIN | INL | PT |
| 10 | CONSERVAS RIANXEIRA SA | JEALSA | ES |

## DELIVERABLE DETAILS

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| **Author:** | Universidade de Vigo<br>Universidade Vigo |
| **Abstract:** | This study explores the alternative protein sector, analyzing its growth dynamics, market segmentation, and challenges. It emphasizes sustainability, technology, and evolving consumer preferences as primary drivers, while acknowledging cost constraints and regulatory complexities. Segment analysis reveals a dominance of food applications, with emerging opportunities in feed and non-food sectors. Future trends include a focus on sustainability initiatives, |

| | |
|---|---|
| | strategic partnerships, innovation in packaging, and technological advancements, all shaping the trajectory of the alternative protein market. |

| Date | Description | Version of the document |
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| **08/03/2024** | Initial version of the market study | 1.0 |
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## 1. EXECUTIVE SUMMARY

This market study presents a comprehensive analysis of the alternative protein sector, elucidating its driving forces, market segmentation, and competitive landscape. Exploring the catalysts behind the industry's growth, the study underscores sustainability concerns, technological advancements, and evolving consumer preferences. However, it acknowledges challenges such as cost constraints and regulatory complexities.

The market segmentation categorizes alternative proteins by source and application. The analysis highlights the predominance of food applications in the competitive landscape, with promising opportunities emerging in feed and non-food sectors.

Looking ahead the study anticipates a continued emphasis on sustainability initiatives, strategic partnerships, innovative packaging solutions, personalized product offerings, and technological innovations, all of which will shape the trajectory of the alternative protein market.

## 2. INTRODUCTION

Current world challenges are encompassed in a dichotomy: economic and technological development of societies without compromising natural resources. This global problem is exacerbated by the extremely growing population, estimated to reach >9 billion people by 2050, which will require an equally severe and unsustainable increase in food production of approximately 70%, unless appropriate measures and policies are implemented. With the increase in world population and well-being, the demand for protein as a food-nutritional component is rising sharply.

Currently, livestock production contributes to 14.5% of anthropogenic greenhouse gas (GHG) emission[1]. Livestock production releases methane and nitrous oxide gases, which have higher global warming potential than carbon dioxide[1]. To prevent potentially disastrous consequences, it is essential to keep global temperature rise within 1.5°C of pre-industrial levels (Intergovernmental Panel on Climate Change). Furthermore, the

[1] Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A., Tempio, G. (2013). Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. FAO, Rome.

significant demand for water and land intensifies the environmental impact of livestock production[2].

Mitigation efforts include improved feeding practices for better forage digestibility, manure management and diversification of crop and animal varieties[3]. However, climate challenges are increasingly urgent, and more drastic measures may be needed to guarantee food security in an environmentally sustainable way. As a response, the concept of alternative proteins emerges as an effort to replace traditional meats with protein sources that demand less resource-intensive production methods[4].

The demand for protein ingredients has surged over the last few years. The global protein ingredient market was worth $77.69 billion in 2022 and is anticipated to grow by 5.8% annually from 2023 to 2030[5].

The expanding food industry, driven by population growth and rising consumer awareness, is fuelling the demand for protein and alternative protein ingredients. Consequently, interest in sustainable and diverse food systems is increasing. From a consumer standpoint, purchasing decisions that positively impact the environment are becoming more significant, with a growing emphasis on transparency and sustainability in the food supply chain[6].

Alternative sources of protein are becoming more mainstream. For instance, Eleven Madison Park, one of the world's best fine dining restaurants, announced a complete move from meat to a plant and AP-based menu[7]. Food producers and retailers including Nestlé, Tesco, Kraft Heinz, General Mills, and Unilever, are also increasingly offering non-animal-based sources of protein, extending their range to include plant-based protein products[8].

Current EU market trends highlight a growing demand for proteins that are healthy (nutritious and well-balanced diets), sustainable (from environmental, economic, and social perspectives) and ethically produced. Therefore, profound changes and major transformation of the sources of proteins are highly required and the development of alternative proteins with minimal environmental impact is the most plausible solution.

## 2.1. Current feedstocks to obtain proteins

Despite their high-environmental impacts (Figure 1), current protein feedstocks are dominated by farm animal sources and, at current consumption levels, 1.25 billion tons/year of meat and dairy would be needed to meet global demand by 2050. Fish and other marine foods are also an essential source of proteins: per capita consumption of marine food has tripled in the last 60 years and, in some parts of the world (i.e., Iceland, Norway, Southeast Asia), marine foods are already the main source of proteins[9]. Although 88% of fishing is used for human eating, over 30% of global marine stocks are overexploited and >35% of the fishing is wasted every year. Thus, it is urgent to repurpose marine catches to avoid overexploitation, reduce biowaste and

[2] Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., de Haan, C. (2006). Livestock's long shadow. FAO, Rome.
[3] Hristov, A. N., Ott, T. Tricarico, J., Rotz, A., Waghorn, G., Adesogan, A., Dijkstra, J., Montes, F., Oh, J., Kebreab, E., Oosting, S. J., Gerber, P. J., Henderson, B., Makkar, H. P. S., Firkins, J. L. (2013). Mitigation of methane and nitrous oxide emissions from animal operations: III. A review of animal management mitigation options. J. Anim. Sci., 91 (11), 5095–5113
[4] Hadi, A., Arab, A., Khalesi, S., Rafie, N., Kafeshani, M., Kazemi, M. (2021). Effects of probiotic supplementation on anthropometric and metabolic characteristics in adults with metabolic syndrome: A systematic review and meta-analysis of randomized clinical trials. Clinical Nutrition, 40(7), 4662-4673.
[5] Grand View Research (2022). Protein Ingredients Market Size, Share & Trends Analysis Report. Grand View Research Inc., San Francisco, USA.
[6] Ismail, B. P., Senaratne-Lenagala, L., Stube, A., Brackenridge, A. (2020). Protein demand: review of plant and animal proteins used in alternative protein product development and production. Animal Frontiers, 10(4), 53–63.
[7] Krader, K. (2021, May 4). Eleven Madison Park is going vegan because Kobe beef is 'gluttony'. Financial Review.
[8] Nguyen, J., Ferraro, C., Sands, S., Luxton, S. (2022). Alternative protein consumption: A systematic review and future research directions. *International Journal of Consumer Studies*, *46*(5), 1691–1717.
[9] Comparison of Global Warming Potential (GWP) of different protein sources: initial LCA study by CTA (2022, EF impact assessment method, ref: Ecoinvent3 database, WFLDB databases 28,29,30)

convert fishing into a sustainable practice.

| Protein Source | GWP (kg CO2-eq/kg of protein) |
|---|---|
| Beef | 80,53 |
| Chicken | 9,2 |
| | |
| Tuna | 11,76 |
| | |
| Soybean | 8,57 |
| Hemp | 0,64 |
| Whey | 0,2 |
| | |
| SSF- non-renew. energy | 17,20 |
| SSF- renewable energy | 2,31 |
| SSF- optimized parameters | 0,41 |
| | |
| SLF-commertial substrate | 1,80 |
| SLF- biowaste substrate | 0,37 |

*Figure 1. Comparison of Global Warming Potential (GWP) of different protein sources: initial LCA study by CTA (2022, EF impact assessment method, ref: Ecoinvent3 database, WFLDB databases)*

### 2.1.1. Alternative proteins and feedstocks.

In the last 20 years, there has been an incipient development of alternative protein sources, including plant-based proteins (e.g., soy, pea), new animal sources (e.g., insects) and biotechnological innovations (e.g., cultured meat or biomass fermentation)[10] (Figure 2). Other sources include mycoproteins and algae[11].

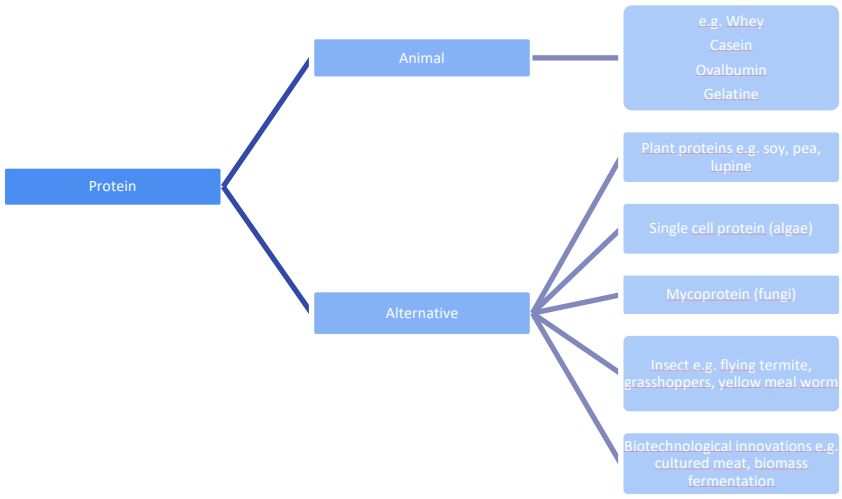



*Figure 2. Classification of proteins based on their origin. Adapted from Karabulut et al., 2024[12].*

Plant-based and insect alternatives have some drawbacks such as organoleptic properties, land use or allergenicity, while proteins from biomass fermentation present great advantages: they are independent of season or climatic factors, use facilities in very small areas, water consumption is drastically reduced, and GHG

[10] Zafer Bashi, Z., McCullough, R., Ong, L., Ramirez, M. (2019, August 16). Alternative proteins: The race for market share is on. McKinsey & Company.
[11] Godfray, H. C. J., Springmann, M., Sexton, A., Lynch, J., Hepburn, C., & Jebb, S. (2019). Meat: The future series—Alternative proteins. World Economic Forum
[12] Munialo, C. D. (2024). An exploration of alternative proteins as a potential sustainable solution to meeting the nutritional needs of the ever-increasing global population. International Journal of Food Science & Technology, 59(5), 2846–2859

emissions are highly reduced.

The use of food waste streams and by-products to produce microbial protein is an emerging area and a more sustainable source of high-quality protein[13]. Lots of research has been done into agri-food industries; however, food waste derived from marine sources has not been totally exploited. Among the marine sources, fish by-products (i.e., heads, bones, guts) are already re-used for several industrial uses, such as fish feed (due to its high protein content, 20-35%), and extraction of fish oil (including omega 3) and collagen.

However, although the processing of seafood (industry and local seafood shops) generates a huge quantity of discards and biowastes (50-80%), seafood biowaste has only been researched to extract biomolecules of interest, such as chitosan[14]. In the case of macroalgae, 20% of biomass remains as residual during seaweed harvest and downstream processing, which has merely been researched as biofuel. Therefore, seafood and macroalgae biowastes and by-products represent a vast opportunity to research new reuses, including the production of alternative proteins by biomass fermentation for novel industrial streams.

Protein production for various applications, such as human consumption, animal feed, and industrial use, depends on a wide range of raw materials. These sources include animal and agrifood by-products, plant-based ingredients, as well as microbial and synthetic alternatives. Gaining insight into the raw materials currently utilized in protein production is essential for improving efficiency and promoting sustainability.

- **Animal By-Products:** Residual raw materials from the fish and meat industry, such as heads, bones, carcasses, blood, skin, viscera, hooves, and feathers, serve as significant protein sources and are commonly used in human food, pet food, and animal feed[15]. Additionally, highly mineralized collagen-rich beef raw materials, including tibia, fibula, and costal bones, are processed through high-temperature hydrolysis and enzymolysis to produce protein-based nutraceuticals[16].
- **Microbial Sources:** Microorganisms such as algae, bacteria, actinomycetes, yeasts, molds, and higher fungi play a key role in the production of single-cell proteins (SCP), thriving on various substrates like hydrocarbons, petrochemicals, and agricultural, industrial, and food-processing wastes[17]. Similarly, paraffin-containing petroleum raw materials and purified liquid waxes are used to produce feed yeast, which serves as a protein source for animal feed[18].
- **Plant-Based Proteins:** Proteins derived from vegetable seeds, such as soybeans, peas, and wheat, are abundant and renewable sources widely utilized for their functional and physicochemical properties in applications like microencapsulation[19]. Soy hydrolysates, in particular, are frequently used as supplements in mammalian cell culture media for the production of therapeutic proteins, with their quality evaluated through spectroscopic techniques combined with chemometrics[20].
- **Synthetic and Engineered Proteins:** Advances in biotechnology and synthetic biology have facilitated

[13] Tubb C., Seba T. (2021) Rethinking food and agriculture 2020–2030. Industrial Biotechnology 17:2, 57-72.
[14] Pal G.K., Suresh P.V. (2016) Sustainable valorisation of seafood by-products: Recovery of collagen. Innov Food Sci Emerg Technol., 37, B, 201-215.
[15] Aspevik, T., Oterhals, Å., Rønning, S., Altintzoglou, T., Wubshet, S., Gildberg, A., Afseth, N., Whitaker, R., & Lindberg, D. (2017). Valorization of Proteins from Co- and By-Products from the Fish and Meat Industry. Topics in Current Chemistry, 375, 1-28.
[16] Mezenova, N., Agafonova, S., Mezenova, O., Baidalinova, L., & Grimm, T. (2021). Obtaining and estimating the potential of protein nutraceuticals from highly mineralized collagen-containing beef raw materials. Theory and practice of meat processing, 6, 10-22.
[17] Litchfield, J. (1980). Microbial Protein Production. BioScience, 30, 387-396.
[18] Chepigo, S., Vorob'eva, G., Kozlova, L., Rozhkova, M., & Proshchina, N. (1974). Raw material for the production of proteins. Chemistry and Technology of Fuels and Oils, 10, 531-535.
[19] Nesterenko, A., Alric, I., Silvestre, F., & Durrieu, V. (2013). Vegetable proteins in microencapsulation: a review of recent interventions and their effectiveness. Industrial Crops and Products, 42, 469-479.
[20] Lee, H., Christie, A., Xu, J., & Yoon, S. (2012). Data fusion-based assessment of raw materials in mammalian cell culture. Biotechnology and Bioengineering, 109.

the artificial production of protein-based materials, which are engineered to replicate natural biopolymers. These materials have diverse applications, including drug delivery and other biomedical uses[21,22].

The raw materials used in protein production are highly diverse, ranging from animal by-products and microbial sources to plant-based proteins and synthetic materials. Each of these sources provides distinct benefits and applications, shaping the wide array of protein products available today. This variety not only supports multiple industries but also drives sustainability and innovation in protein manufacturing.

### 2.1.2. Availability of marine invertebrates and macroalgae in EU

In 2019, 10% of the EU's total fishery products corresponded to shellfish catch (half a million tons/year), and 1% to macroalgae (50,000 tons/year). Aquaculture plays an increasingly vital role across EU countries; especially as wild fish catches have declined steadily since 2000. Today, aquaculture provides 20% of the EU's fish and shellfish supply and directly employs around 70,000 people. In 2022, nearly all aquaculture production in the EU consisted of finfish and molluscs[23]. Mediterranean countries (France, Spain, Italy, Greece) gather the vast shellfish catch and aquaculture production within EU27[24,25].

Data on macroalgae harvesting and cultivation remains scarce, but within the EU, France, Spain, and Portugal appear to be the primary producers. The European algae sector is a combination of wild harvesting and aquaculture, with macroalgae grown both in natural environments and through farming. In contrast, microalgae production relies on advanced systems such as photobioreactors, open ponds, fermenters, and hybrid technologies[26]. Microalgae, found in both marine and freshwater ecosystems, are microscopic, whereas macroalgae are larger and more recognizable as seaweeds.

Although large-scale industrial algae farming is still in its early stages, Europe is witnessing a rise in production facilities, particularly in coastal regions with favorable environmental conditions. These facilities focus on diverse applications, including food, animal feed, bioplastics, and biofuels[27]. France, Spain, and Portugal remain at the forefront of macroalgae production, with continued investment aimed at scaling up sustainable aquaculture practices[28].

Once primarily consumed in East and Southeast Asia, macroalgae are now gaining traction in Europe for a range of uses beyond food, including pharmaceuticals, cosmetics, nutrition, and renewable energy. According to the Global Seaweed Coalition, expanding seaweed farming could boost global food supply by 10%, alleviating land-use pressures, a key issue highlighted by the Food and Agriculture Organization (FAO). Additionally, increased seaweed cultivation has the potential to absorb up to 135 million tons of $CO_2$ annually and reduce ocean nitrogen pollution by 30% by 2050. Growing awareness of these environmental and economic benefits has fueled business interest in algae cultivation and processing across Europe[29].

Recognizing this potential, the European Commission launched the EU Algae Initiative in November 2022. This strategy outlines 23 key actions to establish a competitive and sustainable algae sector by 2027. As part of the

[21] Miserez, A., Yu, J., & Mohammadi, P. (2023). Protein-Based Biological Materials: Molecular Design and Artificial Production. Chemical Reviews, 123, 2049 – 2111.
[22] Martínez-López, A., Pangua, C., Reboredo, C., Campión, R., Morales-Gracia, J., & Irache, J. (2020). Protein-based nanoparticles for drug delivery purposes. International journal of pharmaceutics, 119289.
[23] Aquaculture statistics. (2024). Eurostat.
[24] Eurostat. Database. Catches – major fishing areas (form 2000 onwards).
[25] Eurostat. Database Aquaculture production by species.
[26] Algae production industry in Europe. (2021). Knowledge Centre for Bioeconomy. European Commission.
[27] Map of Algae Production Facilities. European Commission.
[28] Algae production industry in Europe. (2021). Knowledge Centre for Bioeconomy. European Commission.
[29] Global Seaweed Coalition (https://www.safeseaweedcoalition.org/)

EU's Farm to Fork Strategy under the European Green Deal, the initiative promotes algae as a sustainable protein source to enhance food security while addressing environmental concerns. Complementing these efforts, the EU4Algae Platform[30] was created to support a regenerative, climate-friendly algae industry and facilitate the introduction of novel algae species into the market.

Furthermore, the European Commission's Knowledge for Policy[31] platform provides a detailed analysis of the region's emerging algae industry. While macroalgae production remains relatively modest, the sector holds significant growth potential as investments in sustainable aquaculture expand. Algae cultivation is increasingly seen as a key component of the EU's blue economy strategy, helping to reduce pressure on wild fish stocks while supporting the transition toward a circular economy. With ongoing research and investment, the industrial applications of macroalgae, particularly in food, animal feed, bioplastics, and biofuels, are expected to grow substantially in the coming years.

### 2.1.3. Non-conventional marine sources (discards, by-products and waste)

The fishing and aquaculture industries play a vital role in ensuring food security and the livelihoods of billions of people worldwide. According to the Food and Agriculture Organization of the United Nations (FAO), aquatic foods of animal origin contributed at leas 20% of the per capita protein supply from all animal sources, benefiting 3.200 million people[32].

Globally, governments have progressively implemented measures to limit fishing efforts, aiming to promote the sustainability of fishing activities and ensure the long-term availability of exploited marine resources. However, beyond these efforts to mitigate the overexploitation of natural resources, two key challenges remain, which, if not addressed effectively, will seriously compromise the sustainability of fish and seafood supplies. These challenges are:

1. Discards and returns to the sea: This refers to the portion of the biomass of animal origin that is caught and then discarded, including not only non-target species but also plant material and post-harvest waste, such as offal[33]. This phenomenon represents a significant loss of resources, with important ecological and economic implications.
2. Unsustainable management of by-products: This challenge refers to the inadequate management of by-products generated during the processing of fish catches and aquaculture. The lack of efficient valuation of these by-products reduces the comprehensive use of marine resources and limits opportunities for a circular economy in the sector.

Below, we examine both challenges in detail, along with their associated environmental and economic impacts:

#### 2.1.3.1. Discards

A key issue for the sustainability of the fishing industry is the widespread practice of discarding, which is an integral part of most fishing operations. Virtually all fishing gears at some point capture species or specimens that are subsequently returned to the sea.

Discards of target species can occur for several reasons:

- Fishing regulations: when fish do not reach the minimum landing size, or the fisherman does not have a quota for them.

[30] EU4Algae. Maritime Forum. European Commission.
[31] Algae production industry in Europe. (2021). Knowledge Centre for Bioeconomy. European Commission.
[32] FAO. 2024. The State of World Fisheries and Aquaculture
[33] FAO. 2024. The State of World Fisheries and Aquaculture

- Economic reason: the low market value of the catch or limited storage space, leading to the discarding of less valuable species to make room for more valuable catches.
- Deterioration of catches and the capture of non-commercial or protected species.

It is estimated that between 7 and 10 million tons of commercial fish catches are discarded each year worldwide, according to data from the European Commission. This data includes various types of gear and regions[34]. A FAO study covering the period 2010-2014 puts this figure at 9,1 million tons, equivalent to 10,8% of global catches[35]. In Europe, the volume of discards amounts to approximately 1,3 million tons per year. An average of 20% of total catches are discarded, although this figure can reach up to 90%[36]. Much of the discarded fish dies during the process, resulting in both a significant ecological impact and substantial waste of resources.

#### 2.1.3.2. Unsustainable management of by-products

In addition to the impacts associated with discards and non-compliance with the Landing Obligation (LO), the fishing and aquaculture industries continue to face significant challenges regarding the unsustainable management of by-products generated during the processing of fish and seafood, which compromises both the sustainability of marine ecosystems and the economic viability of the sector. In processing, only between 30% and 70% of the animal is commercially used, while the rest (head, skin, fins, viscera, and bones) is discarded[37].

In the European Union, this activity generates around 5.2 million tons of by-products annually, of which a portion is disposed of without recovery (mainly in landfills or dumped at sea from ships). At the same time, the largest percentage is used for low-value-added products, such as fishmeal and fish oil. Although these outlets provide some use, they do not maximize the economic value of the by-products and represent a missed market opportunity[38]. Furthermore, discards landed under the Landing Obligation tend to follow the same processing routes, which translate into low economic returns and also reduces incentives for effective compliance.

Fish and seafood by-products, which are currently underutilized, represent a raw material with high potential for producing food products for human consumption and high-value-added compounds, such as protein hydrolysates, fish and squid oils, mineral fractions, hydrolysed collagen, gelatines, minced meat, chitin, and chitosan. These products have applications in strategic sectors, including functional foods, nutraceuticals, cosmetics, agriculture, and the pharmaceutical industry, with significantly higher market values. Currently, these compounds are mainly obtained from other sources (e.g., targeted fishing, bovine and porcine products), which involves the additional use of natural resources and generates avoidable environmental impacts. Utilizing fishing by-products for these purposes enables us to transition towards more circular, profitable, and sustainable production models, aligning with the objectives of the EU's blue bioeconomy

### 2.1.4. Biochemical composition of marine food biowaste

Macroalgae (red, green and brown seaweeds) are feedstocks very rich in carbohydrates (up to 60% content), with all the essential amino acids for humans (some levels above those found in plants), but low in protein content (< 20%) and digestibility (PDCAAS of 0.59-0.69). Thus, seaweed requires to be treated for proper

[34] Pérez Roda, M.A. (ed.), Gilman, E., Huntington, T., Kennelly, S.J., Suuronen, P., Chaloupka, M. and Medley, P. 2019. A third assessment of global marine fisheries discards. FAO Fisheries and Aquaculture Technical Paper No. 633. Rome, FAO. 78 pp.

[35] Pérez Roda, M.A. (ed.), Gilman, E., Huntington, T., Kennelly, S.J., Suuronen, P., Chaloupka, M. and Medley, P. 2019. A third assessment of global marine fisheries discards. FAO Fisheries and Aquaculture Technical Paper No. 633. Rome, FAO. 78 pp.

[36] Discarding in fisheries. Oceans and fisheries (n/d). European Commission.

[37] FAO. 2024. The State of World Fisheries and Aquaculture

[38] Caruso, G. 2015. Fishery wastes and by-products: a resource to be valorised. J. Fish. Sci. 9, 080–083

protein levels and digestibility[39] and, so far, protein extraction has been the main attempt, although it is challenging due to the intracellular localization of proteins and the complex cell wall, as revealed in our ongoing ALEHOOP project[40]. Nonetheless, macroalgae seem a very promising substrate for biomass fermentation to increase protein content. A recent study from UVIGO[41] showed that (1) *Ulva rigida* (green seaweed) is a suitable substrate to perform biomass fermentation to produce enzymes, (2) pretreatment of the macroalgae improved SSF enzymatic production, and (3) protein content almost doubled after SSF (from 16.9% to 29.8%), with the antioxidant levels increased as well. Then, other unresearched marine sources could also be reasonable substrates for successful biomass fermentations, such as marine invertebrates. Previous works of MOA with agri-food by-products as substrates for submerged fermentation (data not published yet) suggested that the minimum requirements of a medium for submerged liquid protein fermentations are in the range of 5-10 g/L of protein and 20-40 g/L of carbohydrate. Marine invertebrates have a wide range of biochemical compositions (0.5-56% protein, 0.5-25% carbohydrates, see Table 1), within the potential protein and carbohydrate ranges.

Interestingly, seafood products contain highly bioavailable vitamins like vitamins A, B12 and D. These products also contain micronutrients and trace elements like calcium, iron, iodine, zinc, selenium, phosphorus, and zinc), and interesting bio compounds, such as omega-3 fatty acids, polyphenols, and chitosan (see Table 1). Therefore, marine invertebrate biowastes have the potential to be a proper biomass fermentation substrate and useful for further bio-based side-stream processes.

*Table 1. Biochemical profile of different marine sources. n.d. = no data*

| Marine source | | Total content (g/L) | | | | |
|---|---|---|---|---|---|---|
| | | protein | carbohydrate | lipids | others | |
| | | | | | Polyphenols | Chitin |
| Macroalgae | brown seaweed | 5.9 - 12.5 | 55.9 - 69.0 | 1.7 - 3.6 | 0.1 - 5.1 | n.d. |
| | green seaweed | 19.3 | 18.5 | 3.5 | 0.4 - 5.5 | n.d. |
| | red seaweed | 19.3 | 43.0 | 1.8 | n.d. | n.d. |
| Bivalve mollusc | clams | 0.8 - 4.9 | 3.3 - 25 | 0 - 0.2 | n.d. | 23.5 |
| | cockles | 9.1 - 12.8 | 0.3 - 7.9 | 1.6 – 6 | n.d. | 36.1 |
| | mussels | 6.5 – 10 | 3.7 | 1.4 - 2.1 | 0 | 21.3 |
| | oysters | 54.4 - 61.6 | 11.3 - 16.1 | 9.3 – 11 | 0 | 3 - 6 |
| | scallops | 12.1 | 3.2 | 0.5 | 0 | 9.7 |
| Cephalopod mollusc | squid/cuttlefish | 15.6 | 3.1 | 1.4 | n.d. | 7.40 |
| | octopus | 56.5 | 8.3 | 3.9 | n.d. | 7.8 |
| Marine echinoderm | sea urchins | 10.1 | 1.8 | 4.7 | 0 - 2.46 | 0 |
| Salt water fish | Tuna | 24.4 | 0 | 0.5 | 0.05 | n.d. |

## 2.2. Production of alternative proteins by cutting-edge fungal, yeast and bacterial fermentation

Biomass fermentations are nature-based methods that mimic vegetable composting in wildlife and have been primitively used for centuries for food processing (i.e., bread, cheese, koji). Fermentation has been the fastest-growing technology for alternative proteins in the last years: over 80% of alternative protein fermentation companies have been launched in the interval between 2017-2021 and more than 70 big companies (life science, pharmaceutical, nutrition, agricultural, food) have a business line on alternative protein fermentation applications. In Europe, 65% of these companies focus on biomass fermentations[42]. Nowadays in the EU, the microorganism involved in any fermentation to generate products for humans or animals must be GRAS

[39] O' Brien, R., Hayes, M., Sheldrake, G., Tiwari, B., & Walsh, P. (2022). Macroalgal Proteins: A Review. *Foods*, *11*(4), 571.
[40] ALEHOOP (Horizon 2020 project 887259) on biorefineries for the recovering of low-cost dietary proteins from seaweed and legume residuals biomass for high-value food and feed applications. CTA and UVIGO are part of this project (as coordinator and beneficiary, respectively) and will apply the ALEHOOP's know-how on protein analysis and sustainability assessment.
[41] Fernandes H, et al. (2019) Bioprocessing of U. rigida to produce enzymes & improve its nutritional value as aquafeed. Bioresour. Technol. 281, 277–85.
[42] The Good Food Institute. (2021) 2021 State of the industry report: plant-based meat, seafood, eggs and dairy.

(generally regarded as safe) and must be included in the EU's QPS (Qualified Presumption of Safety) list. Nonetheless, marine microorganisms have been little researched for fermentation processes and present a remarkable opportunity to produce novel proteins and other biomolecules: both marine invertebrates and macroalgae are a niche of underexploited microbes.

## 3. ALTERNATIVE PROTEIN MARKET

The forecast growth of the alternative protein market is underpinned by a growing group of "flexitarians" or consumers willing to consider alternative proteins or reduced meat consumption. This group accounts for between 10% and 69% of consumers, depending on the focal nation[43,44]. Forecasts suggest that the entire alternative protein market will reach $290 billion by 2035[45].

A diverse range of cultivated meat, including beef, chicken, pork, shrimp, duck, and fish substitutes, is being developed by startups. However, the market share of alternative proteins remains low compared with traditional meat[46,47].

While consumers are willing to trial and purchase alternative proteins, the role of marketing (i.e., how products are "framed") is critically important in motivating consumption[48]. The success of alternative protein uptake relies on establishing a solid consumer base, building trial and consumption, increasing availability, and framing effective communication[49]. These elements create a chance for marketing strategies to encourage broader acceptance of alternative protein products. Therefore, a comprehensive review of consumer behaviour toward alternative proteins is essential to uncover existing knowledge gaps and propose directions for future research[50].

### 3.1. Market definition

Alternative proteins are an emergent market that specializes in proteins derived from non-traditional sources, such as plants, insects, fermentation processes, and lab-grown meat, offering alternatives to conventional animal-based products.

The alternative proteins market is segmented depending on two characteristics: (1) the source of the protein and (2) the application of the protein.

Based on the source of the protein, the alternative protein market is segmented into:

- **Plant-based proteins**, derived from sources like soy, wheat, and peas, are among the most prevalent

[43] de Bakker, E., & Dagevos, H. (2010). Reducing Meat Consumption: Ethical arguments in the context of today's consumer society. Global food security: Ethical and legal challenges (pp. 275-280). Wageningen Academic Publishers.

[44] Rosenfeld, D. L., & Burrow, A. L. (2017). The unified model of vegetarian identity: A conceptual framework for understanding plant-based food choices. Appetite, 112, 78–95.

[45] Morach, B., Witte, B., Walker, D., von Koeller, E., Grosse-Holz, F., Rogg, J., Brigl, M., Dehnert, N., Obloj, P., Koktenturk, S., Schulze, U. (2021, March 24). Food for Thought: The Protein Transformation. Boston Consulting Group

[46] Curtain, F., & Grafenauer, S. (2019). Plant-Based Meat Substitutes in the Flexitarian Age: An Audit of Products on Supermarket Shelves. Nutrients, 11(11), 2603.

[47] Gravely, E., & Fraser, E. (2018). Transitions on the shopping floor: Investigating the role of Canadian supermarkets in alternative protein consumption. Appetite, 130, 146–156.

[48] Bryant, C., & Dillard, C. (2019). The Impact of Framing on Acceptance of Cultured Meat. Frontiers in nutrition, 6, 103.

[49] Karmaus, A. L., Jones, W. (2021). Future foods symposium on alternative proteins: Workshop proceedings. Trends in Food Science & Technology, 107, 124-129.

[50] Nguyen, J., Ferraro, C., Sands, S., & Luxton, S. (2022). Alternative protein consumption: A systematic review and future research directions. International Journal of Consumer Studies, 46(5), 1691–1717.

alternative protein sources. Their popularity is driven by their nutritional profile, which includes low saturated fat, no cholesterol, and high fiber content. These proteins are increasingly used in plant-based food products, catering to the growing trend of vegan diets. While soy remains the most popular source, its use extends beyond human consumption to animal feed. Other sources, including chickpeas, rice, and various cereals, legumes, and nuts, also contribute to the diversity of plant-based proteins.

- **Insect-based proteins**, sourced from insects like crickets, mealworms, and black soldier flies, are gaining traction in the alternative protein market. These proteins are lauded for their sustainability and environmental benefits, as they require significantly less land, water, and feed compared to traditional livestock. Their nutritional value and eco-friendly nature have made them an appealing source for both human consumption and animal feed.
- **Cell-based or cultured meat proteins** are produced by cultivating animal cells in a controlled laboratory environment. They represent a new frontier in alternative proteins. Despite this, no cultured animal cell products are currently available for sale in the E.U. or U.S. markets. These proteins are primarily developed for human consumption, but they also present an alternative for pet food production.
- **Microbial proteins** are derived from microorganisms like algae, fungi, yeasts, and bacteria, and are gaining interest in the alternative protein market. These proteins are produced through fermentation processes, where microbes serve as bioproduction platforms. They can generate functional ingredients for food processing such as flavorings or enzymes or large quantities of protein biomass for alternative meat and dairy products. The industry employs fermentation in three ways: traditional fermentation, which uses microbes to process plant-derived ingredients; biomass fermentation, which leverages the wwhigh protein content of microbes to produce large quantities of protein; and precision fermentation, which uses microbes to create specific functional ingredients that enhance the sensory attributes of food products. This category encompasses a variety of unconventional marine sources, from microalgae to marine bacteria, each with its own characteristics and unique potentialities.

Segmentation by application examines how proteins are used across various industries, including:

- **Food** for human consumption, the largest segment, with applications in plant-based meat, dairy alternatives, protein bars, snacks and beverages. Companies invest in improving texture, taste and nutritional content to enhance consumer acceptance.
- Animal **feed**, particularly insect-based and microbial proteins, serve as sustainable feed options for livestock, aquaculture and pet food. Their nutritional benefits and lower environmental impact make them increasingly attractive to the feed industry.
- **Non-food** applications such as pharmaceuticals and cosmetics.

## 3.2. Market key figures

There are different estimates about the size and growth expectations of the global alternative protein market (Table 2). Four projections estimate a market size of $15-20 billion between 2023 and 2024 and a growth rate projection between 9.84% and 13.6% in the following 7-13 years. A higher and more optimistic estimate defines a $25.7 billion market in 2022 with a growth rate of up to 15.6% until 2030.

*Table 2. Alternative protein market size and growth*

| Market size in billion USD | Compound annual growth rate (CAGR) | Market size projection in billion USD | Source |
|---|---|---|---|
| $18.58B (2024) | 11.2% | $74.67B (2037) | Research Nester[51] |
| $17.32B (2023) | 13.6% | $47.05B (2031) | Meticulous Market Research[52] |
| $15.3B (2023) | 12.14% | $37.88B (2031) | InsightAce Analytic[53] |
| $20.36 (2024) | 9.84% | $43.14B (2032) | Maximize Market Research[54] |
| $25.7B (2022) | 15.6% | $81.9B (2030) | DataM Intelligence[55] |

These reports indicate that the largest share of this growth is expected to belong to the plant-based proteins segment, especially soy-based proteins. Insect-based proteins are estimated to be the fastest-growing alternative protein segment.

### 3.3. Key Stakeholders

The alternative protein market represents a dynamic and rapidly evolving ecosystem characterized by innovative approaches to protein sourcing and consumption. At the heart of this burgeoning industry lies a diverse array of stakeholders, each playing a crucial role in shaping its trajectory and impact.

Understanding their roles, motivations, and interactions is essential for comprehending the complex dynamics of the alternative protein market.

- **Food/feed system actors and consumers**: This category encompasses a wide range of stakeholders including food manufacturers, retailers, restaurants, and consumers. These stakeholders are directly involved in the production, distribution, and consumption of alternative protein products.
- **Biowaste providers**: This group consists of entities involved in the generation and supply of biowaste materials that can be utilized for alternative protein production. This includes fishermen, aqua culturists, and macroalgae biorefineries that supply seafood by-products and waste materials for protein extraction and fermentation.
- **Protein end users**: These stakeholders are the recipients of alternative protein products. They include food and feed producers who incorporate alternative proteins into their products, as well as pharmaceutical and cosmetic companies that utilize proteins for various applications.

[51] Alternative Protein Market Sixe & Share, by Type (Plant-Based Protein, Insect-Based Protein, Microbial-Based Protein), Application (Food & Beverages, Animal Feed & Pet Food, Nutraceuticals) – Global Supply & Demand Analysis, Growth Forecasts, Statistics Report 2025-2037. (2024). Researh Nester.
[52] Alternative Protein Market Size, Share, Forecast, & Trends Analysis by Type (Plant Protein [Soy, Pea, Potato], Insect Protein [Crickets, BSF], Microbial [Algae Protein, Fungal Proteins]), Application (Food & Beverage, Alternative Proteins) - Global Forecast to 2031. (2024). Meticulous Market Research.
[53] Alternative Proteins Market Size, Share & Trends Analysis Report, By Product (Plant Protein, Microbe-based Protein, Insect Protein), By Application (Food & Beverages, Clinical Nutrition, Animal Feed, Others), By Region, Forecasts, 2024-2031. (2024). InsightAce Analytic.
[54] Alternative Protein Market: Global Industry Analysis and Forecast (2025-2032). (2025). Maximize Market Research.
[55] Alternative Protein Market Size, Share, Industry, Forecast and Outlook (2024-2031). (2024). DataM Intelligence.

- **End users of circular bio-based industries** (nutritionists, grangers, health specialists): This category includes professionals such as nutritionists, dieticians, researchers, and health specialists who are involved in the utilization and promotion of bio-based products, including alternative proteins, for various health and industrial applications.
- **End consumers** (citizens): Individuals who purchase and consume alternative protein products for personal use. Understanding consumer preferences and behavior is crucial for market acceptance and adoption of alternative protein sources.

At individual level, Nguyen et al. (2022)[56] identified six individual socio-ecological level capabilities: cooking skills, food beliefs, food familiarity, food choice impacts, food neophobia, and taste experience. These personal characteristics can enhance or diminish capabilities that support consumers' choices and ability to consume alternative proteins.

*Table 3. Socio-ecological level capabilities.*

| Individual capability | Particularities |
|---|---|
| **Cooking skills** | An individual's cooking skills are a physical capability that provides the necessary baseline skills enabling people to prepare protein alternatives as a part of a meal. The absence of cooking skills presents a significant barrier to alternative proteins consumption. |
| **Food beliefs** | Consumer beliefs about meat consumption are a crucial psychological capability influencing alternative protein consumption. Beliefs about meat-based diets have led to perceptions that meat is healthy, climate-friendly, biologically necessary, and required in order for one to feel satiated. |
| **Food familiarity** | Consumer familiarity with novel food products is a psychological capability influencing alternative protein consumption, whereby those who are more familiar with alternative protein food sources are more likely to consume it. The consumers' prior experiences, and their aversion to novel foods, influences their willing-ness to consume alternative proteins. Familiarity and experience are influenced by geographic context, and Familiarity has also been shown to have a spill-over effect on the acceptance of alternative proteins in what consumers perceive to be "traditional" meals. For instance, when a consumer is presented with a familiar meal style, they may be more receptive to the inclusion of unfamiliar or novel ingredients. |
| **Food choice consequences** | Individuals' awareness, knowledge, and concern about the consequences of their food choices is a psychological capability that influences alternative protein consumption. For example, awareness of the environmental impact of meat can encourage behavioural shift toward alternative proteins. |
| **Food neophobia** | Fear of novel foods is an important psychological capability and predictor of alternative protein consumption, with food neophobia being especially prevalent in regard to the consumption of insect protein. Indeed, people with a greater tendency to reject novel and unfamiliar food are more likely to reject unprocessed insects than are those with a weaker tendency to reject unfamiliar food. Educating consumers about the process and technology behind novel food production may have a positive effect on acceptance, and counteract this challenge. |
| **Taste experiences** | People who have tasted alternative protein food in the past tend to have greater acceptance of and future intentions to consume these products. This acceptance tends to be a result of consumers' reduced fear and increased hedonic evaluation, leading consumers to make more informed choices. |

Nguyen et al. (2022)[57] also identified six individual socio-ecological level motivations related to AP consumption: taste preference, food mindset, food habits, desire for novelty, desire for health, ethics and sustainability, and desire to reduce or eliminate meat consumption.

[56] Nguyen, J., Ferraro, C., Sands, S., & Luxton, S.. (2022). Alternative protein consumption: A systematic review and future research directions. International Journal of Consumer Studies, 46(5), 1691–1717.

[57] Nguyen, J., Ferraro, C., Sands, S., & Luxton, S.. (2022). Alternative protein consumption: A systematic review and future research directions. International Journal of Consumer Studies, 46(5), 1691–1717.

*Table 4. Socio-ecological level motivations related to AP consumption.*

| Individual motivations | Particularities |
|---|---|
| **Taste preference** | Sensory preferences, informed by what is liked and expected, are important, with research finding that consumer preconceptions about the sensory quality of non-animal proteins are a significant barrier to alternative protein consumption. Further, consumers' strong preference for the sensory appeal of meat acts as a barrier to the consumption of a variety of alternative proteins, including insects, plant-based products, and cultivated meat. |
| **Food mindset** | Different consumer mindsets regarding meat include those attached to meat, exhibit disgust toward meat, or exhibit low levels of attachment to meat. Indeed, consumer mindsets are typically "all-or-nothing" regarding meat consumption or reduction, and such a binary mindset means that non-vegetarian consumers view vegetables as a complement rather than a meat substitute. |
| **Food habits** | Food habits are especially ingrained in consumers with a strong preference for meat, those who respond strongly to sensory cues, and those who cannot self-regulate or reflect on their food choices—a constraint particularly applicable to consumers who are overweight or obese. For many consumers, meat consumption is an enduring habit, and meat is included in meals by default, with little con-sideration given to the alternatives. |
| **Desire for novelty** | The desire for novelty is an automatic motivation that can drive alternative protein consumption. However, while novelty alone can be sufficient to encourage a trial of alternative proteins, it is not sufficient to motivate repurchase. Novelty motivations are still important because a person who is open to trying new foods has an increased chance of learning about the food properties and liking the foods they trial. |
| **Desire for health, ethics and sustainability** | While many factors can motivate consumers to change their diet and consume alternative proteins, health, ethics, and sustainability are commonly cited in the literature. These factors encompass automatic and reflective motivations, as well as psychological capabilities. A decrease in meat consumption can be motivated by health concerns; however, consumers have different perceptions of the health properties of meat. For some, meat is integral to a healthy diet, while for others it is not; moreover, those who associate meat consumption with a healthy diet are less willing to substitute meat with alternative proteins. Health-related motives are also associated with sustainability and ethics in regard to intensive farming and animal welfare, for example. |
| **Desire to reduce or eliminate meat consumption** | Consumers do not tend to use meat substitutes to reduce meat consumption; instead, they prefer to eat smaller portions of meat or consume sustainably farmed fish or organic meat. Similarly, a study observed that the intention to reduce meat consumption was not a significant predictor of willingness to consume insect burgers or buffalo worms. |

- **Governmental bodies**: Regulatory authorities at both national and supranational levels play a significant role in shaping policies and regulations related to food safety, labelling, and environmental sustainability. Examples include the Food and Agriculture Organization (FAO) at the global level, the European Food Safety Authority (EFSA) in the European Union, and national agencies such as AECOSAN in Spain, INSA in Portugal, IZZ in Poland, COR in Hungary, and BVL in Germany.
- **EU COMMISSION & other EU platforms**: The European Commission plays a central role in setting regulatory frameworks and promoting initiatives related to food security, sustainability, and innovation within the European Union. Additionally, various EU platforms and organizations such as the European Food Information Council, EU Food for Life, and EU Platform on Food Losses and Food Waste are involved in addressing key issues and facilitating collaboration in the food industry.

## 4. MARKET DYNAMICS

The surge in demand for alternative proteins, propelled by heightened consumer awareness about health and

environmental issues, is well-documented across numerous studies and market analyses. Wood and Tavan[58] underscore this trend in their comprehensive review of the alternative protein industry. Moreover, reports from reputable organizations like Market Data Forecast[59] and Mordor Intelligence[60] corroborate the increasing consumer interest in sustainable and nutritious protein alternatives. This growing inclination towards eco-friendly options signifies a notable shift in dietary preferences, particularly favoring proteins sourced from microbial fermentation of unconventional marine origins. The rising global food demand, coupled with consumer concerns around animal rights, welfare, and dietary trends like veganism and vegetarianism, fuel interest in these proteins.

## 4.1. Market Drivers

### 4.1.1. Sustainability: demand from consumers and promotion from other stakeholders

Alternative proteins, developed for both human and animal nutrition, are primarily driven by sustainability. They offer benefits such as reduced land and water usage, lower greenhouse gas emissions, and less strain on natural resources. The Global Food Institute (GFI) asserts that alternative proteins provide a more sustainable way to meet the world's food needs[61]. With meat consumption at an all-time high and expected to increase, alternative proteins, derived from plants and cell-cultivation, can modernize meat production, lessen environmental impacts, feed more people efficiently, mitigate antibiotic resistance, and aid in biodiversity restoration.

Several stakeholders, including international institutions such as GFI and various governments[62], are promoting the development of alternative proteins due to their potential to transform food systems, improve food security and mitigate climate change. They recognize the role of alternative proteins in meeting the increasing food demand due to population growth, reducing the environmental impact of traditional protein sources, and aligning with consumer trends around health and sustainability. The development of the alternative protein market could contribute to several Sustainable Development Goals (SDGs), such as SDG 2 Zero Hunger, SDG 3 Good Health and Well-being, SDG 12 Responsible Consumption and Production, SDG 13 Climate Action, SDG 14 (Life Below Water) and SDG 15 (Life on Land).

### 4.1.2. Improvement of the organoleptic properties of alternative protein products

Organoleptic properties are the aspects of food, water or other substances that create an individual experience via the senses. They include taste, sight, smell, and touch. The goal for alternative proteins used in human food is to create products that taste, look, and feel just like traditional proteins from animals. However, these products should be affordable or cheaper to produce than animal proteins, or else they won't be seen as a viable alternative. When it comes to using alternative proteins in animal feed, the objective is to find ingredients that are cheaper, have a smaller environmental footprint, and are thus more sustainable.

### 4.1.3. Technological developments in alternative protein production

Advancements in technology and innovation are predicted to help the market grow. More investments in the development of alternative proteins are expected to significantly boost the market. Furthermore, the creation of technologies that allow for large-scale production and cost reduction of alternative proteins will help the

[58] Wood, P., & Tavan, M. (2022). A review of the alternative protein industry. Current Opinion in Food Science, 47, 100869.
[59] Market Data Forecast. (2021). Europe pet food market by ingredient, by animal type and by region.
[60] Mordor Intelligence. (2022). Global alternative protein market - growth, trends, COVID-19 impact, and forecasts (2022 - 2027).
[61] The Good Food Institute (s.f.). Environmental impacts of alternative proteins.
[62] The Good Food Institute (s.f.). How Governments Are Supporting Sustainable Protein Research in APAC.

market grow by making these proteins more available and affordable.

### 4.1.4. Changes in consumer preferences

Research by Deloitte[63] and Martínez et al.[64] emphasizes the shift in consumer preferences toward alternative proteins, driven by sustainability and health concerns. This trend aligns with the rise in plant-based diets and the growing alternative protein market. Consumers are exploring non-traditional options, including marine-sourced proteins. The alternative protein market, aimed at human nutrition, is shaped by these trends. As per the Research Nester report[65], as of September 2021, about 1% of the global population, or 79 million people, have adopted veganism. This shift from animal-based to plant-based foods, along with concerns for animal welfare and health, is driving the plant- and algae-based protein segment.

Additionally, the demand for protein supplements is on the rise; for example, 2 out of 5 people from USA regularly consume protein beverages.

The rising interest in alternative proteins is fueled by health, environmental, and ethical factors. Understanding consumer preferences is essential for encouraging their adoption and integration into daily diets. This analysis explores current trends and motivations behind alternative protein choices, including plant-based options, cultured meat, and insect-based proteins.

- **Preference for Plant-Based Proteins:** Plant-based proteins are the preferred alternative protein source across various countries due to their availability and perceived health benefits[66]. Most of these proteins are not new to the market, and consumers are already familiar with them.
- **Health and Safety Perceptions:** Consumers' willingness to purchase alternative proteins is significantly influenced by their perceptions of healthiness, safety, and nutritional content. This is particularly true for cultured meat and insect-based proteins[67].
- **Economic and Cultural Factors:** Wealthier countries tend to be more willing to substitute traditional meats with alternative proteins, as economic status and cultural norms significantly influence their acceptance. The level of economic development often shapes consumer attitudes and openness toward incorporating these protein sources into their diets.[68].
- **Challenges in Sensory Acceptance:** Achieving desirable sensory properties similar to conventional meat is a significant challenge for alternative proteins, which affects their acceptance[69,70].
- **Drivers of Acceptance:** The acceptance of alternative proteins is influenced by key factors such as taste, health motivations, familiarity, personal attitudes, food neophobia, disgust, and social norms. The importance of each factor varies based on the specific type of alternative protein and individual

[63] Jagt, R., Nijland, F. (2023, March 23). Alternative Proteins - A reality check. Deloitte.
[64] Martínez, D., et al. (2023). Global alternative protein market: insights and outlook. International Journal of Business Studies, 15 (2), 187-199.
[65] Alternative Protein Market Sixe & Share, by Type (Plant-Based Protein, Insect-Based Protein, Microbial-Based Protein), Application (Food & Beverages, Animal Feed & Pet Food, Nutraceuticals) – Global Supply & Demand Analysis, Growth Forecasts, Statistics Report 2025-2037. (2024). Researh Nester.
[66] Gómez-Luciano, C., Aguiar, L., Vriesekoop, F., & Urbano, B. (2019). Consumers' willingness to purchase three alternatives to meat proteins in the United Kingdom, Spain, Brazil and the Dominican Republic. Food Quality and Preference, 78.
[67] Siddiqui, S., Alvi, T., Sameen, A., Khan, S., Blinov, A., Nagdalian, A., Mehdizadeh, M., Adli, D., & Onwezen, M. (2022). Consumer Acceptance of Alternative Proteins: A Systematic Review of Current Alternative Protein Sources and Interventions Adapted to Increase Their Acceptability. Sustainability.
[68] Gómez-Luciano, C., Aguiar, L., Vriesekoop, F., & Urbano, B. (2019). Consumers' willingness to purchase three alternatives to meat proteins in the United Kingdom, Spain, Brazil and the Dominican Republic. Food Quality and Preference, 78.
[69] Tso, R., Lim, A., & Forde, C. (2020). A Critical Appraisal of the Evidence Supporting Consumer Motivations for Alternative Proteins. Foods, 10.
[70] Kurek, M., Onopiuk, A., Pogorzelska-Nowicka, E., Szpicer, A., Zalewska, M., & Półtorak, A. (2022). Novel Protein Sources for Applications in Meat-Alternative Products—Insight and Challenges. Foods, 11.

consumer differences.[71].

- **Interventions to Increase Acceptance:** Educational interventions, persuasion, training, and modelling strategies have proven effective in enhancing the acceptance of alternative proteins. However, more targeted approaches are needed to specifically address familiarity and emotional factors, which play a crucial role in consumer willingness to adopt these protein sources[72].

In summary, consumer preferences for alternative proteins are largely shaped by perceived health benefits and safety, with plant-based options being the most preferred. Economic and cultural factors also play a significant role, especially in wealthier countries. Enhancing sensory appeal and familiarity is key to boosting acceptance. Successful strategies should prioritize education and address food neophobia and disgust to encourage the adoption of alternative proteins in everyday diets.

### 4.1.5. Growing world population

Another key factor, and possibly the main one, driving the growth of the alternative proteins market is the increasing food demand due to the world's growing population. As per Research Nester[73], alternative proteins are expected to play a crucial role in meeting this demand and driving market growth, alongside animal proteins. The United Nations Food and Agriculture Organization (FAO) predicts that by 2050[74], the demand for cereals, for both human consumption and animal feed, will rise from the current 2.1 billion tons to nearly 3 billion tons.

### 4.1.6. Growth for alternative protein used in animal feed

The growing population of cattle animals is expected to increase the demand for alternative proteins in animal feed. A report by Research Nester[75] states that the number of cattle worldwide rose to around 1 billion in 2022. This growth is driving the demand for alternative proteins, especially soy, a primary ingredient in animal feed. However, the animal nutrition industry is also looking for new feed ingredients that won't compete with human food. They're interested in alternative protein sources that are environmentally friendly and can enhance production while reducing the environmental impact of animal farming. Proteins derived from insects, microbial and single cells are some of these sought-after sources.

### 4.1.7. Alternative protein is attracting investment

In recent years, there has been an increase in Venture Investments for boosting the production of alternative proteins[76,77]. Notable examples include Calysta (U.S.), which raised $39 million in a financing round for the worldwide scale-up of the production of their FeedKind protein. Similarly, in 2022, InnovaFeed SAS (France) raised $250 million to increase its Black Soldier Fly (BSF) production capacity. Australia has also made substantial investments, allocating $ 262.6 million to transform South Australia in a hub for plant-based protein manufacturing, with three new production plants planned to supply both domestic and international markets. In Canada, a $74 million investment in Merit Functional Foods (Canada) in 2020 aimed to support the production

[71] Onwezen, M., Bouwman, E., Reinders, M., & Dagevos, H. (2020). A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. Appetite, 159.

[72] Onwezen, M., Bouwman, E., Reinders, M., & Dagevos, H. (2020). A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. Appetite, 159.

[73] Alternative Protein Market Sixe & Share, by Type (Plant-Based Protein, Insect-Based Protein, Microbial-Based Protein), Application (Food & Beverages, Animal Feed & Pet Food, Nutraceuticals) – Global Supply & Demand Analysis, Growth Forecasts, Statistics Report 2025-2037. (2024). Researh Nester.

[74] FAO (2009). Global agriculture towards 2050. (2009). High Level Expert Forum - How to Feed the World in 2050.

[75] Alternative Protein Market Sixe & Share, by Type (Plant-Based Protein, Insect-Based Protein, Microbial-Based Protein), Application (Food & Beverages, Animal Feed & Pet Food, Nutraceuticals) – Global Supply & Demand Analysis, Growth Forecasts, Statistics Report 2025-2037. (2024). Researh Nester.

[76] Alternative Protein Market Size, Share, Forecast, & Trends Analysis by Type (Plant Protein [Soy, Pea, Potato], Insect Protein [Crickets, BSF], Microbial [Algae Protein, Fungal Proteins]), Application (Food & Beverage, Alternative Proteins) - Global Forecast to 2031. (2024). Meticulous Market Research.

[77] Alternative Protein Market: Global Industry Analysis and Forecast (2024-2030). (2024). Maximize Market Research.

of high-quality pea and canola proteins for plant-based foods.

Additionally, Spain is making significant strides in the sector. Tebrio, a company based in Salamanca, is currently constructing the world's largest insect protein factory, spanning 16,000 square meters. This facility will focus on producing mealworms as a sustainable protein source for animal feed, biofertilizers, and other chemical products. It is expected to contribute to the alternative protein landscape by promoting a circular economy and reducing the environmental impact of food production. Furthermore, the project is set to create around 200 jobs, strengthening the local agricultural and industrial sectors[78].

Despite these investments, global funding for alternative proteins experienced a downturn in 2024. According to data from The Good Food Institute (GFI), total global investment in alternative proteins, encompassing plant-based, cell-based and fermentation-based proteins, amounted to $1B, as illustrated in Figure 3. This figure represents a 26.7% decrease compared to the previous year and falls significantly short of the $2.9B invested in 2022.

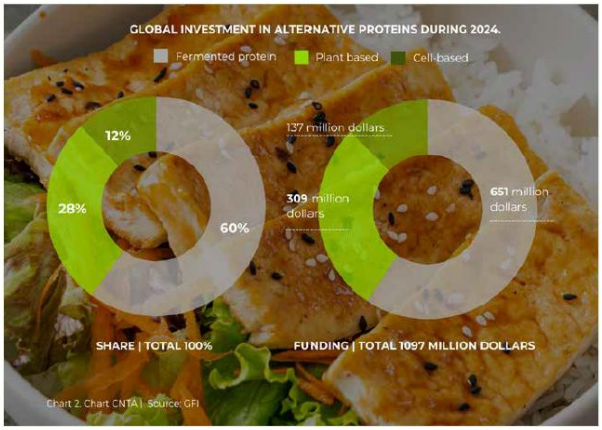



*Figure 3 Global investment in alternative proteins during 2024*

The decline in investment can be attributed to several factors, including geopolitical tensions, macroeconomic challenges, and the rise of governments favoring traditional food sectors. These conditions have led investors to exercise caution, particularly in light of potential new restrictions or bans on alternative protein products. Within the sector, however, fermentation-based proteins attracted the most investor interest. Notable investments included $90 million secured by Perfect Day and $61 million raised by Formo, both specializing in dairy proteins through precision fermentation.

Strategic partnerships also played a key role in the sector's development. One of the most notable agreements was between Grupo Palacios and The EVERY Co, enabling the Spanish company to incorporate precision-fermented egg proteins from the American startup into its products.

Regulatory progress further shaped the industry in 2024, particularly in precision fermentation. Several legislative approvals were granted for the commercialization of dairy proteins, including Imagindairy's beta-lactoglobulin in Israel, AIIG's bovine lactoferrin in China, and Remilk's beta-lactoglobulin in Canada.

European startups such as Fermify and 21st.BIO also made strides, securing GRAS (Generally Recognized As Safe) status from the U.S. Food and Drug Administration (FDA) for various dairy proteins. Meanwhile, the European Food Safety Authority (EFSA) issued positive safety opinions for genetically modified ingredients

[78] RTVE.es. (2025, 29 enero). Salamanca acogerá la mayor fábrica de insectos de todo el mundo. *RTVE.es*. https://www.rtve.es/noticias/20250115/salamanca-obras-mayor-fabrica-insectos-mundo/16408345.shtml#:~:text=En%20Salamanca%20se%20ha%20puesto,biofertilizantes%20y%20otros%20productos%20qu%C3%ADmicosc

developed through precision fermentation, including heme from Impossible Foods.

Other types of alternative proteins also reached significant legislative milestones in 2024. A notable example is Solein, a protein developed by the Finnish startup Solar Foods. This novel ingredient became available in select dishes at the Omsted restaurant in New York after the company registered its production plant in Vantaa, Finland, with the FDA and met all necessary U.S. regulatory requirements.

Despite challenges, the alternative protein sector continues to evolve, driven by innovation, investment, and regulatory advancements. While recent financial trends reflect a temporary slowdown, the industry's long-term potential remains strong as companies, investors, and governments work towards a more sustainable future in food production[79].

## 4.2. Market Restraints

Despite the promising growth trajectory of alternative proteins, emerging sources such as insects, cultured meat, and fungal fermentation encounter barriers hindering their market penetration. These barriers include potential allergies and technological complexities. However, ongoing advancements and research in these areas suggest potential for overcoming these challenges and expanding their market presence in the future.

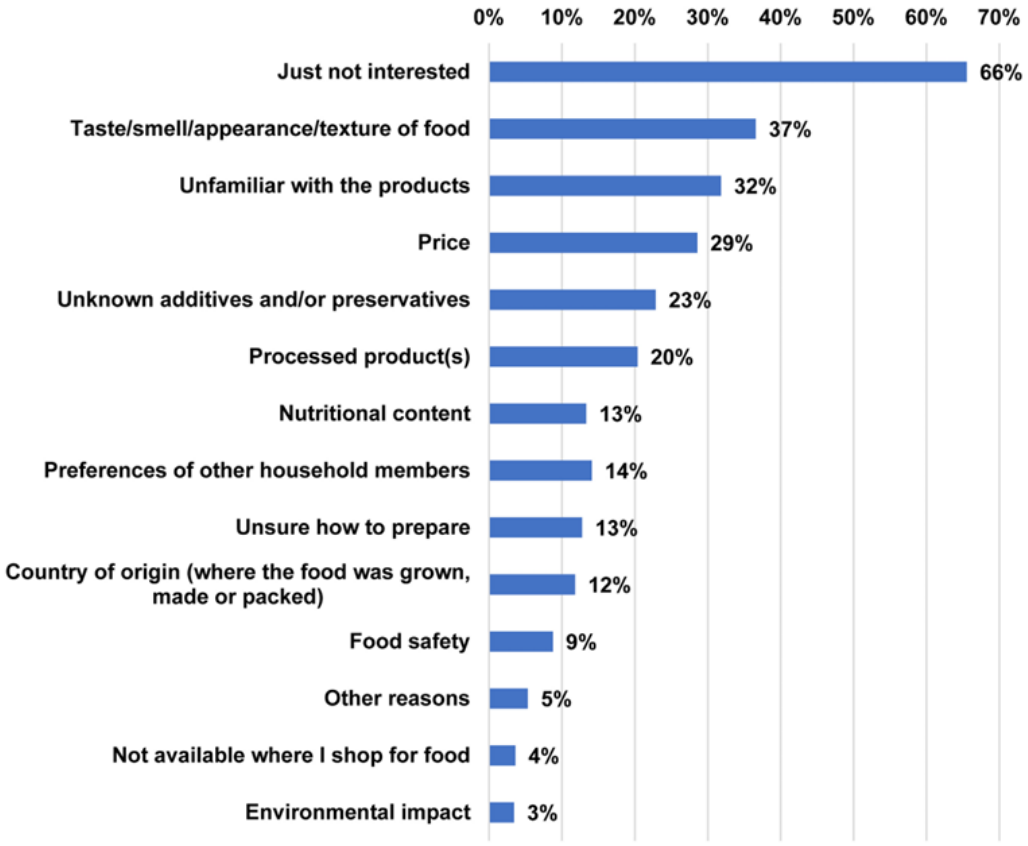



*Figure 4. Main reasons for not purchasing alternative proteins when grocery shopping (n=525). Source: Malek, L., Umberger, W.J., & Goddard, E. (2019). Committed vs. uncommitted meat eaters: Understanding willingness to change protein consumption. Appetite, 138, 115-126.*

79 Proteínas, grasas y alimentos alternativos. (2024). Escenarios de oportunidad Food Tech. https://escenariosfoodtech.cnta.es/proteinasgrasas-y-alimentos-alternativos_septiembre-noviembre-2024/

*Table 5. Overview of main findings for drivers and interventions of various meat alternatives. Source: Onwezen et al., 2021.*

| | |
|---|---|
| **Pulses** | **Product related attributes:**<br>• Motives or barriers to accept: health, taste, environment, weight control, reflection-oriented motives, variety, versatility, perceived benefits, flatulence, preparation difficulty and viewing pulses as food for vegetarians, time needed to prepare, a lack of knowledge of how to prepare legumes or incorporate in meals and legume distaste.<br>**Psychologic factors:**<br>• Attitudes<br>**External attributes:**<br>• Social environment: family preferences<br>**Interventions:**<br>• Health and sustainability claims increase willingness-to- pay for legumes<br>• Lentil consumption increased based on environmental (78%), economic (75%) and nutritional (72%) information |
| **Algae** | **Product-related attributes:**<br>• Motives or barriers to accept: health, taste, reflection-oriented motives, organic, ethical and local.<br>• Familiarity (previous consumption and level of meat consumption) is associated with acceptance.<br>**Psychological factors:**<br>• Attitudes<br>• Food neophobia is relevant in understanding willingness to consume seaweed<br>**External attributes:**<br>Trust: Independent promoters increase trust in the product<br>**Interventions:**<br>• Health and environmental claims increase acceptance of seaweed<br>• The lesser the environmental impact of the meat substitute (compared to pork/beef), the more it is accepted<br>• Acceptance of seaweed claim is influenced by the location at which consumers purchase seaweed<br>• Disguising ingredients increases familiarity |
| **Insects** | **Product-related attributes:**<br>• Motives or barriers to accept: health, taste, environment, appearance, safety, convenience, price, naturalness, not immoral, but nutritious, quality, selectiveness/fussiness in food choice as barriers, risk/danger regarding insects, lack of availability and incompatibility with local food culture, unnaturalness<br>• Familiarity and past experience with eating insects increases consumption and tastiness of insects<br>**Psychological factors:**<br>• Attitudes: and negative beliefs. Also, within the theory of planned behavior attitudes, subjective norms and perceived behavioral control have a significant impact on acceptance.<br>• Food neophobia, disgust and affect: food neophobia and disgust, and affective attitudes towards eating insects and affective variables like emotions ambivalence and disgust affected willingness to eat specific insects.<br>• Curiosity, sensation seeking.<br>**External attributes:**<br>• Trust Public health institutions suggested to play a role in promoting consumption of insects.<br>• Social environment: eating insects perceived to be not supported by family and/or friends. High |

| | |
|---|---|
| | social acceptance and the more participants thought other participants ate mealworm-containing products, or perceived eating insects as a socially acceptable activity, the more likely they were to try insect foods themselves. Perceptions of a conspiracy theory (regarding a social movement toward growing insect consumption)<br>• Cultural appropriateness: insects were perceived as inappropriate in culture. Insects that were marketed more in one's own culture were preferred more<br>**Interventions**<br>*Product attributes*<br>• Price interventions showed that high prices were associated with increases in expected quality<br>• Health and environmental claims increase acceptance of insects<br>• Information on benefits nutrition, social benefits general - (compared to specific information) increased acceptance<br>• Familiarity with products increases willingness to try. Familiarity with products can be increased by producing products such that they fit with known products, prior information or tasting<br>• Willingness to eat insects decreases when insects are visible in the products, hidden ingredients of insects are revealed, for unprocessed compared to processed insects, for insects as food compared to insects as feed, for common versus uncommon products, or when descriptions in a menu setting were very explicit (instead of vague)<br>*Social environment*<br>• Participants exposed to positive peer rating of a nutrition bas expected it to be of higher quality than did participants exposed to negative peer ratings |
| **Plant-based meet alternatives** | **Product-related attributes**<br>• Motives or barriers to accept: moral and ethical motives, perceived appeal, perceptions of environmental impact, and health-consciousness, internalized motivation, enjoyment of eating and cooking, type of mince, fat content, country of origin, price, concerned about the additives, artificiality, and insufficient essential vitamins and micronutrients, and taste of meat<br>• Familiarity: familiarity and previous experience<br>**Psychological factors**<br>• Attitudes and beliefs toward meat substitutes and food neophobia<br>• Food neophobia, disgust and affect: food neophobia, disgust<br>**External attributes**<br>*Interventions*<br>• Plant-based meat alternatives have less shelf space compared to traditional meat, less promotions. Consumers found it slightly more satisfying as well as easier to shop for animal-based compared to plant-based protein sources |
| **Cultured meat** | **Product-related attributes**<br>• Motives or barriers to accept: health, taste, environment, green eating behavior, perceived appeal and goodness of clean meat, food security and safety, and selectiveness/fussiness in food choice as barriers.<br>• Familiarity: of participants familiar with cultured meat, 64% were willing to try it, whereas 40% of participants unfamiliar with cultured meat would be willing to try it<br>**Psychological factors**<br>• Attitudes towards the environment and agriculture |

| | |
|---|---|
| | • Food neophobia, disgust and affect: food neophobia, disgust and disgust sensitivity<br>**External attributes**<br>• Trust: concerned about risk governance, control and need for regulation and proper labelling, and associations with political conservatism and distrust in science<br>**Interventions**<br>• Naturalness and food additives (perceived naturalness, 'same meat' framing (positive attitudes, describing cultured meat in a nonethical way that focuses on the final product increases acceptance of cultured meat<br>• 'high-tech' framing led to the least positive attitudes, 'clean meat is natural'-message, production of cultured meat and its benefits E-numbers or possible negative health effects (perceived naturalness), information about cultured meat (tasty and nutritious as a conventional burger) result in lower levels or negative effects on the acceptance of cultured meat<br>• Information affects explicit (and not implicit) attitude, especially for unfamiliar respondents |

### 4.2.1. Costs and lack of production scale

The growth of the alternative protein market is currently constrained by two major factors: high production costs and limited production volumes. These barriers[80] hinder the widespread adoption of alternative proteins in both human diets and animal feed, slowing market expansion.

- **High production costs:** The production of alternative proteins, especially those derived from sources like cultured meat and insects, often requires significant initial investments in technology and infrastructure. These expenses encompass research and development, regulatory compliance and the establishment of production facilities. High upfront costs make it challenging for many start-ups to enter the market and scale their operations effectively. Additionally, the use of specialized ingredients and processes can drive up the cost per unit, making alternative proteins less competitive compared to traditional protein sources.
- **Limited production volumes**: Many alternative protein companies are still in early growth stages, operating on a small scale that restricts their ability to meet increasing consumer demand. Without achieving economies of scale, production costs remain high, making competitive pricing difficult. This limitation also leads to supply chain challenges, as manufacturers and retailers struggle to secure consistent and reliable supplies of alternative proteins.
- **Impact on market expansion**: The combination of high costs and restricted production capacity contributes to the perception that alternative proteins are niche products, accessible mainly to early adopters or those willing to pay premium prices. This perception slows mainstream acceptance and integration. Furthermore, slow market growth can discourage investment, creating a cycle where limited funding hinders innovation and expansion, ultimately keeping prices elevated.

To overcome these barriers, collaboration and investment in research and development are essential. Industry stakeholders, including investors, policymakers, and business leaders, must support advancements in production techniques, supply chain improvements, and scaling efforts. Addressing these challenges will be key to making alternative proteins more affordable and widely available, facilitating their adoption in both human diets and animal feed.

[80] Yildiz, D. (2023, 8 Decembre). Global Alternative Proteins Market. Feed Additive.

### 4.2.2. Cultural resistance

Cultural resistance to non-traditional protein sources is still a barrier to widespread adoption. Alternative protein solutions should explore how to address and overcome these resistances, showing effective marketing and consumer education strategies. Although there is a market niche and a change in dietary habits and food choices, consumers might not readily accept the new alternative protein ingredients and products or show a lack of interest in learning about the benefits of microbial alternative proteins. Consumer preference for animal-based products is still strong, hampering market growth.

### 4.2.3. Concerns on human and animal health

The integration of alternative proteins into food and feed systems offers clear environmental and nutritional benefits but also raises several safety concerns, particularly regarding allergenic potential, tolerability and long-term health impacts. These issues must be carefully assessed to ensure consumer and animal safety and to prevent market resistance.

- **Human health risks**

  One of the key concerns regarding alternative proteins is their potential to cause allergenic reactions, particularly when derived from sources biologically related to known allergens.

  For instance, many edible insects (e.g., *Tenebrio molitor, Acheta domesticus*) contain tropomyosin, arginine kinase and chitin-binding proteins. These are pan-allergens also found in crustaceans, mites, and molluscs, raising the risk of cross-reactivity in individuals already sensitised to shellfish or dust mites. Such risks have been highlighted in scientific risk assessments, including EFSA's evaluation of *Tenebrio molitor*[81], which flagged these proteins as a potential hazard for susceptible consumers.

  A study conducted in the Isan region of northeastern Thailand by the University of Nottingham found that 7,4% of respondents experienced adverse reactions to edible insects, and 14,7% had more than one allergic episode. Nearly half of these individuals (46,2%) had pre-existing food allergies, which were exacerbated by insect consumption[82].

  Additional concerns include residual allergens from insect feed (such as gluten)[83] and the presence of chitin in insect exoskeletons, which can distort crude protein measurements and act as an indigestible fibre. Furthermore, insects can accumulate contaminants like heavy metals or arsenic from their rearing substrates, potentially exceeding legal limits if not properly managed.

  Other alternative proteins, such as those derived from fungi (e.g., mycoprotein) or fermented microbial biomass, may also provoke immune responses. For example, *Fusarium venenatum*, the fungus used to produce *Quorn*™, has been associated with gastrointestinal symptoms and anaphylaxis in sensitive individuals[84]. A survey data involving 1.752 self-reported adverse events found that 18% of cases were allergic reactions, some of them severe and occurring withing one hour, while the remaining 82% involved gastrointestinal symptoms such as vomiting and diarrhoea, typically appearing within 4 to 8 hours after consumption. Recurrent reactions were observed in individuals with mold sensitivities upon

[81] Safety of dried yellow mealworm (*Tenebrio molitor larva*) as a novel food pursuant to Regulation (EU) 2015/2283. (2021). EFSA Panel on Nutrition, Novel Foods and Food Allergens (NDA)

[82] Sirimungkararat, S. et al. (2010). A survey of edible insect consumption and allergy in northeastern Thailand. University of Nottingham.

[83] Edible insects: the science of novel food evaluations (2021). European Food Safety Authority (EFSA).

[84] Quorn Allergy. Factsheet. (n/d). Anaphylaxis UK

re-exposure[85].

Additionally, concerns have been raised about digestibility and bioavailability. Some plant-based or algae-based proteins contain antinutritional factors such as lectins, phytic acid, oxalates, or heavy metals, which can interfere with nutrient absorption or cause gastrointestinal distress and discomfort[8687].

the potential long-term health effects of alternative proteins remain an open question. Given that most of these ingredients are relatively new to widespread consumption, there is still limited understanding of their potential long-term impacts on aspects such as gut microbiota composition, immune system modulation, metabolic responses, or chronic disease markers. Although regulatory frameworks, such as the UE Novel Foods Regulation (2015/2283), require rigorous pre-market safety evaluations, including toxicological and allergenicity assessments, for each individual product, post-market surveillance remains limited, especially regarding cumulative exposure.

- **Animal health risks**

  In animal nutrition, alternative proteins such as insect meal, microbial biomass and algae are being considered to replace traditional ingredients. While these sources often have promising nutritional profiles, they also bring potential digestibility, safety and palatability challenges.

  For example, some insects contain chitin, a structural polysaccharide that is poorly digested by monogastric animals and may lead to gastrointestinal irritation or reduced nutrient uptake if not properly processed. Studies in aquaculture have reported variable growth performance and inflammatory responses in fish fed high levels of insect meal, depending on species and inclusion rates[88]. Proteins from novel sources may also introduce new allergens or anti-nutritional factors to the food chain. Insect proteins, for example, have been shown to trigger immune responses in some animals.

  Another consideration is the potential carryover of allergens or contaminants from animal feed into animal-derived products such as meat, milk or eggs. For example, heavy metals absorbed by insects or algae can deposit in animal tissues if not excreted[89]. Although the overall risk appears to be low, further research is needed to understand how novel feed ingredients might affect the composition and safety of animal-based food products.

  Regulatory bodies such as EFSA have established mechanisms like the Qualified Presumption of Safety (QPS) list for evaluation microbial feed ingredients[90]. However, the rapid pace of innovation in the sector highlights the need for more harmonised and adaptive regulatory frameworks that can keep up with emerging risks.

### 4.2.4. Regulatory Challenges

Strict regulatory frameworks in the key markets continue to pose significant challenges for the development and commercialisation of alternative proteins. These regulations affect various aspects of the value chain, from

[85] MF Jacobson. (2018) Self-reported adverse reactions associated with mycoprotein (Quorn-brand) containing foods. Volume 120, issue 6, P626-630, June 2018. Annals of Allergy, Asthma & Immunology

[86] Bleakley, S., & Hayes, M. (2017) Algal proteins: Extraction, application, and challenges concerning production. Foods, 6(5), 33.

[87] Mrinal Samtiya (2020). Plant food anti-nutritional factors and their reduction strategies: an overview. Food Production, Processing and Nutrition 2, article 6.

[88] Clauda Aragao. Alternative proteins for fish diets: implications beyond growth. Animals (Basel). 2022; 12(9):22111 PMC PubMed Central

[89] Jose A.M Prates. The role of microalgae in providing essential minerals for sustainable swine nutrition. Front. Anim. Sci. volume 6 - 2025

[90] Qualified presumption of safety (QPS). 2025. European Food Safety Authority (EFSA)

product classification and safety assessments to labelling and market authorisation, often introducing uncertainty and delays form producers and investors.

- **Regulatory environment in the European Union**

  In the European Union, alternative proteins, particularly those derived from insects, microbial fermentation or cell culture, are generally under the Novel Food Regulation (EU) 2015/2283[91]. This regulation requires that any food not consumed "to a significant degree" before 15 May 1997 undergoes a centralized safety assessment by the European Food Safety Authority (EFSA) before it can be placed on the market.

  Although this process ensures high safety standards, it also imposes significant administrative and scientific burdens. Applicants must submit extensive toxicological, microbiological and nutritional data, as well as demonstrate product traceability and stability. As of early 2025, only a limited number of insects species have been authorized for human consumption in the EU (e.g. *Tenebrio molitor, Acheta domesticus, Locusta migratoria*), with several other applications pending due to insufficient data or concerns over allergenicity[92]. For example, EFSA's initial opinion on *Locusta migratoria* required additional allergenicity data, delaying the product's market entry.

  Moreover, products developed using genetically modified organisms (GMOs) or synthetic biology techniques often face an additional layer of regulatory scrutiny under Directive 2001/18/EC[93], further extending the approval timeline. This is particularly relevant for precision fermentation-derived proteins, where the production strain may be genetically modified event if the final product is GMO-free.

  An illustrative case is the approval of UV-treated yellow mealworm powder, authorized by the European Commission on 20 January 2025 under the Novel Food Regulation[94]. This decision followed a series of earlier authorizations covering mealworm, locust, cricket, and lesser mealworm (including defatted cricket powder).

  However, the underlying approval process remains lengthy and complex. EFSA's updated 2025 guidance on novel food applications introduced even more stringent requirements[95], including additional data on long-term toxicity, allergenicity in vulnerable groups, and comprehensive exposure estimates.

- **Regulatory environment in the United States**

  In the United States, the regulatory environment is generally perceived as more flexible and innovation oriented. The Food and Drug Administration (FDA) oversees food safety under the Federal Food, Drug and Cosmetic Act, with particular attention to substances that qualify for the Generally Recognized as Safe (GRAS) status[96]. As an alternative protein ingredient meets GRAS criteria, either through scientific evidence or widespread historical use, companies can bypass the need for formal pre-market approval.

  This regulatory pathway has facilitated the introduction of products such as fungal mycoproteins, precision-fermented dairy proteins and plant-based meat analogues. However, not all proteins are

[91] Regulation (EU) 2015/2283 on novel foods. Official Journal of the European Union (2015). European Parliament and Council.

[92] Safety of dried yellow mealworm (Tenebrio Molitor larva) as a novel food. EFSA Journal, 19(1), e06343 (2021). EFSA NDA Panel

[93] Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms.

[94] Approval of another insect/insect-derived food as a Novel Food (2025). European Commission.

[95] Katona & Partners (2025). Updates to Novel Food Guidance: stricter rules for innovation in the European Union. Lexology.

[96] Generally Recognized as Safe (GRAS) (2023). U.S. Food & Drug Administration

eligible for GRAS status. For example, certain single-cell proteins produced from novel microbial strains may be excluded due to lack of historical use or insufficient safety data, requiring a New Dietary Ingredient (NDI) notification or full FDA evaluation.

A notable regulatory milestone in the U.S has been the joint oversight of cultivated meat by the FDA and the United States Department of Agriculture (USDA), which introduced a shared framework for approving cellular agriculture products. This has enabled companies like *UPSIDE Foods* and *GOOD Meat* to secure market approval ahead of their European counterparts[97].

While the FDA's approach is widely seen as flexible and innovation-friendly, there have been increasing calls for reform. In 2025, the U.S. Department of Health and Human Services (HHS) instructed the FDA to revise the GRAS framework[98], proposing that notifications and supporting data become mandatory, aiming to address long-standing concerns about transparency and oversight.

- **Examples from other markets: Japan, South Korea and China**

  Outside the EU and U.S., cultural perceptions and regulatory uncertainties present further challenges. In Japan and South Korea, regulatory frameworks for alternative proteins are still developing and can vary by product category. For instance, edible insects are not uniformly classified, and the approval process for novel foods remains fragmented across multiple agencies.

  Japan has proactively studied alt-protein rules: in 2020 MAFF launched a "Food Tech" industry group and Japan's cellular agriculture association is drafting guidelines. Japan's Food Sanitation Law will soon include detailed reviews of cultivated meat safety. For example, a government panel is evaluating toxicity and labeling of cell-based foods[99].

  South Korea has adopted a relatively cautious stance, especially concerning products involving genetically modified microorganisms (GMMs) or non-traditional fermentation techniques, which require detailed risk assessments and may trigger public resistance. In 2024, MFDS (Korea's FDA) established the first pre-market approval process for cultivated meat: companies can now submit dossiers (including detailed cell origin, nutritional and toxin data) for review[100].

  In China, recent policy signals have shown support for alternative proteins, particularly under the banner of food security[101]. However, the absence of a dedicated regulatory framework for cultivated meat or precision fermentation has resulted in a case-by-case approval process, which limits scalability and predictability for foreign and domestic producers alike.

- **Regulatory impact on innovation**

  The contrasting regulatory approaches across regions underscore the complexity facing alternative protein producers. While the EU model prioritizes consumer safety and transparency, its lengthy approval timelines can hinder innovation and delay time-to-market. In contrast, U.S. and some Asian frameworks allow for faster market access but may expose companies to greater reputational or safety risks if oversight mechanisms are perceived as insufficient.

  The case of insect protein regulation in Europe is illustrative: despite growing consumer interest and

[97] Cell-based meat one step closer to entering U.S Market as two companies receive USDA Approvals. (2023) FoodSafety magazine

[98] Avia M. Dunn, Rachel Turow. (2025) Closing the GRAS Loophole: Secretary Kennedy's Plan to enhance FDA Food Safety Regulations. Skadden Publication / The Nucleus: Life Sciences Enforcement and Regulatory Updates

[99] Novel Food Regulations around the World (n.d) GFI Asia Pacific

[100] South Korea establishes framework for regulatory approval of cultivated meat, with applications expected soon (2024). Green Queen

[101] Chinese Lawmakers promote alternative protein policies during annual political summit (2025). Green Queen

environmental benefits, market penetration remains limited due to the time and cost involved in achieving novel food approval. Similarly, precision fermentation companies have encountered delays in both the EU and Asia due to regulatory uncertainty surrounding the microbial production process, even when the final protein is identical to those found in nature.

### 4.2.5. Internationalization difficulties

The internationalization of products encounters significant obstacles, particularly due to regulatory misalignments among different regions. This logistical and regulatory challenge demands thorough consideration, as it profoundly influences market entry strategies across diverse geographical areas.

Insights into these challenges are elucidated by market reports like Mordor Intelligence[102], shedding light on the intricate nature of expanding into new markets within the alternative protein sector. Furthermore, through the examination of case studies and analyses of successful internationalization strategies, these reports offer invaluable lessons on surmounting regulatory and logistical barriers effectively.

Educational interventions aim to provide consumers with information that enhances their knowledge, improves mood, and reduces uncertainty, ultimately influencing psychological behaviour. Since knowledge serves as the foundation for behavioural change, it encourages individuals to adopt self-care approaches. However, information alone is insufficient to drive behavioural change; it must be specifically tailored to the targeted behaviour.

Framing information with persuasion can increase the effectiveness of educational interventions. Persuasion involves strategically presenting information to shape perceptions, which has been shown to enhance consumer acceptance of alternative proteins. For example, explaining how cultured meat is produced increases its acceptance more effectively than simply describing it. However, like educational interventions, persuasion alone does not significantly reduce conventional meat consumption or increase alternative protein adoption.

To maximize impact, persuasion and educational strategies should be combined with other interventions. For instance, integrating educational approaches with text message reminders or self-care exercises that encourage consumers to envision future goals has been shown to reduce conventional meat consumption. This highlights the importance of using a multi-faceted approach when designing interventions to promote alternative proteins.

Training interventions focus on skill development, enhancing an individual's ability to adopt targeted behaviours. Another key approach is benefit-based intervention, which leverages incentives and expectations to attract consumers to alternative proteins. When consumers anticipate rewards, such as price promotions, they are more likely to choose meat alternatives. Studies have shown that these strategies can effectively reduce red meat consumption and encourage environmentally friendly purchasing behaviours.

Modelling approaches also play a significant role in shaping consumer behaviour by leveraging influential figures, such as celebrities. Research indicates that people often mimic the behaviours of admired individuals, including dietary choices. Although shifting societal norms around conventional meat consumption is challenging, studies on dynamic norms suggest that people are more likely to reduce meat intake when they see specific role models adopting plant-based or vegetarian diets.

As the demand for protein increases, the food industry and scientific community are actively exploring novel sources, including plant-based, insect-based, and microorganism-derived proteins such as single-cell proteins. These alternatives offer high-protein food options with potential sustainability benefits. However, consumer

[102] Mordor Intelligence. (2022). Global alternative protein market - growth, trends, COVID-19 impact, and forecasts (2022 - 2027).

acceptance varies across these categories due to different motivations and barriers[103].

### 4.2.6. Barriers to food consumption

Greater public support is essential to foster enabling policies and increased R&D funding. Policy measures should aim to create a favourable environment that encourages private sector investment with greater confidence and lower costs. A key focus should be addressing regulatory and consumer acceptance challenges associated with alternative protein sources, as these barriers hinder market development[104].

Governments have a wide set of policy options for addressing market barriers:

*Table 6 Magnitude of barriers to food consumption for the four types of novel, protein-rich products*

| Protein source | | Economic barriers | Behavioral barriers | Regulatory barriers |
|---|---|---|---|---|
|  | Precision-fermented | Medium | Low | Low |
|  | Plant-based meat | Medium | Low | Low |
|  | Insect-based | Medium | High | High |
|  | Cellular agriculture | High | Medium | Low |

*Source:* Vivid Economics.

- **Economic barriers**: Investment in R&D and commercialization can significantly lower production costs, though this process takes time. Governments can accelerate price parity of alternative proteins and traditional livestock products by:
    - Interventions incorporating price incentives, such as financial subsidies, have demonstrated effectiveness in encouraging the adoption of alternative protein sources. These interventions play an important role in making sustainable protein options more accessible to a broader consumer base[105].
    - Implementing stricter climate change policies and regulations. In 2021, 64 carbon-pricing initiatives were introduced globally to increase costs for emission-intensive products (Carbon Pricing Dashboard). However, none currently apply to livestock products. Including livestock emissions in such initiatives could narrow the price gap between conventional and alternative proteins, making the latter more competitive.
- **Behavioral barriers:** Governments can boost consumer acceptance of alternative proteins by providing

[103] Siddiqui, S. A., Alvi, T., Sameen, A., Khan, S., Blinov, A. V., Nagdalian, A. A., Mehdizadeh, M., Adli, D. N., & Onwezen, M. (2022). Consumer Acceptance of Alternative Proteins: A Systematic Review of Current Alternative Protein Sources and Interventions Adapted to Increase Their Acceptability. Sustainability, 14(22), 15370.

[104] GINAs Protein diversity. (2021, 1 Novembre). Climate Works.

[105] Onwezen, M., Dagevos, H. (2024). A meta-review of consumer behaviour studies on meat reduction and alternative protein acceptance. Food Quality and Preference, 114, 105067.

information on their health and environmental benefits. Studies have demonstrated that interventions focused on shifting social norms can be successful in inducing behavioural changes. For example, providing restaurant customers with information highlighting social norms of how people are starting to reduce their meat consumption (e.g., dynamic norms) can support meat reducing behaviours[106].

- **Regulatory barriers**: a supportive regulatory framework is critical for alternative proteins such as insect-based products, whose commercialization depends on country-specific legislation. Public support should focus on developing jurisdictional mechanisms to ensure the safe production and distribution of these products, facilitating their market entry.

## 4.3. PEST analysis

*Table 7. PEST Analysis*

| POLITICAL[107] | ECONOMIC[108] |
|---|---|
| • **Government support and regulation**: Governments worldwide are increasingly recognizing the benefits of alternative proteins for environmental sustainability and food security. Countries like the United States, the European Union, and Singapore have implemented supportive policies and invested in research and development.<br>• **Trade policies**: International trade policies can impact the availability and cost of raw materials for alternative protein production. Favourable trade agreements can facilitate market expansion, while restrictive policies may pose challenges.<br>• **Food safety regulations**: Regulatory frameworks for food safety and labelling are crucial for consumer trust. Clear and consistent regulations can help standardize the industry and ensure product safety | • **Market growth**: The alternative protein market is projected to grow significantly, driven by increasing consumer demand and investment. The market could reach $50.45 billion by 2035.<br>• **Investment and funding**: Significant investment from both private and public sectors is fuelling innovation and expansion. Companies like Beyond Meat and Impossible Foods have attracted substantial venture capital.<br>• **Cost of production**: High production costs remain a challenge, particularly for newer technologies like cultured meat. Economies of scale and technological advancements are expected to reduce costs over time. |
| **SOCIAL** | **TECHNOLOGICAL** |
| • **Consumer awareness**: Growing awareness of health and environmental issues is driving consumer interest in alternative proteins. However, acceptance varies by region and demographic. | • **Innovation in production**: Advances in biotechnology, such as fermentation and tissue engineering, are driving the development of new alternative protein products. |

[106] Onwezen, M., Dagevos, H. (2024). A meta-review of consumer behaviour studies on meat reduction and alternative protein acceptance. Food Quality and Preference, 114, 105067.
[107] The State of Global Policy on Alternative Proteins. (2024). The Good Food Institute.
[108] Annual Report Financial Year 2023. (2024). The Good Food Institute.

| | |
|---|---|
| • **Cultural preferences**: Cultural and dietary preferences play a significant role in the adoption of alternative proteins. Tailoring products to meet local tastes can enhance market penetration.<br>• **Health trends**: Increasing health consciousness is leading consumers to seek out protein sources perceived as healthier. Plant-based proteins are seen as beneficial for heart health and weight management. | • **Research and Development**: Ongoing R&D is essential for overcoming technical challenges and scaling up production. Collaboration between industry, academia, and government can accelerate innovation.<br>• **Supply chain and infrastructure**: Developing efficient supply chains and infrastructure is vital for the growth of the alternative protein market. Investments in production facilities and distribution networks are necessary to meet increasing demand. |

### 4.4. SWOT analysis

The alternative protein market is experiencing rapid growth as consumers, businesses and policymakers increasingly recognize the benefits of sustainable protein sources. A SWOT analysis helps assess the industry's strengths, weaknesses, opportunities and threats to better understand the factors shaping its future trajectory.

*Table 8. SWOT Analysis*

| STRENGHTS | WEAKNESSES |
|---|---|
| • **Consumer demand**: a growing global interest in sustainable, ethical and health-conscious food choices is driving demand for alternative proteins.<br>• **Technological advancements**: innovations in fermentation, cellular agriculture and plant-based processing are improving product quality and scalability.<br>• **Regulatory support and incentives**: governments worldwide are investing in alternative protein research and setting favorable policies.<br>• **Diverse applications**: alternative proteins are expanding into food, animal feed, pharmaceuticals and cosmetics, increasing their market potential. | • **High production costs**: many alternative proteins, particularly cell-based meats, are expensive to produce on a scale.<br>• **Consumer skepticism**: some consumers perceive alternative proteins as unnatural or inferior in taste and texture compared to traditional meat.<br>• **Regulatory hurdles**: approvals for novel proteins can be complex, time-consuming and vary by region.<br>• **Supply chain challenges**: sourcing raw materials and scaling production efficiently remains a barrier to widespread adoption. |
| **OPPORTUNITIES** | **THREATS** |
| • **Expansion into emerging markets**: countries like Asia and Latin America present untapped potential due to rising protein demand.<br>• **Strategic partnerships**: collaborations between biotech firms, food manufacturers | • **Competition from conventional proteins**: traditional meat and dairy industries continue to dominate the market and lobby against alternative proteins.<br>• **Cultural resistance**: consumer hesitancy, particularly around lab-growth and insect- |

| | |
|---|---|
| and retailers can drive innovation and market penetration.<br>• **R&D for improved products**: investment in texture, flavor and cost reduction can enhance consumer acceptance.<br>• **Supportive policies**: new regulations and incentives for sustainable food production can accelerate industry growth. | based proteins may slow adoption.<br>• **Economic downturns**: financial instability can affect investment and consumer spending on premium alternative protein products.<br>• **Ethical and environmental concerns**: questions around genetic modification, synthetic biology and sustainability claims may impact consumer trust. |

### 4.5. Nutritional challenges and opportunities of alternative protein sources for future foods

As the demand for sustainable food sources grows, alternative proteins have emerged as a viable solution to address environmental concerns and food security. However, their integration into mainstream diets presents both nutritional opportunities and challenges that must be considered for the successful development of future foods.

One of the most significant advantages of alternative protein sources is their potential to provide high-quality proteins comparable to traditional animal products. Many plant-based, microbial, and insect-derived proteins offer essential amino acids necessary for human health. While some plant proteins lack specific amino acids, blending different sources, such as legumes and grains, can create a complete amino acid profile. Additionally, certain innovative proteins, including mycoproteins and precision-fermented proteins, are designed to enhance their nutritional value, making them strong competitors to conventional meat and dairy.

Despite these advantages, alternative proteins face several nutritional challenges that must be addressed. One primary concern is the digestibility and bioavailability of plant-based proteins. Certain compounds, such as phytates and lectins, can inhibit the absorption of essential minerals, making it necessary to develop processing techniques that improve digestibility. Insect and algae-based proteins, although nutritionally dense, require further research to determine their long-term impact on human health.

Another challenge is the potential for nutrient deficiencies. While alternative proteins provide essential macronutrients, they often lack specific micronutrients naturally found in animal-based foods. Ensuring that products contain adequate amounts of vitamin B12, iron, and omega-3 fatty acids is crucial to preventing deficiencies, particularly among consumers who follow entirely plant-based diets. The level of processing in some alternative protein products is also a concern. Highly processed plant-based meat substitutes may contain excessive sodium, artificial binders, and unhealthy fats, which can counteract the health benefits of reducing animal protein intake.

Moving forward, the future of alternative proteins will depend on technological advancements that enhance protein quality, digestibility, and nutritional completeness. Hybrid protein solutions that combine plant, microbial, and cultured proteins may provide a well-rounded nutritional profile while maintaining sustainability. Moreover, regulatory frameworks and industry standards will play a crucial role in ensuring that alternative protein products meet nutritional guidelines and consumer expectations.

Ultimately, while alternative proteins present promising nutritional benefits, addressing their limitations through innovation, fortification, and consumer education will be key to their successful integration into global food markets.

# 5. MARKET SEGMENTATION

The market segmentation analysis is conducted comprehensively, considering both the source of alternative proteins and their specific applications. This approach allows for a deep understanding of the diversity and opportunities within the market for proteins derived from microbial fermentation of unconventional marine sources.

## 5.1. By source

This analysis focuses on four primary sources of alternative proteins (Figure 5), each distinguished by its distinct attributes and capacity to redefine the food sector: plant-based, insect-based, cell-based, and microbial-based proteins. These sources signify a fundamental departure from conventional animal-derived sources towards more sustainable and innovative alternatives.

Projections indicate a distribution of market share as follows: 35% for plant-based proteins, 35% for insect-based proteins, and 30% for microbial-based proteins by the year 2035[109].

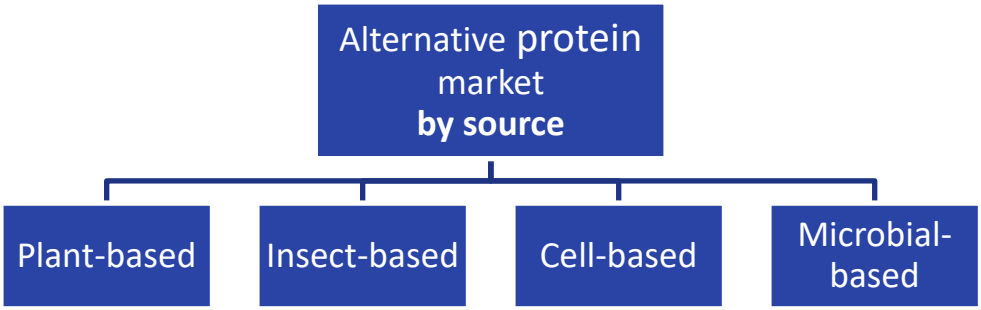



*Figure 5. Alternative protein market by source*

### 5.1.1 Plant-based proteins

Within the alternative protein market, the plant-based protein segment has emerged as a dominant force, as evidenced by DataM Intelligence's[110] extensive analysis. This dominance stems from several key factors, including heightened demand from food and beverage manufacturers, the abundance of raw materials available for processing, and the relatively lower production costs compared to other alternative protein sources.

As of 2024, the plant protein segment maintained its position as the primary contributor to the alternative protein market. This trajectory is propelled by continued demand from food and beverage manufacturers, ample availability of raw materials, and cost-effectiveness relative to other alternatives[111].

*Table 9 Plant-based protein market outlook 2024-2034. Source: Future market insights[112].*

| | |
|---|---|
| Estimated global industry size (2024) | **US$ 18.6 billion** |
| Projected global industry value (2034) | US$ 42.5 billion |
| Value-based (2024 to 2034) | 8.6% CAGR |

[109] Alternative Protein Market Sixe & Share, by Type (Plant-Based Protein, Insect-Based Protein, Microbial-Based Protein), Application (Food & Beverages, Animal Feed & Pet Food, Nutraceuticals) – Global Supply & Demand Analysis, Growth Forecasts, Statistics Report 2025-2037. (2024). Researh Nester.
[110] Alternative Protein Market Size, Share, Industry, Forecast and Outlook (2024-2031). (2024). DataM Intelligence.
[111] Alternative Protein Market Size, Share, Forecast, & Trends Analysis by Type (Plant Protein [Soy, Pea, Potato], Insect Protein [Crickets, BSF], Microbial [Algae Protein, Fungal Proteins]), Application (Food & Beverage, Alternative Proteins) - Global Forecast to 2031. (2024). Meticulous Market Research.
[112] Plant-Based Protein Market Analysis – Size, Share & Forecast 2024-2034. (2024). Future Market Insights.

Within the plant protein market, segmentation is based on various types, including soy protein, wheat protein, pea protein, canola protein, potato protein, rice protein, corn protein, and other plant proteins.

The soy protein segment is anticipated to command the lion's share of the plant protein market. This substantial portion is attributed to several factors, including the widespread availability of soy protein, its competitive pricing, the rising demand for meat protein substitutes, its versatility across various product applications, and its manifold health benefits.

The global soy protein isolate market (Table 10) acquired a value of US$ 3,675.1 million in 2024. Changing consumer preferences towards conventional proteins will propel the market to reach a sum of US$ 8,573.2 million by 2034, garnering a CAGR of 8.8% during the forecast period 2024 to 2034[113].

*Table 10. Soy Protein Isolate Market 2022. Source: Future Market Insights*

| | |
|---|---|
| Estimated Market Value (2024) | **US$ 3,675.1 million** |
| Projected Forecast Value (2034) | US$ 8,573.2 million |
| Anticipated Growth Rate (2024 to 2034) | 8.8% CAGR |
| Growth Factor | Increased demand for soy isolates in various powder forms for health drinks and infant milk are boosting demand |
| Future opportunities | Is dominated by North America, Eastern and Western Europe. As a result of the rising interest in and acceptance of organic as well as animal-free food items. |
| Market trends | Many customers suffer from food allergies as well as intolerances, which has led to a preference for plant-based replacements, such as soy protein isolate, which has fuelled market expansion. |

### 5.1.2 Insect-based Proteins

Insects have been a part of the human diet for centuries, particularly in Asia and Africa[114]. According to the Food and Agriculture Organization of the United Nations (FAO), there are over 1900 insect species consumed around the world[115] (Table 11).

*Table 11. Major groups of insects consumed around the world. Source: van Huis et al., (2013).*

| Insect Class | Insect Species | Percentage (%) |
|---|---|---|
| Coleoptera | Yellow mealworm, palm weevil | 31 |
| Lepidoptera | Caterpillars of butterflies or moths | 18 |
| Hymenoptera | Weaver ants, yellow jacket wasp and honeybees | 14 |

[113] Soy Protein Isolate Market Outlook from 2024 to 2034. (2024). Future Market Insights.
[114] Ramos-Elourdy, J. (2009). Anthropo-entomophagy: Cultures, evolution and sustainability. Entomological Research, 39: 271-288.
[115] van Huis A. (2013). Potential of insects as food and feed in assuring food security. Annual review of entomology, 58, 563–583.

| | | |
|---|---|---|
| Orthptera | Crickets and locusts | 13 |
| Hemiptera | Cicadas, pentatomid bugs | 10 |
| Isoptera, Odonata, Diptera and others | Termites, dragonflies, flies and others | 14 |

The practice of consuming insects, known as entomophagy, is considered a sustainable dietary choice due to the high protein content and abundance of polyunsaturated fatty acids found in edible insects. However, these nutritional properties vary across different insect species[116]. Insects are significantly more efficient at converting feed into edible body mass compared to traditional livestock[117]. These advantages make them an appealing choice for expanded production, contributing to improved global food security.

In recent years, insect-based proteins have made significant strides in establishing their presence within the alternative protein market. Renowned for their nutritional value, eco-friendliness, and sustainability as both human food and animal feed, insect-based proteins are projected to experience the highest compound annual growth rate (CAGR) in the foreseeable future, according to Meticulous Market Research's analysis[118]. This upward trajectory is further bolstered by the increasing investment in industrial-scale production facilities.

The insect protein segment is anticipated to witness the highest CAGR during the forecast period from 2023 to 2030. This notable growth is primarily fuelled by the escalating demand for eco-friendly, protein-rich food options and the surge in investments in edible insect farming.

Segmentation within the insect protein market includes categories such as crickets, black soldier fly (BSF), mealworms, and other insect proteins.

As of 2023, the crickets' segment is projected to hold the largest share of the insect protein market. This dominance can be attributed to several factors, including the high nutritional content of crickets, their ease of farming and processing, their integration into various food products and recipes, and the growing consumer demand for cricket-based products such as protein powders, bars, and snacks. However, the black soldier fly segment is expected to exhibit the highest CAGR over the forecast period.

The insect protein market (Table 12) is forecasted to grow from its 2023 value of US$ 602.3 million to US$ 3.1 billion by 2033, representing a remarkable compound annual growth rate (CAGR) of 17.7%[119].

*Table 12. Insect Protein Market Outlook 2023. Source: Future Market Insights*

| | |
|---|---|
| Insect Protein Market Size (2022) | US$ 510.4 million |
| Insect Protein Market Size (2023) | US$ 602.3 million |
| Projected Forecast Value (2033) | US$ 3.1 billion |
| Anticipated Growth Rate (2023 to 2033) | 17.7% CAGR |
| Growth Factor | Increased demand for alternative protein sources due to next-generation plant-based meats and on-the-go protein snacks. |

[116] Kouřimská, Lenka & Adámková, Anna. (2016). Nutritional and sensory quality of edible insects. NFS Journal. 4.
[117] van Huis A. (2013). Potential of insects as food and feed in assuring food security. Annual review of entomology, 58, 563–583.
[118] Alternative Protein Market Size, Share, Forecast, & Trends Analysis by Type (Plant Protein [Soy, Pea, Potato], Insect Protein [Crickets, BSF], Microbial [Algae Protein, Fungal Proteins]), Application (Food & Beverage, Alternative Proteins) - Global Forecast to 2031. (2024). Meticulous Market Research.
[119] Insect Protein Market By Insect Type, Form, Application and Region | Forecast 2023 to 2033. (2023). Future Market Insights.

| | |
|---|---|
| Future opportunities | Demand for alternative proteins is driving market growth. |
| Market trends | Insects with high protein content and growing use demand for insect protein are growing. |

The consumption of edible insects, including crickets, mealworms, grasshoppers, beetles, ants, silkworms, termites, and waxworms, is gaining momentum due to their high nutritional value, sustainability, and potential role in addressing global food security challenges. As interest in alternative protein sources grows, many consumers are still unfamiliar with the health and environmental benefits of incorporating insects into their diets. The market for edible insects intended for human consumption is projected to expand significantly, rising from an estimated US$ 653.3 million in 2024 to over US$ 1.1 billion by 2034, reflecting a compound annual growth rate (CAGR) of 5.3% over the forecast period[120].

### 5.1.3 Microbial Proteins

Microbial proteins derived from single-celled microorganisms, including algae, fungi, yeasts, and bacteria, continue to garner attention as a sub-category within the alternative proteins market. Within this group, algal proteins are particularly poised for significant demand growth[121].

The Microbial Protein Market is projected to expand to $5.192 billion by 2030, exhibiting a robust compound annual growth rate (CAGR) of 7.70% from 2023 to 2030. This growth trajectory is propelled by escalating demand for sustainable and alternative protein sources. Microbial proteins, cultivated through fermentation processes utilizing microorganisms like bacteria, yeast, and fungi, present a promising solution to traditional protein production challenges.

A primary driver of market growth is the burgeoning global population and the imperative for a sustainable food supply. Microbial proteins can be cultivated utilizing diverse feedstocks, including agricultural waste and industrial byproducts, thereby mitigating the environmental impact associated with conventional livestock farming.

Furthermore, microbial proteins offer versatility and can be customized to fulfill specific nutritional needs, serving as valuable ingredients in various applications such as animal feed, food products, and dietary supplements. The market witnesses' significant investments and research endeavors aimed at optimizing production processes and enhancing microbial protein functionality.

In 2024, the algae protein segment (Table 13) was anticipated to dominate the microbial protein market with the share of 70% of the microbial protein market[122]. This dominance is primarily attributed to the expansion of the dietary supplements industry, growing preference for spirulina-based products, and the proliferation of products incorporating algae as ingredients.

Moreover, the algae protein segment is forecasted to grow at a CAGR of 5.4% during the forecast period (2024-2032)[123]. This accelerated growth is driven by factors such as the increasing vegetarian demographic, rising instances of diet-related illnesses like malnutrition, expansion of the nutraceutical industry, and the heightened

[120] Edible Insects for Human Consumption Market Statistics. (2024). Fact.MR
[121] Microbial Protein Market – Forecast (2024 - 2030). (2022). IndustryARC.
[122] Alternative Protein Market Size, Share, Forecast, & Trends Analysis by Type (Plant Protein [Soy, Pea, Potato], Insect Protein [Crickets, BSF], Microbial [Algae Protein, Fungal Proteins]), Application (Food & Beverage, Alternative Proteins) - Global Forecast to 2031. (2024). Meticulous Market Research.
[123] Algae Protein Market Size - By Source (Seaweed (Brown Algae, Green Algae, Red Algae), Micro algae {Blue-Green Algae, Green Algae}), By Application (Dietary Supplements, Food & Beverage, Animal Feed, Cosmetics), Dosage Form & Forecast, 2024-2032. (2024). Global Market Insights.

utilization of chlorella in aquaculture diets.

*Table 13. Algae Protein Market 2023. Source: Global Market Insights*

| | |
|---|---|
| Algae Protein Market Size (2023) | US$ 876 million |
| Projected Forecast Value (2032) | US$ 1.41 billion |
| Anticipated Growth Rate (2024 to 2032) | 5.4% CAGR |
| Growth drivers | Initiatives to boost algae products production. Obligation to maintain animal feed quality. Widening demand for nutritional products. Increasing consumption of protein supplements. |

### 5.1.4 Cell-based Proteins

Cultured meat, also referred to as in vitro, lab-grown, or cell-based meat, is produced from animal stem cells cultivated in controlled environments[124]. It offers a promising solution to meet the growing global demand for meat in a more sustainable and ethical way. As an emerging industry, it holds significant potential for future expansion. However, the market remains in its early stages, facing challenges such as regulatory approvals, consumer acceptance, and the need to scale production to meet worldwide demand.

Cell-based protein production mirrors the biological processes occurring within living animals to generate meat. The costs associated with cell-based production are anticipated to decline by 50%-80% over the next five years, chiefly driven by reductions in cell culture medium and inputs expenses, which currently constitute 80%-90% of production costs.

Price parity with conventional beef is forecasted to be achieved around 2028-2029. The outlook for cell-based meat appears optimistic due to inherent cost advantages such as higher feed conversion rates (25% vs. 4%), shorter production cycles (~2 weeks vs. 3 years) and streamlined supply chains. However, significant challenges persist, particularly regarding texture discrepancies and the intricate nature of the production process.

The cultured meat market is poised to grow at a compound annual growth rate (CAGR) of 33.3% from 2028 to 2034, projecting to reach USD 6,169.6 million by 2034 from an estimated $272.4 million in 2023[125]. Additionally, since 2023, the market is expected to witness a CAGR of 16.1% over the subsequent five-year period. This growth trajectory is propelled by a shifting consumer preference towards alternatives that circumvent the ethical and cruelty concerns associated with conventional meat production, rendering cultured meat an increasingly attractive option.

## 5.2. By application

Segmentation by application (Figure 6) examines how alternative proteins are used across various industries, including food, pharmaceuticals, cosmetics, and more. This analysis underscores the adaptability and expansive potential of these proteins in diverse products and processes.

[124] Hadi, J., & Brightwell, G. (2021). Safety of Alternative Proteins: Technological, Environmental and Regulatory Aspects of Cultured Meat, Plant-Based Meat, Insect Protein and Single-Cell Protein. Foods, 10(6), 1226.
[125] Cultured Meat Market Size, Share, Share, Industry Growth, Trends Report by Source (Poultry, Beef, Seafood, Pork, Duck), End Use (Nuggets, Burgers, Meatballs, Sausages, Hot Dogs), and Region (North America, Europe, Asia Pacific, South America, Middle East & Africa) - Global Forecast to 2034. (2023). Markets and Markets.

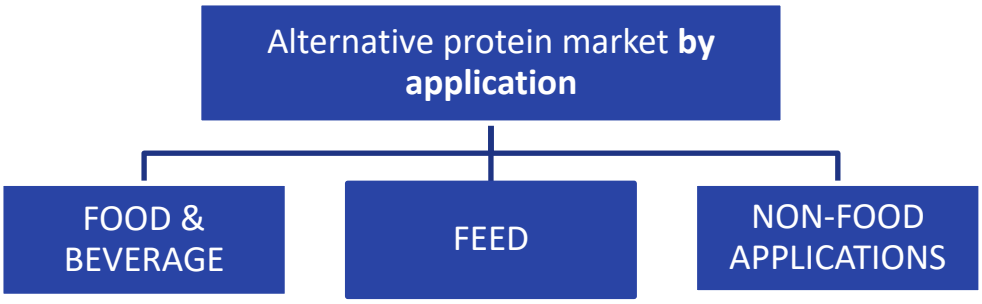



*Figure 6. Alternative protein market by application*

### 5.2.1 Food & Beverage

The food and beverage market are positioned for robust growth, with a compound annual growth rate (CAGR) exceeding 17.5% from 2023 to 2032[126]. This growth is propelled by the increasing adoption of plant-based trends and ongoing innovations in plant-based alternatives. As of 2023, the food and beverage segment are expected to dominate the global plant protein market, attributed to escalating consumer preferences for plant-based foods, heightened awareness of protein-rich food products, and the versatile functionality of plant-based proteins, particularly compatible with vegetarian and vegan lifestyles, and the rise of clean-label trends.

Conversely, the nutrition and health supplements segment are forecasted to witness significant growth during the forecast period. This growth is primarily driven by evolving lifestyles, growing health and wellness trends, and the increasing prevalence of diseases.

In the insect protein market, segmented into food & beverage and animal feed, the food & beverage segment is fueled by global food shortages, growing consumption of processed whole insects as food, and rising demand for high-quality alternative protein and amino acid sources among consumers.

#### 5.2.1.1. High protein foods

Protein ingredients are increasingly consumed to maintain the body's protein levels, crucial for health and fitness[127]. The human body cannot produce essential amino acids necessary for cell healing, hence the reliance on external protein sources. As urbanization rates rise, the geriatric population expands, lifestyles evolve, and more women enter professional spheres, consumers increasingly prioritize health and wellness options.

This shifting landscape has led to a surge in demand for protein-fortified foods to fulfill daily dietary requirements. Protein ingredients have transitioned from being low-profile commodities to value-enhancing ingredients sought after for their health benefits. High-protein foods offer several advantages, including aiding weight management by promoting a feeling of fullness and requiring additional energy expenditure for digestion. Clinical trials support the notion that high-protein diets can help preserve lean body mass and contribute to maintaining a favorable body composition.

The protein ingredients market (Table 14) was estimated to be valued at US$ 85,886.80 million in 2024. According to Future Market Insights[128], it is expected to witness significant growth, reaching a valuation of US$

[126] Alternative Protein Market Size for Food Application - By Source (Plant-based, Insect-based, Microbial-based), Application (Food {Meat Analogs, Bakery, Dairy Alternatives, Cereals & Snacks, Beverages}), Regional Outlook & Forecast, 2024- 2032. (2023). Global Market Insights.
[127] Protein Ingredients Market Size & Share Analysis - Growth Trends & Forecasts (2024 - 2029). (2023). Mordor Intelligence.
[128] Protein Ingredient Market Forecast by Animal and Plant Sources 2024 to 2034. (2024). Future Market Insights.

164,376.9 million by 2034, with a compound annual growth rate (CAGR) of 6.7% from 2024 to 2034.

The high-protein food category encompasses protein-rich packaged foods, protein-rich beverages, high-protein and high-energy sports drinks, as well as high-protein and nutritious sports drinks.

A significant factor driving growth in the high protein-based food market is the increasing consumer preference for natural and herbal products. This trend reflects a broader societal shift towards healthier and more holistic lifestyle choices.

Within the sports nutrition industry, it is experiencing rapid growth across both developed and emerging markets. The increasing popularity of fitness events, along with a greater focus on recovery and athletic performance, is driving demand for protein-based products. Protein ingredients are highly valued in sports nutrition due to their essential amino acids, which play a crucial role in muscle repair, recovery, and growth. Among these, whey protein stands out for its rapid absorption and rich amino acid profile, making it a preferred choice among fitness enthusiasts[129].

As consumers become more health-conscious and prioritize nutrition, the demand for protein-rich sports nutrition products continues to rise, contributing significantly to market expansion.

However, a major challenge facing the high protein-based food market is the stringent regulatory environment. Compliance with government regulations, particularly in regions like Europe, presents significant hurdles for vendors. For example, in the European market, adherence to regulations set by the European Food Safety Authority (EFSA) is essential. These regulations govern various aspects including manufacturing, labeling, marketing, and ingredient usage. Moreover, certain ingredients commonly used in sports nutrition products may be banned due to safety concerns, further complicating regulatory compliance.

Compliance with stringent government regulations can lead to delays in production processes as vendors navigate complex regulatory requirements. The need for meticulous adherence to regulations, including scrutiny of health claims and increased inspections, adds pressure on vendors, potentially hindering market growth during the forecast period.

*Table 14. Protein ingredient market 2024. Source: Future Market Insights*

| | |
|---|---|
| Protein ingredient Market Size (2024) | US$ 85,886.8 million |
| Projected Forecast Value (2034) | US$ 164,376.9 million |
| Anticipated Growth Rate (2024 to 2034) | 6.70% CAGR |
| Market drivers | Consumer preferences shifting between synthetic ingredients to natural, preferences on herbal products, increasing demand in high-protein foods in due to new healthy habits. |
| Market barriers | Strongly regulated market; regulation on labelling, manufacturing, and marketing; difficult internationalization (e.g., there are ingredients banned in the EU that are allowed in the US and vice versa). |

[129] Protein Ingredient Market Forecast by Animal and Plant Sources 2024 to 2034. (2024). Future Market Insights.

#### 5.2.1.2. Protein supplements

The Protein Supplements Market (Table 15) is estimated to be valued at USD 30.08 billion in 2025, with projections indicating a growth to USD 43.08 billion by 2030, boasting a Compound Annual Growth Rate (CAGR) of 7.45% during the forecast period (2025-2030)[130].

Protein supplements have garnered significant popularity among gym enthusiasts and fitness aficionados, owing to their perceived influence on various bodily functions such as muscle growth, metabolism, energy levels, heart health, and weight management. The market's dynamism is further fueled by the extensive variety of protein supplements available, offering diverse claims, protein content, sources, forms, and flavors, thereby appealing to a broad consumer base globally. This diversity is expected to continue driving market momentum in the foreseeable future. Moreover, the escalating demand for plant-based protein is propelling manufacturers to introduce organic and clean-label protein supplements across market channels.

The rising prominence of sports activities, celebrity endorsements, international sports and fitness events, social media influencers, and government initiatives and campaigns have been instrumental in encouraging consumers to engage in fitness and sports-related activities. Consequently, there has been a noticeable increase in consumer expenditure on maintaining a healthy lifestyle, further contributing to the growth of the protein supplements market.

Despite the market's growth trajectory, it faces challenges stemming from government scrutiny in the sports nutrition category, including protein supplements. Regulatory oversight has led to limitations on the types of products introduced to the market, while the absence of robust guidelines and regulatory frameworks has resulted in several recalls of protein supplements due to safety concerns. Addressing these regulatory challenges will be imperative for sustaining the growth of the protein supplements market.

The protein supplements market encompasses a variety of products, including protein powder, ready-to-drink beverages, and protein bars. This market can be segmented based on several factors such as type, age, gender, and source.

The alternative protein market in sports supplements is rapidly expanding, fueled by growing consumer demand for sustainable and bioactive nutrition options. This analysis examines the current landscape of alternative protein sources, highlighting their benefits and the scientific evidence supporting their role in sports nutrition.

- **Sustainability and Bioactivity of Alternative Proteins:** Alternative protein sources, including insects, plants, and mycoproteins, are increasingly recognized for their high bioactivity and sustainability[131]. Among them, plant-based proteins such as pea proteins stand out due to their low environmental impact and rich amino acid composition, making them a strong alternative to traditional animal proteins[132].
- **Effectiveness of Protein Supplementation:** Protein supplementation is widely practiced among athletes and holds a strong market presence, particularly in the USA[133]. Whey proteins and amino acid supplements dominate the industry due to their proven ability to enhance muscle protein synthesis

[130] Protein Ingredients Market Size & Share Analysis - Growth Trends & Forecasts (2025 - 2030). (2024). Mordor Intelligence.
[131] López-Martínez, M., Miguel, M., & Garcés-Rimón, M. (2022). Protein and Sport: Alternative Sources and Strategies for Bioactive and Sustainable Sports Nutrition. Frontiers in Nutrition, 9.
[132] Loureiro, L., Ferreira, T., Cahuê, F., Bittencourt, V., Valente, A., & Pierucci, A. (2023). Comparison of the effects of pea protein and whey protein on the metabolic profile of soccer athletes: a randomized, double-blind, crossover trial. Frontiers in Nutrition, 10.
[133] Poulios, A., Georgakouli, K., Draganidis, D., Deli, C., Tsimeas, P., Chatzinikolaou, A., Papanikolaou, K., Batrakoulis, A., Mohr, M., Jamurtas, A., & Fatouros, I. (2019). Protein-Based Supplementation to Enhance Recovery in Team Sports: What is the Evidence?. Journal of sports science & medicine, 18 3, 523-536 .

and offer additional health benefits[134].

- **Comparative Performance of Plant vs. Animal Proteins:** Research comparing pea protein and whey protein indicates that plant-based proteins can be just as effective as animal proteins in supporting athletic performance and recovery. While some biochemical differences exist, plant proteins offer specific advantages and remain a viable alternative without compromising muscle growth, performance, or post-exercise recovery[135].
- **Consumer Motivations and Market Trends:** The growing consumer interest in alternative proteins is largely motivated by perceived health benefits, reduced environmental impact, and ethical concerns. However, while these factors drive adoption, the scientific evidence supporting these claims is still developing. Further research is needed to fully understand the long-term benefits and implications of replacing conventional animal-based proteins with alternative sources[136].

*Table 15. Protein supplement market 2024. Source: Mordor Intelligence*

| | |
|---|---|
| Protein supplement Market Size (2025) | US$ 30.08 billion |
| Projected Forecast Value (2030) | US$ 43.08 billion |
| Anticipated Growth Rate (2025 to 2030) | 7.45% CAGR |
| Market drivers | Society is concerned about health; lifestyle changes; increasing health-oriented demand; consumer demands several ready-to-drink supplements (this allows to spend on various products at the same time); very popular between young people in due to health benefits; increasing demand of plant-based supplements. |
| Market barriers | Producing with raw materials so prices are very volatile (e.g., soy or milk prices); Ukraine war affects directly to this market; consumer has seasonal pattern (such as gym), highly regulated market. |

### 5.2.2. Feed

The global animal feed alternative protein sales were forecasted to reach a value of US$ 180 billion by the year 2024, with a projected Compound Annual Growth Rate (CAGR) of 8.0%. By 2034, the projected size of the animal feed alternative protein market is US$ 388.5 Billion[137].

Sales of animal feed alternative protein are experiencing a major transformation. Traditional feed production has been associated with environmental concerns.

This rise in demand for alternative proteins is also spurred by factors such as increased incidence of cattle diseases and epidemics, alongside the growing recognition of the nutritional value of alternative proteins in animal diets.

[134] Ha, E., & Zemel, M. (2003). Functional properties of whey, whey components, and essential amino acids: mechanisms underlying health benefits for active people (review).. The Journal of nutritional biochemistry, 14 5, 251-8.
[135] Loureiro, L., Ferreira, T., Cahuê, F., Bittencourt, V., Valente, A., & Pierucci, A. (2023). Comparison of the effects of pea protein and whey protein on the metabolic profile of soccer athletes: a randomized, double-blind, crossover trial. Frontiers in Nutrition, 10.
[136] Tso, R., Lim, A., & Forde, C. (2020). A Critical Appraisal of the Evidence Supporting Consumer Motivations for Alternative Proteins. Foods, 10.
[137] Animal Feed Alternative Protein Market. (2024). Future Market Insights.

Fermentation, a biological process, produces nutrient-rich feed through microbial action, promoting sustainable practices. Enzyme treatment optimizes nutrient utilization, enhancing feed efficiency for different animals.

*Table 16. SWOT Analysis of insect use in animal feed. Source: Gasco et al., (2020).*

| | |
|---|---|
| **Strengths** | **Weaknesses** |
| Composition<br>Shaping insect nutrient profile<br>Contents of nutrients and bioactive compounds | Market price<br>PUFA and minerals<br>Research and development |
| **Opportunities** | **Threats** |
| Insects for organic waste valorization<br>Feed vs. Food<br>Lifting insects' ban<br>Scaling up insect production<br>Live insect larvae | Legal framework<br>Risk related to insect uses<br>Welfare<br>Safety and legislation |

#### 5.2.2.1. Livestock

Technological advancements, particularly in the realm of microbial and plant-based proteins, have facilitated the development and adoption of alternative proteins in the livestock industry. Notably, plant-based proteins like pea and soy proteins, as well as microbial proteins, are witnessing increased popularity. The livestock industry, with its perennially high demand for alternative proteins, is driving food manufacturers to diversify into alternative protein markets, aligning with consumer preferences.

#### 5.2.2.2. Pet food

The pet ownership surge, particularly in the wake of the COVID-19 outbreak, has fueled an increase in pet food sales. This uptick in demand has also spurred a strong interest in alternative proteins within the pet food sector. Consumer awareness regarding the nutritional benefits of soybean protein, boasting over 65% protein content and meeting diverse nutritional requirements, has further fueled this demand. Consequently, there has been a significant increase in the adoption of alternative protein-based pet foods.

The European pet food market, valued at €55.02 billion,[138] is expected to exhibit a Compound Annual Growth Rate (CAGR) of 7.47% from 2024 to 2029.

#### 5.2.2.3. Aquaculture feed

The market comprises compounded meals for various aquatic species, providing balanced diets tailored to specific nutritional requirements. With a global value of $62.4 billion in 2023, registering a CAGR of 4% from 2024 to 2034, this market is driven by increasing seafood consumption, growing fish farming activities, and the consumer shift towards healthy animal protein alternatives[139].

Factors driving market growth include the rising consumption of seafood, increased demand for healthy animal protein, and consumer efforts to reduce meat consumption. Additionally, fish farming practices necessitate high-quality feed formulations for optimal fish development. However, challenges such as volatile product prices due to feed manufacturing inputs and regulatory hurdles on product approvals pose barriers to market

[138] Europe Pet Food Market SIZE & SHARE ANALYSIS - GROWTH TRENDS & FORECASTS UP TO 2029. Mordor Intelligence.
[139] Aquafeed Market Size, Share, Competitive Landscape and Trend Analysis Report, by Additives, by End Consumption: Global Opportunity Analysis and Industry Forecast, 2024-2034. (2024). Allied Market Research.

expansion.

### 5.2.3 Non-food applications

The nutraceuticals market size is estimated to be USD 488.41 billion in 2024 and is anticipated to reach USD 626.02 billion by 2029, growing at a CAGR of 5.09% during the forecast period (2024-2029)[140]. The global nutraceuticals market is expected to witness consistent growth following the outbreak of COVID-19, as these products provide medical or health benefits to prevent diseases and boost the overall immune system.

In Europe, the nutraceuticals market is primarily driven by anti-aging concerns among the elderly population. This market is concentrated in countries like France, Italy, Germany, the United Kingdom, and Spain[141]. Increasing pressure from European consumers and regulatory authorities is contributing to the demand for nutraceutical products. Western Europe continues to see growth in nutraceutical sales, particularly through health professional pharmacy-based distribution channels.

Moreover, factors such as rising obesity, cardiovascular diseases, and other health concerns are expected to drive the nutraceutical industry in the forecast period. As consumers become more health-conscious and seek preventive measures against diseases, the demand for nutraceutical products is expected to continue rising, contributing to the growth of the market.

Meanwhile, the encapsulation market reached $35 billion in 2021, experiencing a growth rate of 12.5% (CAGR 2021-2028)[142]. with the pharmaceuticals and nutraceuticals segment holding 66% of the market share. Moreover, the increasing popularity of hydrogels in cosmetics contributed to the market's expansion to $28.91 billion in 2023, with a growth rate of 7% (CAGR 2024-2032[143]).

#### 5.2.3.1. Pharma applications

The global protein therapeutics market witnessed substantial growth, with an estimated market size of USD 375.26 billion in 2024 and is predicted to increase from 401.97 billion in 2025 to approximately USD 741.16 billion by 2034, experiencing a CAGR of 7.04% from 2025 to 2034. The increasing cases of chronic disease and the advancements in biotechnology are driving the growth of the protein therapeutics market[144]. Therapeutic proteins constitute genetically engineered versions of naturally occurring human proteins, engineered to address deficiencies or abnormalities associated with specific diseases.

These proteins serve multiple purposes, ranging from replacing abnormal or deficient proteins to supplementing the supply of beneficial proteins, thereby mitigating the effects of diseases or medical treatments like chemotherapy. Engineered proteins can closely resemble the natural proteins they replace, or they can be enhanced through the addition of sugars or other molecules, extending their activity duration for improved therapeutic efficacy.

Therapeutic protein drugs are utilized across a wide spectrum of diseases, including cancer, metabolic disorders, immunological conditions, hematological disorders, hormonal imbalances, genetic disorders, infectious diseases, and others. Their potential to significantly enhance human health is profound, akin to the principles underlying gene therapy, wherein proteins are delivered in precise amounts to facilitate the optimal functioning of various glands and organs within the body.

The protein therapeutics market is segmented based on product type, application, and geographical region.

[140] Nutraceuticals Market Size - Industry Report on Share, Growth Trends & Forecasts Analysis (2024 - 2029). Mordor Intelligence.
[141] Nutraceuticals Market Size - Industry Report on Share, Growth Trends & Forecasts Analysis (2024 - 2029). Mordor Intelligence.
[142] Encapsulation Market Size, Share | Global Analysis by 2028. The Insight Partners.
[143] Global Hydrogel Market Report and Forecast 2025-2034. Expert Market Research.
[144] Protein Therapeutics Market Size, Share, and Trends 2025 to 2034. (2025). Precedence Research.

Regarding product classification, it encompasses monoclonal antibodies, insulin, fusion proteins, erythropoietin, interferon, human growth hormone, and follicle-stimulating hormone. These product categories represent various types of therapeutic proteins engineered to address specific medical conditions.

On one hand, the high production costs associated with the development and manufacturing of protein-based therapeutics pose a significant challenge and are anticipated to hinder the market's growth. Conversely, the substantial increase in global healthcare expenditure has fueled the expansion of the protein therapeutics market. This rise in healthcare spending reflects a growing investment in advanced medical treatments, including protein-based therapies, which is expected to drive market growth despite the associated production costs.

#### 5.2.3.2. Cosmetic application (hydrogel)

Hydrogel, a three-dimensional network of hydrophilic polymers capable of retaining large amounts of water, can be derived from either synthetic or natural polymers. These materials are responsive to external stimuli such as temperature and pH, allowing them to adapt their function and structure based on the surrounding environment.

The Hydrogel market is estimated to reach USD 24.80 billion in 2025, growing at a CAGR of 7.10% during the forecast period (2025-2030), and is expected to reach USD 34.95 billion by 2030[145].

The market caters to various end-user industries, including personal care and hygiene, pharmaceuticals, healthcare, food, agriculture, and others. Each industry utilizes hydrogels for specific purposes, ranging from skincare products to medical devices and agricultural applications.

The COVID-19 pandemic initially posed challenges to the hydrogel sector, with global lockdowns and stringent regulations leading to production shutdowns. However, since 2021, the industry has been gradually recovering and is projected to witness significant growth in the coming years.

Short-term growth drivers for the hydrogel market include increasing applications in the healthcare sector and rising adoption in agriculture. However, the market may face hindrances due to the high production costs associated with hydrogel manufacturing.

Despite these challenges, the emergence of new application areas for hydrogel and increasing awareness and adoption in the biomedical and personal care sectors present opportunities for market growth in the future.

## 5.3. By region

### 5.3.1. North America

In 2024, North America maintained a leading position in the global alternative protein ingredients market[146], accounting for approximately 40.6% of global revenue. This dominance is attributed to increasing consumer awareness of environmental sustainability ethical considerations related to animal protein consumption, a rising vegan population, and an increase in investments in alternative protein products. The demand for healthy and nutritious products is also on the rise, and there's a growing emphasis on sustainable protein production, facilitated by technological advancements in the food industry, exemplified by companies like Beyond Meat and Impossible Foods. The U.S. alternative protein ingredients industry is projected to grow at a compound annual growth rate (CAGR) of 13.5% from 2025 to 2030, driven by health and wellness trends and the growing

[145] Hydrogel Market Size & Share Analysis - Growth Trends & Forecasts (2024 - 2029). Mordor Intelligence.
[146] Yildiz, D. (2023). Global Alternative Proteins Market. Feed Additive.

popularity of plant-based diets[147].

However, the region's dense livestock population, high meat consumption, and the burgeoning pet food sector also contribute to limiting the demand for alternative proteins for feed.

#### 5.3.2. Asia Pacific

The Asia-Pacific region is poised for significant expansion in the alternative protein market, with projections indicating a CAGR of 15.4% from 2025 to 2030[148]. This surge is primarily due to increasing awareness of the benefits of protein-rich diets, advancements in food and beverage technology, a rapidly expanding economy, and abundant raw materials. Additionally, the efforts of the food & beverage industry to enhance alternative protein innovation are expected to further propel market growth in the region.

China, holding a 35.0% share of the Asia-Pacific alternative protein ingredients market in 2024, is experiencing increased demand due to its substantial population and rapid urbanization. Companies like Whole Perfect Food are investing in plant-based meat products to cater to this growing market.

##### 5.3.2.1. Singapore: A case study in innovation

Singapore has emerged as a global hotspot for alternative protein innovation. Investments in the sector surged from US$5.9 million in 2019 to US$169.8 million by 2022, reflecting the nation's commitment to food security and innovation.

The Singapore Food Agency (SFA) has approved various alternative protein products, including cultivated meats, positioning Singapore as a leader in regulatory support for novel food technologies. The government's "30 by 30" initiative aims to produce 30% of the country's nutritional needs locally by 2030, further bolstering the alternative protein sector[149].

#### 5.3.3. Europe

Europe is another major regional force in the alternative protein market[150], with an expected CAGR of 14.0% from 2025 to 2030. For similar reasons as in North America, the demand for alternative protein options from both the food and feed sectors continues to grow rapidly here. The European Commission actively supports the production of plant proteins, reviewing supply and demand to develop sustainable production methods. Germany leads the European market, accounting for 23.8% of the region's alternative protein ingredients market in 2024. This leadership is driven by changing dietary preferences, with over 13% of the German population following a vegetarian diet and approximately 2.7% adhering to a vegan lifestyle. The United Kingdom's market is projected to grow at a CAGR of 14.5% from 2025 to 2030, influenced by health awareness and environmental sustainability concerns[151]. Yet, stringent legislation in the region is considered to be an important factor causing the market to grow at a slower rate.

## 6. COMPETITIVE LANDSCAPE

### 6.1. Alternative proteins are mainly requested for FOOD applications

Alternative proteins are primarily sought after for food applications due to various factors such as health

[147] Alternative Protein Ingredients Market Trends. (2024). Grand View Research.
[148] Asia Pacific Alternative Protein Market Size & Outlook. Grand View Research.
[149] Where can Singapore take the lead in alternative proteins? (2023, Marzo 24). EDB Singapore.
[150] Alternative Protein Market Size, Share, Forecast, & Trends Analysis by Type (Plant Protein [Soy, Pea, Potato], Insect Protein [Crickets, BSF], Microbial [Algae Protein, Fungal Proteins]), Application (Food & Beverage, Alternative Proteins) - Global Forecast to 2031. (2024). Meticulous Market Research.
[151] Alternative Protein Ingredients Market Trends. (2024). Grand View Research.

concerns, environmental considerations, and ethical considerations related to animal welfare. The food industry has responded to this emerging trend by developing a wide range of products and ingredients using different sources of alternative proteins, including plant-based proteins like soy and pea, new animal sources like insects, and biotechnological innovations such as cultured meat or biomass fermentation.

However, alternative protein sources like plant-based and insect alternatives may have some disadvantages, including sensory properties and environmental impacts. The production of mycoproteins, which are proteins produced by non-yeast fungi, has been researched for nearly two decades, but their presence in the market has only recently begun to increase. In Europe, nearly 20 companies are involved in mycoprotein research[152], with only five producing them using microorganisms, mainly focused on the Fusarium fungus: Quorn Foods, Contempehrary, Tempty Foods, Enough Food (Abunda) (UK) and Promyc (SE).

Exploration of non-Fusarium species presents new opportunities for improving sensory features, nutritional composition, and scalability potential in mycoprotein production[153]. While a few companies in Europe perform biomass fermentation with yeast, yeast single-cell protein (SLF) offers advantages such as suitable bioprocess scalability and desirable protein biomass features.

Despite the potential benefits, there are not many companies in Europe performing biomass fermentation with bacteria for protein food applications. However, biomass fermentation using bacteria holds significant potential in terms of yield and efficiency, particularly in anaerobic bioprocesses).

In the formulation of cheese-like and seafood-like products, only plant-based alternative proteins have been utilized thus far. This highlights the ongoing innovation and exploration in alternative protein sources for various food applications, aiming to address consumer preferences and market demands while also addressing sustainability and environmental concerns.

### 6.2. Among the FEED applications

Efforts to ensure the long-term sustainability of the aquaculture industry have centered on replacing the primary source of protein used in fish meals. Soybean remains the most important and preferred source of high-quality alternative plant-based protein for animal feed manufacture. Other legumes such as peas, beans, and lupins, as well as traditional cereal sources like maize, rice, and wheat, also play a significant role in providing protein for animal feed.

However, there is a growing trend towards utilizing protein biomass fermentation in feed production[154]. Currently, eniferBio, based in Finland, commercializes mycoprotein ingredients in Europe for use in aquafeed and pet food, in addition to food applications. This demonstrates the evolving landscape of alternative protein sources in the feed industry, with a focus on sustainability and innovation to meet the growing demand for feed ingredients in aquaculture and other animal farming sectors.

### 6.3. Protein extracts have great potential for NON-FOOD applications

Proteins are indeed an emerging and challenging biomaterial for biomedical applications, particularly as delivery systems. One of the primary challenges in using proteins for this purpose is their tendency to become unstable

[152] Rodger G., et al. (2001). Production and properties of mycoprotein as a meat alternative. Food Technol., 55, 36-38.

[153] Souza, P., Balachandran, N., Ramkumar & Andersson, D., Lennartsson, P., Taherzadeh, M. (2018). Vegan-mycoprotein concentrate from pea-processing industry byproduct using edible filamentous fungi. Fungal Biology and Biotechnology, 5.

[154] Souza, P., Balachandran, N., Ramkumar & Andersson, D., Lennartsson, P., Taherzadeh, M. (2018). Vegan-mycoprotein concentrate from pea-processing industry byproduct using edible filamentous fungi. Fungal Biology and Biotechnology, 5.

and aggregate at excessive concentrations, which can compromise the formulation's effectiveness. To address this issue, delivery systems often require the presence of polysaccharides, which provide structure and stability to the final formulation[155]. Chitosan and Chitin, for example, have been utilized to enhance colloidal stability in protein-based delivery systems.

Similarly, in the realm of natural cosmetics, there is a growing trend towards combining bio-based ingredients with pharmaceutical techniques to create naturally derived cosmetic actives with well-defined structure, purity, and efficacy. Protein extracts, particularly those derived from microbial sources, represent a significant advancement in the development of hydrogel formulations for cosmetics. These protein extracts offer unique properties that can revolutionize the cosmetic industry by providing innovative and effective solutions for skincare and beauty products.

## 6.4 Company profiles

This section provides an overview of the key players in the alternative protein sector, leveraging data from the Good Food Institute's Alternative Protein Database[156].

This database offers a comprehensive mapping of companies involved in the development and commercialization of alternative proteins.

To better understand the landscape, the companies have been analyzed and categorized based on various criteria, including animal type, protein category, company focus and operating regions. The following visualizations illustrate the clustering of companies according to these factors, providing valuable insights into the structure and dynamics of the alternative protein industry.

- **By animal type**

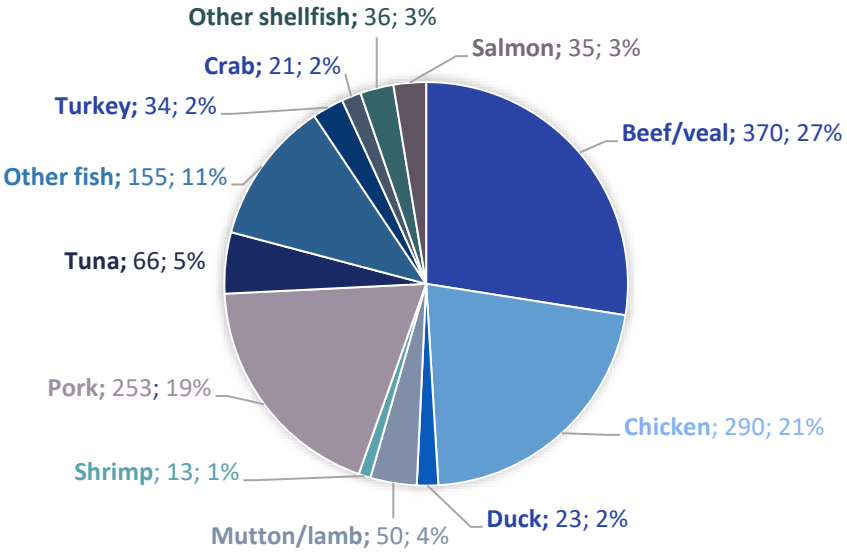



*Illustration 1 Animal type. Source: Good Food Institute's Alternative Protein Database*

The alternative protein market is highly diversified, with a strong focus on beef and chicken analogs, which together account for nearly half (48.36%) of all companies. Beef/veal substitutes lead the sector

[155] Parhi, R. (2020) Drug delivery applications of chitin and chitosan: a review. Environ. Chem. Lett., 18, 577–594.
[156] Alternative protein company database. (2025). The Good Food Institute.

with 370 companies (27.11%), followed by chicken at 290 companies (21.25%).

Pork alternatives also hold a significant share (18.53%), while seafood analogs, covering shrimp, tuna, salmon, crab, and other fish, collectively represent about 21.88% of the market. Within this segment, "other fish" and tuna substitutes are the most developed, with 155 (11.36%) and 66 (4.84%) companies, respectively.

Lamb, turkey, and other shellfish analogs remain niche, each comprising less than 4% of the total. The relatively low presence of companies focused on duck (1.68%) and shrimp (0.95%) suggests potential gaps or challenges in scaling production for these categories.

This distribution highlights the market's current priorities, with plant-based and cultivated meat companies primarily targeting widely consumed proteins like beef, chicken, and pork, while seafood and less conventional alternatives remain emerging segments.

- **By protein category**

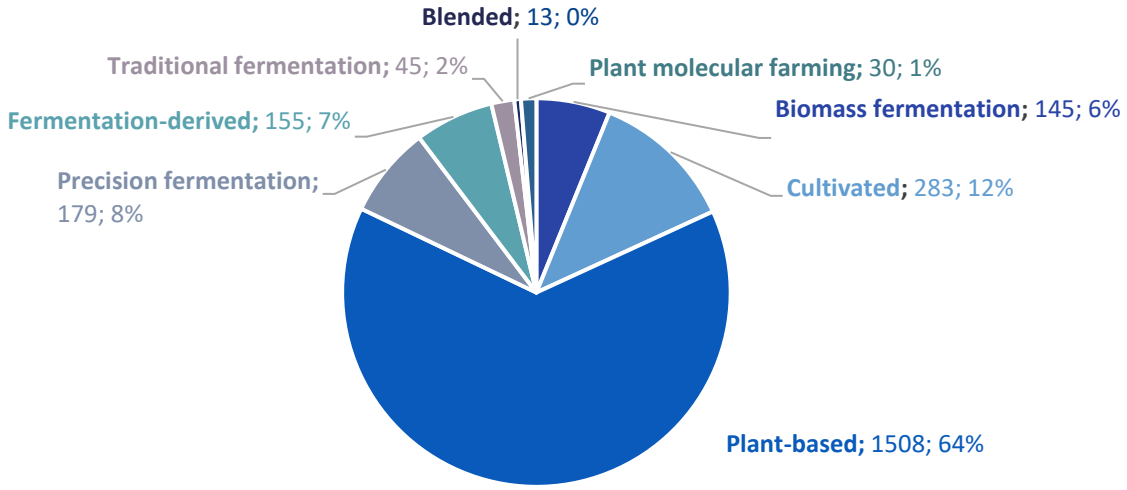



*Illustration 2 Protein category. Source: Good Food Institute's Alternative Protein Database*

The alternative protein market is dominated by plant-based products, which account for 63.95% of all companies analyzed. This reflects the strong consumer acceptance, established supply chains, and lower regulatory barriers compared to other protein production methods.

Cultivated meat represents the second-largest category, with 283 companies (12.00%), indicating growing interest and investment in lab-grown proteins despite ongoing regulatory and scaling challenges. Precision fermentation (7.59%) and fermentation-derived proteins (6.57%) are also emerging as key segments, highlighting the increasing role of microbial fermentation in alternative protein development.

Biomass fermentation (6.15%) and traditional fermentation (1.91%) remain smaller but relevant categories, while plant molecular farming (1.27%) and blended approaches (0.55%) are still niche areas.

This segmentation underscores the current industry focus on plant-based solutions while signaling the growing potential of fermentation and cultivated technologies as they advance toward commercialization.

- **By company focus**

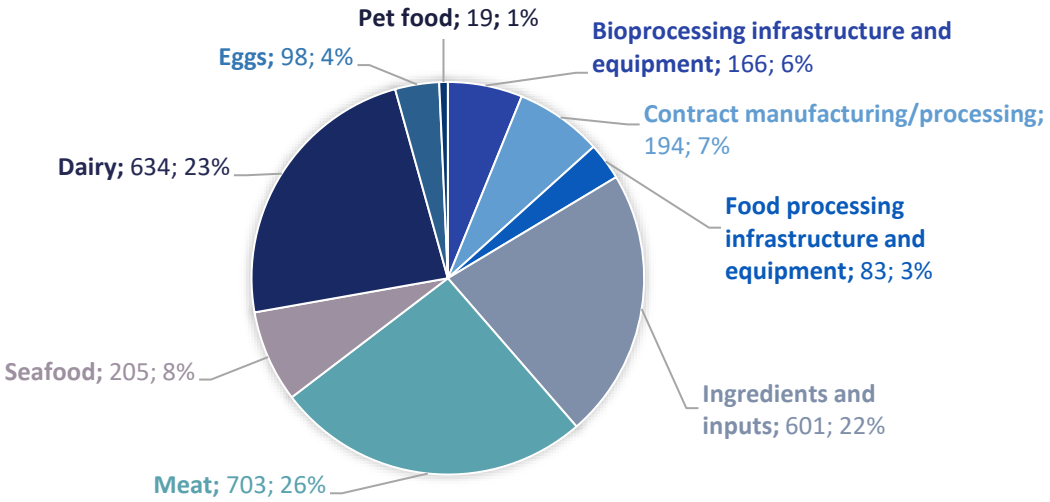



*Illustration 3 Company focus. Source: Good Food Institute's Alternative Protein Database*

The alternative protein sector is primarily driven by companies focusing on meat (26.01%) and dairy (23.46%), reflecting strong consumer demand for alternatives to traditional animal products. Ingredients and inputs (22.23%) also make up a significant portion, highlighting the importance of raw materials and functional ingredients in supporting the industry's growth.

Seafood alternatives account for 7.58%, indicating a developing but still smaller segment compared to meat and dairy. Egg substitutes (3.63%) and pet food (0.70%) remain niche markets, suggesting potential opportunities for innovation and expansion.

Beyond end-product manufacturing, bioprocessing (6.14%), contract manufacturing (7.18%), and food processing infrastructure (3.07%) play essential roles in building the industry's supply chain and production capabilities.

This segmentation highlights a well-established market for meat and dairy alternatives, while seafood and egg substitutes are still emerging. The presence of infrastructure and ingredient-focused companies suggests ongoing investment in scaling production and improving product quality.

- **By operating regions**

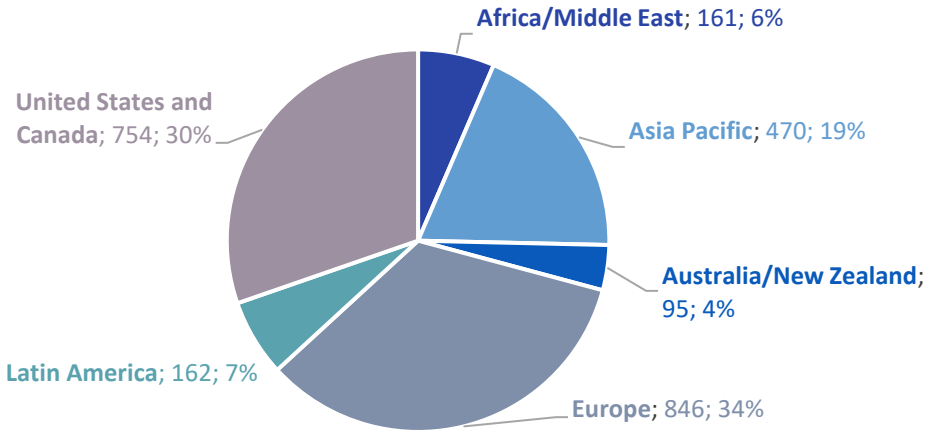



*Illustration 4 Operating regions. Source: Good Food Institute's Alternative Protein Database*

The alternative protein market is primarily concentrated in Europe (34%) and North America (30%), which together account for nearly two-thirds of all companies. This reflects strong investment, regulatory advancements, and consumer demand in these regions.

The Asia Pacific (19%) also represents a significant share, driven by increasing interest in alternative proteins due to food security concerns, sustainability efforts, and cultural shifts in dietary habits.

Other regions, such as Latin America (7%), Africa/Middle East (6%), and Australia/New Zealand (4%), have a smaller presence but are likely to grow as technology and consumer adoption expand globally.

This distribution suggests that while the industry is currently led by Western markets, there is strong potential for expansion in Asia and other emerging regions as infrastructure and regulatory support improve.

Following this analysis, a brief overview of some of the companies in the sector is presented:

### 6.4.1. QUORN FOODS (UK)

It is a pioneer in Europe. It produces Quorn by fermenting *F. venenatum* and sell meat-like and fish-like products worldwide.

Since 1985, with their brands Quorn and Cauldron, they have been providing food with protein cultivated from non-animal sources. Producer of meat-free frozen foods committed to getting more people into vegetarian and vegan meals. The company offers a range of products including mince and meatballs along with big bags variant for pieces, sausages, steak strips, crispy nuggets and Swedish-style balls, ensuring its customers with healthy meat-free food for them and the planet. Their products[157]: chilled, frozen, vegetarian, vegan and gluten free.

[157] Quorn. Products. https://www.quorn.co.uk/products

### 6.4.2. Impossible Foods Inc. (US)

Impossible Foods Inc. is a food technology company that develops plant-based substitutes for meat, dairy and fish products. It selects specific proteins and nutrients from greens, seeds and grains to recreate the experience of meats and dairy products. Founded in 2011, is headquartered in California.

The company's signature product, the Impossible Burger, was launched in July 2016 as a vegan alternative to a beef hamburger.

The company discovered that a molecule called heme is primarily responsible for the taste and aroma of cooked meal. Heme is found in both animal and plant cells, and the company uses a plant-based heme protein called leghemoglobin to give their burgers a meaty flavour[158].

### 6.4.3. ADM

Bades in the United States, ADM is a global human and animal nutrition provider. The company markets non-GM (genetically modified organism) vegetable protein ingredients in the meat alternative, protein bars, candy, pet food, pharmaceutical and animal feed sector[159].

It also offers several high-value products made from soy, such as textured flavour, soy protein concentrates and soybean lecithin.

### 6.4.4. Tempty Foods (DA)

This Danish company[160] performs SSF on starch-rich plant-based sources to generate tempeh-like food products.

Tempty is an alternative to tofu and meat made from fungi (protein from fungi's mycelium, mycoprotein), herbs and vegetables. They use mycoprotein as the main ingredient because it has good nutrition, texture, and great sustainability benefits. This mycoprotein is high in protein, fiber, vitamins, and minerals. On top of that it is more sustainable than e.g. soy in terms of the use of land and water, as well as CO2 emissions.

Tempty is estimated to produce 34x less CO2 than minced beef.

[158] Who's Leading the Alternative Proteins Industry? (2023). GreyB. https://www.greyb.com/blog/alternative-proteins-companies-and-startups/
[159] Who's Leading the Alternative Proteins Industry? (2023). GreyB. https://www.greyb.com/blog/alternative-proteins-companies-and-startups/
[160] Tempty Foods. https://www.tempty-foods.com/

### 6.4.5. Contempehrary (DA)

Contempehrary is a young Danish food company[161], with a mission to create innovative and tasty, plant-based foods. They are inspired by traditional Indonesian and Japanese fermentation methods, which they merge with local organic raw materials and innovative food technology. The focal point is organic Nordic Tempeh[162] of the highest quality, as well as products made from it.

CONTEMPEHRARY

### 6.4.6. Enough Food (Abunda) (UK)

ENOUGH produces ABUNDA® mycoprotein[163], a complete food ingredient containing all essential amino acids as well as being high in dietary fiber.

ENOUGH®
Sustainable protein

It is versatile and can be made into alternative/vegan meat, seafood, and dairy products. The company will supply ABUNDA as a B2B (business to business) food ingredient to consumer brands and retailers, addressing the need for high scale supply of healthy and sustainable protein to address a rapidly growing market.

The impact of introducing 1 million tons of ABUNDA mycoprotein by 2032 is equivalent to replacing 5 million cows, over 1 billion chickens and reducing more than 5 million tons of CO2 emissions[164].

### 6.4.7. Promyc (Mycorena) (SE)

Promyc is a fungi-based mycoprotein developed by Naplasol, a leader in sustainable protein innovation and part of the VEOS Group[165]. Designed to meet the growing demand for plant-based and hybrid foods, Promyc offers a complete amino acid profile, high fiber content, and exceptional versatility across various applications.

Mycorena was acquired by Biomass Fermentation Firm Naplasol, member of the Animal Protein VEOS Group.

Promyc®

The range includes Promyc S110, ideal for smooth textures like sauces and spreads, and Promyc L100, which replicates the texture of traditional meat for products like burgers and nuggets[166] Produced with significantly lower environmental impact than traditional proteins, Promyc is a key solution for food producers aiming to create nutritious and sustainable products. Naplasol's commitment to innovation positions Promyc as a vital ingredient in the future of eco-friendly food systems.

[161] Contempehrary. https://contempehrary.com/
[162] Contempehrary. Nordic Tempeh. https://contempehrary.com/en/nordic-tempeh
[163] Enough. https://www.enough-food.com/what-is-it
[164] Enough. Sustainbility. https://www.enough-food.com/sustainable
[165] Promyc. https://www.promyc.com/
[166] Promyc. Products. https://www.promyc.com/products

### 6.4.8. Protein Distillery GmbH (DE)

Relying on biomass fermentation, Protein Distillery has created Prew:tein[167], a clean label protein ingredient with superior functional and nutritional properties. Prew:tein can reduce or fully eliminate unwanted additives and animal-based ingredients in a large variety of food products.

They offer a vegan and non-novel food protein ingredient:

- Meat alternatives
- Egg replacement
- Baked goods
- Dairy alternatives

With their process, they separate brewer's yeast into its functional building blocks and then recompose them to meet the needs of their customers. Their processing ensures a clean and fully native protein that can be used in food products to bring all the benefits of animal-based protein functionalities, without sacrificing taste, quality, or nutritional value.

### 6.4.9. MOA (ES)

MOA is a B2B platform for healthy and sustainable ingredients obtained by food by-product's valorization through fermentation process optimized with their own artificial intelligence tool[168]. MOA combines fermentation and AI to obtain sustainable ingredients, proteins among them.

Their products are healthy and sustainable, based on single cell protein (SCP) with excellent nutritional qualities, versatility, and low environmental impact. It contains all essential amino acids, is easily digestible (0.9 PDCASS) and has no allergenic potential.

### 6.4.10. Cargill Incorporated (US)

Cargill is a global supplier of agriculture, food, financial and industrial products and services. With the help of this company's plant proteins, formulators make foods that taste and feel good to the consumer and have better nutritional profiles[169].

In 2020, the company launched a plant-based protein consumer brand in China named PlantEver that offers a

[167] Protein Distilery. Prew:tein. https://proteindistillery.com/#product
[168] MOA. https://www.moafoodtech.com/aboutus
[169] Who's Leading the Alternative Proteins Industry? (2023). GreyB. https://www.greyb.com/blog/alternative-proteins-companies-and-startups/

beef-alternative patty and a chicken-alternative nugget.

### 6.4.11. Avant Meats (HKG)

Avant, headquartered in Hong Kong, has a patent-pending unique biotechnology platform to develop animal-free fish proteins from fish cells in a cost-effective and fully traceable bioprocess. The technique enables companies to produce meat and animal proteins without raising, capturing, or slaughtering animals. Its cell cultivation technology for meat production can save natural resources for the ecosystems while assisting malnourished populations. It also reduces waste and public health hazards related to breeding animals for food.

avant

In 2022, Avant Meats partnered with QuaCell, enabling a 90% decrease in production costs. This new collaboration quickened its scale-up goals, lowering the startup's schedule for bringing its spectrum of cell-based proteins to the market[170].

### 6.4.12. BENEO GmbH (A Part of Südzucker AG) (Germany)

Beneo offers plant-based functional ingredients for food, feed and pharma that help improve the nutritional and technical properties of a wide variety of products, while maintaining or even improving taste or texture[171].

beneo
connecting nutrition and health

They offer customers the basis for new product ideas and product launches.

The Barn is an open innovation platform of the Suedzucker Group, including BENEO. As part of the Suedzucker Group, BENEO is also actively looking for new market solutions and pioneering technologies to shape the future of existing and new food concepts[172].

### 6.4.13. eniferBio (FI)

Enifer is a biotech start-up based in Espoo, Finland, founded in 2020[173]. They harness the power of fungal fermentation to upcycle agrifood industry byproducts into nutritious mycoprotein ingredients. Products[174]:

enifer®

- PEKILO® is a highly nutritious, fungi-based protein with neutral taste and color. As a versatile and sustainable source of nutrients, PEKILO® makes an ideal drop-in ingredient for aquafeed, pet food, and food production.
- PEKILO®: is a drop-in ingredient for food producers looking for a sustainable protein source with neutral taste and texture. It contains up to 55% protein, 35% fibre and has an optimal amino acid composition.
- PEKILO®Pet: Is the premium source of sustainable pet food protein, that is highly digestible and

[170] Who's Leading the Alternative Proteins Industry? (2023). GreyB. https://www.greyb.com/blog/alternative-proteins-companies-and-startups/
[171] Beneo. About us. https://www.beneo.com/about-us
[172] TheBarn. https://www.thebarn.io/
[173] Enifer. https://enifer.com/about
[174] Enifer. Products. https://enifer.com/products

palatable to both cats and dogs. It is produced from renewable raw materials using fermentation and contains 60% protein and 30% fiber, along with smaller amounts of fat, minerals and vitamins.

- PEKILO®Aqua: is the aquafeed ingredient of the future. Sustainably produced using agri- or forest industry by-products, it boasts 65% crude protein content and high levels of nucleotides and beta-glucans.

### 6.5 Other companies

- Archer-Daniels-Midland Company (U.S.)
- Axiom Foods Inc. (U.S.)
- DSM-Firmenich (Netherlands and Switzerland)
- Armstrong Cricket Farm Georgia (U.S.)
- Aspire Food Group (U.S.)
- Calysta Inc. (U.S.)
- Kerry Group plc (Ireland)
- Ingredion Incorporated (U.S.)
- AlgaeCan Biotech Ltd (Canada)
- Algatechnologies (Israel and U.S.)
- AMCO Proteins (U.S.)
- Batory Foods Chapul (U.S.)
- Cosucra Groupe (Belgium)
- Emsland Group (Germany)
- Hamlet Protein (U.S.)
- Lallemand Inc. (U.S.)
- Puris (U.S)

## 7. MARKET OPPORTUNITIES AND FUTURE TRENDS

### 7.1. Forecast of Trends

The forecast suggests that the consumption of alternative proteins will experience a significant surge, growing more than sevenfold over the next fifteen years to reach 97 million metric tons by 2035[175]. At this point, it is anticipated that alternative proteins, across the three types, will account for approximately 11% of the overall protein market. Based on an assumption of average revenues of $3 per kilogram, this translates to a substantial market size of around $290 billion[176]. This projection underscores the growing demand and adoption of

[175] Morach, B., Witte, B., Walker, D., von Koeller, E., Grosse-Holz, F., Rogg, J., Brigl, M., Dehnert, N., Obloj, P., Koktenturk, S., and Schulze, U. (2021). Food for Thought: The Protein Transformation. Boston Consulting Group.
[176] Morach, B., Witte, B., Walker, D., von Koeller, E., Grosse-Holz, F., Rogg, J., Brigl, M., Dehnert, N., Obloj, P., Koktenturk, S., Schulze, U. (2021, March

alternative proteins as consumers increasingly seek sustainable, ethical, and healthier protein sources.

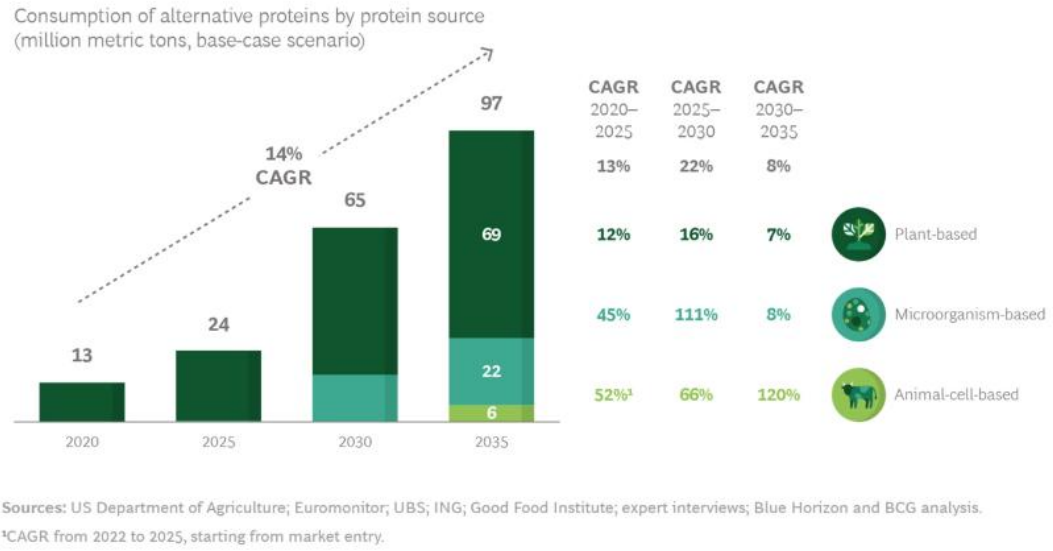



*Figure 7. Alternative Protein Consumption. Source: Boston Consulting Group.*

Achieving parity with animal proteins in taste, texture, and price is crucial for the widespread adoption of alternative proteins.:

- **Taste**. Consumers are accustomed to the distinct flavors and aromas of animal-derived proteins such as meat, seafood, dairy, and eggs. Alternative proteins must effectively mimic these sensory characteristics to appeal to consumer preferences and encourage acceptance.
- **Texture**. The texture of food plays a significant role in the overall eating experience. Alternative proteins need to replicate the fibrous structure and mouthfeel of animal proteins to provide a satisfying culinary experience. Whether it's the flakiness of fish, the stretchiness of cheese, or the creaminess of dairy, achieving similar textures is essential for consumer acceptance.
- **Price**. Cost is a significant factor influencing consumers' purchasing decisions. While alternative proteins may offer benefits such as sustainability and health, they often come with a higher price tag compared to animal proteins. To attract a broader consumer base, alternative proteins must become more competitively priced and align with or undercut the cost of animal-derived proteins.

By addressing these key areas of taste, texture, and price parity, alternative protein manufacturers can enhance consumer acceptance and drive market growth, ultimately contributing to a more sustainable and diversified food system.

The growth projections for the alternative-protein market are based on several key assumptions, including consumer acceptance, regulatory support, and technological advancements. However, changes in these factors can have a significant impact on market growth. According to alternative scenarios developed by The Boston Consulting Group, these changes are expected to have a mostly positive effect on market growth, particularly on the upside.

24). Food for Thought: The Protein Transformation. Boston Consulting Group

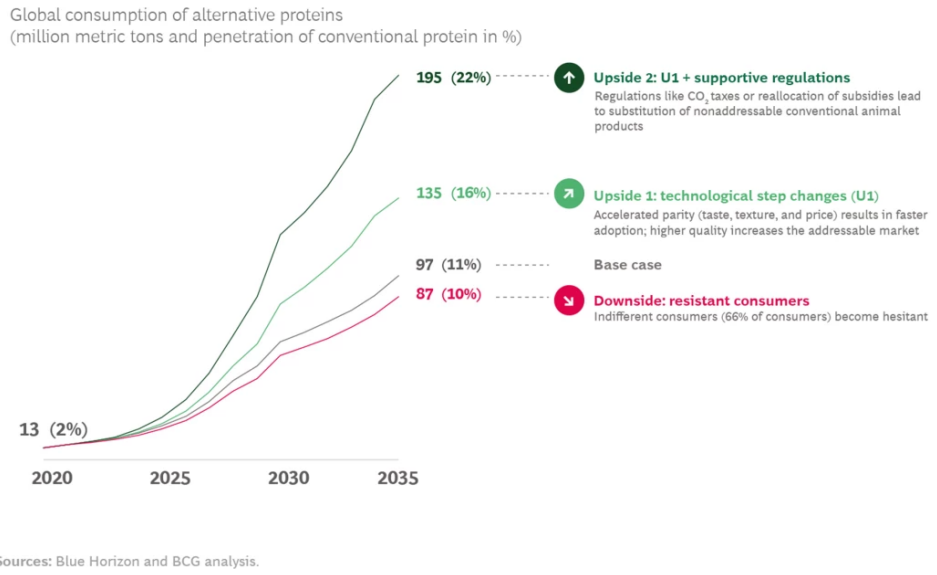



*Figure 8. Alternative Proteins. Overall protein market by 2035. Source: Blue Horizon and Boston Consulting Group.*

On Figure 8[177]:

- **Upside 1**. In this scenario, concerted efforts from scientists, startups, incumbent food companies, and investors lead to significant technological advancements in alternative protein production. These advancements result in improved product quality and a faster time to achieve parity with animal proteins. As a result, alternative proteins grow more quickly, capturing 16% of the market share by 2035.
- **Upside 2**. This scenario involves the implementation of more supportive policies and regulations, such as widespread taxation of greenhouse gas emissions and reallocation of agricultural subsidies to favor alternative proteins. These policies make alternative proteins substantially less expensive compared to conventional animal foods. With lower costs and regulatory support, alternative proteins penetrate the market more deeply, reaching 22% of the market share by 2035.
- **Downside**. Conversely, if consumers who are currently ambivalent about protein substitutes become more reluctant to try them, market growth could slow. However, this scenario only results in a marginal decrease in market penetration, with alternative proteins accounting for 10% of the market share by 2035.

### 7.1.1. Focus on Sustainability

The alternative protein market is poised to benefit from an increasing emphasis on sustainability. As consumer awareness of environmental issues continues to grow, there is a growing demand for products that offer reduced environmental impact. Both production and marketing strategies that prioritize sustainability and ethical practices are expected to gain momentum in the alternative protein market.

In terms of production, there is a shift towards more sustainable methods of sourcing and processing alternative proteins. This includes reducing reliance on resource-intensive farming practices and exploring innovative techniques such as vertical farming and fermentation. Additionally, efforts to minimize waste and

[177] Morach, B., Witte, B., Walker, D., von Koeller, E., Grosse-Holz, F., Rogg, J., Brigl, M., Dehnert, N., Obloj, P., Koktenturk, S., Schulze, U. (2021, March 24). Food for Thought: The Protein Transformation. Boston Consulting Group

optimize resource utilization throughout the production process are becoming increasingly important.

On the marketing front, companies are highlighting the sustainability credentials of their products to appeal to environmentally conscious consumers. This includes transparent labeling that communicates the environmental benefits of alternative proteins, such as reduced greenhouse gas emissions and water usage compared to traditional animal agriculture. Brands also emphasize ethical sourcing practices, such as cruelty-free production and fair labor practices, to align with consumer values.

### 7.1.2. Strategic Collaborations

Collaborations among key players, including research institutions, food companies, and government agencies, are anticipated to increase in the alternative protein market. These partnerships are expected to play a vital role in accelerating research, development, and the introduction of new products to the market.

Research institutions possess expertise in areas such as biotechnology, food science, and nutrition, making them valuable partners for companies seeking to innovate in the alternative protein space. By collaborating with research institutions, food companies can access cutting-edge research and development capabilities, as well as specialized knowledge that can help drive product innovation.

Food companies can leverage their industry experience, market insights, and distribution networks to bring alternative protein products to market effectively. Collaborations with research institutions allow them to tap into new technologies and ingredients, enabling them to develop products that meet consumer preferences for taste, texture, and nutritional value.

Government agencies can also play a crucial role in fostering collaboration and supporting the alternative protein market. They can provide funding for research and development initiatives, as well as regulatory guidance to ensure the safety and quality of alternative protein products. Additionally, government support can help create a favorable policy environment that encourages investment and innovation in the alternative protein sector.

### 7.1.3. Innovation in Packaging and Presentation

Innovation in sustainable packaging and attractive presentation is poised to play a crucial role in the alternative protein market. With modern consumers increasingly prioritizing sustainability and environmental impact, packaging solutions that minimize waste and reduce carbon footprint are becoming essential for companies operating in this space.

Sustainable packaging encompasses a range of practices aimed at reducing the environmental impact of product packaging. This includes using recyclable or biodegradable materials, minimizing packaging waste, and optimizing packaging design to reduce resource consumption and emissions throughout the product lifecycle. By adopting sustainable packaging solutions, companies can appeal to environmentally conscious consumers and differentiate their products in the market.

Attractive presentation is also important in capturing consumer attention and driving purchasing decisions. In addition to being sustainable, packaging should be visually appealing and effectively communicate the value proposition of the product. This can include eye-catching designs, clear messaging about product benefits, and engaging branding that resonates with target consumers.

By innovating in sustainable packaging and attractive presentation, companies can align with consumer preferences for environmentally friendly products while also enhancing the overall consumer experience. Additionally, investing in sustainable packaging can yield long-term benefits such as cost savings, brand loyalty, and improved brand reputation.

### 7.1.4. Product Personalization

The trend towards product personalization in the alternative protein market is expected to increase as companies seek to cater to individual consumer needs and preferences. This trend involves offering products that are tailored to specific dietary requirements, flavor preferences, and lifestyle choices, allowing consumers to customize their food options to align with their unique preferences and nutritional needs.

With an increasing number of consumers following specific diets such as vegetarian, vegan, gluten-free, or ketogenic, there is a growing demand for alternative protein products that cater to these dietary preferences. Companies can develop a range of products that meet these specific dietary requirements, providing consumers with more choices and flexibility.

Taste preferences vary widely among consumers, and offering a variety of flavor options can help attract a broader customer base. Companies can develop alternative protein products in various flavors, ranging from classic to exotic, to cater to different taste preferences and cultural preferences.

Personalized nutrition is gaining traction as consumers become more aware of the importance of nutrient intake for health and wellness. Alternative protein products can be formulated to meet specific nutritional needs, such as protein content, vitamins, minerals, and other functional ingredients.

### 7.1.5. Technological Integration

The integration of advanced technologies like biotechnology and artificial intelligence (AI) is expected to play a crucial role in enhancing the efficiency and quality of alternative protein production. These technologies offer innovative solutions to address key challenges in the production process, leading to improved productivity, sustainability, and product quality.

## 7.2. Recent developments in the alternative proteins market[178]

- In October 2024, Impossible Foods launched three new plant-based retail products aimed at providing families with convenient meal options.
- In July 2024, Lallemand (A Canadian company) invested in Livzym, a Turkish Enzyme company specializing in fungi-based enzymes, to expand the alternative from protein, and chemicals to sugar.
- In May 2024, The Good Food Institute and IKP Knowledge Park jointly introduced the latest Alternative Protein Innovation Center in India.
- In May 2024, Roquette unveiled its first protein isolate called Feva S900M, derived from fava bean in Roquette's Nartralys plant protein range.
- In April 2024, Wamame Foods (*a Canadian company known for its plant-based product*) launched the world's highest protein content called Outlier Protein. This new product is a meat alternative that is made using several ingredients.
- In April 2024, Innovafeed (*a leading company in insect protein production*) inaugurated a new Insect Innovation Center in North America. Through the launch of this center, the company aims to scale up the production and commercialization of insect protein in the US.
- In February 2024, Roquette launched a new four multi-functional pea protein, designed to enhance

[178] Alternative Protein Size & Share Report, 2035. (2024). Roots Analysis.

taste and texture in plant-based food and high-protein portfolio.

- In January 2024, ÿnsect became the first company authorized to commercialize mealworm proteins for dog food in the United States as of January 24,2024. This milestone allows them to expand in sustainable insect protein offerings into the US pet food market, meeting the rising consumer demand for eco-friendly pet nutrition[179].

## 7.3. Strategic applications for marine-based alternative proteins for Promiseang

### 7.3.1. Food applications

The global market for alternative proteins in human nutrition is expanding rapidly, driven by rising consumer demand for sustainable, nutritious, and ethically sourced protein options.

- **High-protein food products** such as meat and dairy analogues, baked goods, and plant-based seafood are increasingly popular among health-conscious and environmentally aware consumers. These products offer a healthier, lower-impact alternative to traditional animal proteins.
- **Marine-derived proteins**, including those from fish, algae, and krill, are being used in functional foods like sports nutrition products, protein-enriched snacks, and fortified beverages. These proteins are highly digestible and rich in bioactive compounds (e.g., omega-3s, antioxidants) that support muscle recovery and general health.
- **Functional ingredients** such as marine-sourced omega-3 fatty acids, collagen, and bioactive peptides are being integrated into dietary supplements and nutraceuticals due to their anti-inflammatory, cardiovascular, and joint-supporting properties.
- The growing interest in **clean-label and natural ingredients** is accelerating the adoption of marine-based proteins, valued for their nutritional benefits and minimal processing. Consumers increasingly favour transparency and traceability, pushing food manufacturers to incorporate sustainable marine ingredients.
- **Biotechnology and biomass fermentation** are key enablers of innovation, allowing high-value extraction of functional compounds from microalgae and marine byproducts.

### 7.3.2. Animal feed

The use of marine-based alternative proteins in animal nutrition is gaining momentum as the livestock, aquaculture, and pet food industries seek environmentally responsible protein solutions.

- The alternative protein market for animal feed is projected to grow from $3.96 billion in 2023 to $8.2 billion by 2033, with a CAGR of 7.5%, supported by concerns over livestock disease and the need for sustainable protein inputs.
- **Aquaculture feed**, in particular, is under transformation, with market projections reaching $80 billion by 2030. Insect, plant-based, and marine proteins are emerging as viable alternatives to fishmeal and soybean meal, both of which have high ecological footprints.
- The **European pet food sector**, valued at €55.02 billion, is expected to grow at 7.47% CAGR (2024–2029), partly driven by the popularity of high-protein, sustainable formulations. Marine proteins are

[179] Protein Alternatives Market Size, Share, and Industry Outlook (2024-2029). (2024). Markets and Markets.

favoured for their digestibility and benefits for skin, coat, and gastrointestinal health.

- Pet food producers are shifting towards **functional and traceable protein sources**, with marine-derived ingredients meeting consumer expectations for health-enhancing and environmentally sound formulations.
- The **valorisation of marine byproducts** (e.g., fish heads, bones, viscera) into high-protein feed ingredients supports EU circular economy objectives, reduces waste, and enhances the overall efficiency of marine resource use.

### 7.3.3. Non-food applications

Marine proteins are also finding robust applications in high-value non-food markets such as pharmaceuticals, dietary supplements, and cosmetics.

- The **global nutraceutical market** is projected to reach $626.02 billion by 2029 (CAGR 5.09%), driven by consumer demand for functional ingredients. Marine-derived proteins like omega-3s, collagen, and peptides are widely used in formulations targeting heart health, aging, and immunity.
- The **marine-based cosmetic ingredients market** is expanding in response to sustainable beauty trends. Collagen, seaweed extracts, and algae are featured in anti-aging and hydrating skincare formulations.
- The **protein therapeutics market** is forecasted to double from $283.64 billion in 2020 to $566.66 billion by 2030 (CAGR 7.1%), with marine proteins like chitosan and collagen used in drug delivery, tissue engineering, and regenerative medicine.
- The **encapsulation technology market**, valued at $35 billion in 2021 (CAGR 12.5% through 2028), leverages marine-derived hydrogels and polysaccharides in biomedical and cosmetic applications.
- **Marine waste valorisation**, aligned with EU circular bioeconomy policies, supports the transformation of marine side streams into high-value products. This opens new funding and regulatory opportunities and supports the development of innovative bio-based industries.

### 7.3.4. Connection of the specificities of Promiseang

The alignment between PROMISEANG's technical focus and the market opportunities identified in this report is outlined in **Deliverable 2.6: Features of marine by-products for successful biomass fermentations**. This document presents the rationale for selecting the ten biomass samples prioritised in the project.

The selection was strategically guided by market potential across food, feed, and non-food sectors, taking into account **biochemical composition**, **industrial relevance**, and **sustainability criteria**.

The identified biomasses have been cross-referenced with the market trends and application areas analysed in this report, particularly in the fields of **food innovation**, **aquaculture feed**, **pet nutrition**, and **non-food sectors** such as **nutraceuticals** and **cosmetics**.

## 8. CONCLUSION

In conclusion, the protein industry is witnessing a significant transformation driven by evolving consumer preferences, technological advancements, and growing awareness of health and sustainability. The market for alternative proteins, including plant-based, microbial, and animal cell-based options, is experiencing rapid growth, with projections indicating a substantial increase in market size and penetration by 2035.

The market segmentation analysis highlights the diverse landscape of alternative proteins, revealing ample

opportunities across various sectors, including food and beverage, pharmaceuticals, cosmetics, and animal feed. This segmentation underscores the adaptability and versatility of alternative proteins, paving the way for innovative applications and sustainable solutions to global challenges such as food security and environmental sustainability.

The emphasis on sustainability, innovation, and collaboration among key players underscores the industry's commitment to addressing global challenges such as food security, environmental sustainability, and public health. Moreover, the integration of advanced technologies, such as biotechnology and artificial intelligence, promises to enhance efficiency and quality in alternative protein production.

Overall, the protein industry presents vast opportunities for innovation, collaboration, and market expansion. By addressing consumer needs, embracing sustainability, and leveraging technological advancements, stakeholders can capitalize on the growing demand for protein-based products and contribute to a healthier, more sustainable future.