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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

D2.2

Alternative proteins market study v1

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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
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DELIVERABLE DETAILS

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Task:	2.3. Review of the market specifications for new alternative proteins
Author:	Universidade de Vigo UniversidadeVigo
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
08/03/2024	Initial version of the market study	1.0

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.

It's worth noting that this is an initial version of the market analysis, and further information will be added as the study progresses.

2. INTRODUCTION

Current world challenges are encompassed in a dichotomy: economic and technological development of societies without compromising the 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.

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[1]. 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 convert fishing into a sustainable practice.

[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 28,29,30.)

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)[2]. Plant-based and insect alternatives have some drawbacks such as organoleptic properties and land use, 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 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[3]. Lots of research has been done with agri-food industries; however, food wastes derived from marine sources have 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[4]. 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.

[2] McKinsey (2019) Alternative proteins (www.mckinsey.com/industries/agriculture/our-insights/alternative-proteins-the-race-for-market-share-is-on, Aug 2022)
[3] Tubb C., Seba T. (2021) Rethinking food and agriculture 2020–2030. Industrial Biotechnology 17:2, 57-72.
[4] 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.

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 important role in most EU countries: since 2000 there has been a constant reduction in the fish caught while aquaculture has reached 20% of the fish and shellfish supply and directly employs about 70,000 persons. Mollusks reported for 51.8 % of the EU's total aquaculture production in 2019. Mediterranean countries (France, Spain, Italy, Greece) gather the vast shellfish catch and aquaculture production within EU27[5,6]. Data on macroalgae catches and cultivation is almost nil but, within EU27, seems to be in France, Spain and Portugal.

2.1.3. 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 protein levels and digestibility[7] 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[8]. Nonetheless, macroalgae seem a very promising substrate for biomass fermentation to increase protein content. A recent study from UVIGO[9] 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.

[5] Eurostat. Database. Catches – major fishing areas (form 2000 onwards).
[6] Eurostat. Database Aquaculture production by species.
[7] Brien R.O., et al. (2022). Macroalgal Proteins: A Review. Foods 11, 571.
[8] 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.
[9] Fernandes H, et al. (2019) Bioprocessing of U. rigida to produce enzymes & improve its nutritional value as aquafeed. Bioresour. Technol. 281, 277–85

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 past five years (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[10]. Nowadays in the EU, the microorganism involved in any fermentation to generate products for human or animals must be GRAS (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

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 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

[10] Good Food Institute. (2021) State of the industry, report on fermentation: meat, seafood, eggs and dairy.

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 high 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.
- Animal **feed**.
- **Non-food** applications such as pharmaceuticals and cosmetics.

3.1. 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 $15-16.8 billion in 2022 and a growth rate projection between 9.84% and 15.6% in the following 7-13 years. A higher and more optimistic estimate defines a $25.7 billion market with a growth rate of up to 15.6%.

Table 2. Alternative protein market size and growth

Market size 2022 in billion USD	Compound annual growth rate (CAGR)	Market size projection in billion USD	Source
$15B	11%	$40B (2035)	Research Nester[11]
$15.3B	13%	$40.7B (2030)	Meticulous Market Research[12]

[11] https://www.researchnester.com/reports/alternative-protein-market/4748
[12] https://www.meticulousresearch.com/product/alternative-protein-market-4985

$15B	11.06%	$38B (2031)	InsightAce Analytic[13]
$16.8B	9.84%	$32.5B (2029)	Maximize Market Research[14]
$25.7B	15.6%	$81.9B (2030)	DataM Intelligence[15]

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.

3.2. 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.
- **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.
- **Governmental bodies**: Regulatory authorities at both national and supranational levels play a significant role in shaping policies and regulations related to food safety, labeling, and

[13] https://www.insightaceanalytic.com/report/global-alternative-proteins-market/1085
[14] https://www.maximizemarketresearch.com/market-report/global-alternative-protein-market/52719
[15] https://www.datamintelligence.com/research-report/alternative-proteins-market

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[16] underscore this trend in their comprehensive review of the alternative protein industry. Moreover, reports from reputable organizations like Market Data Forecast[17] and Mordor Intelligence[18] 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[19]. 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[20], 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

[16] Wood, P., & Tavan, M. (2022). A review of the alternative protein industry. Current Opinion in Food Science, 47, 100869.
[17] Market Data Forecast. (2021). Europe pet food market by ingredient, by animal type and by region.
[18] Mordor Intelligence. (2022). Global alternative protein market - growth, trends, COVID-19 impact, and forecasts (2022 - 2027).
[19] https://gfi.org/resource/environmental-impacts-of-alternative-proteins/
[20] https://gfi-apac.org/how-governments-are-supporting-sustainable-protein-research-in-apac/

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, SDG12 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 as 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 market grow by making these proteins more available and affordable.

4.1.4. Changes in consumer preferences

Research by Deloitte[21] and Martínez et al.[22] 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[11], 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 Americans regularly consume protein beverages.

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[11], 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[23], 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[11] 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

[21] https://www2.deloitte.com/nl/nl/pages/consumer/articles/alternative-proteins.html
[22] Martínez, D., et al. (2023). Global alternative protein market: insights and outlook. International Journal of Business Studies, 15 (2), 187-199.
[23] https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf

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[11,12,14]. Examples include Calysta (U.S.), which recently raised $39 million in a financing round for the worldwide scale-up of the production of their FeedKind protein. In 2022, InnovaFeed SAS (France) raised $250 million to increase its Black Soldier Fly (BSF) production capacity. Australia had invested $ 262.6 million in transforming South Australia into a plant-based protein manufacturing powerhouse. Three new production plants will be constructed using the investment to supply to domestic and international partners. In 2020, Canada invested $74 million in Merit Functional Foods (Canada), a provider of ingredients for plant-based foods. This investment was aimed at supporting the production of high-quality pea and canola protein.

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.

4.2.1. Costs and lack of production scale

The growth of the alternative protein market is currently being held back primarily due to two factors: high costs of production and limited production volumes. These challenges hinder the extensive adoption of alternative proteins, both in human diets and as components of animal feed. Consequently, the expansion of this market is slowed down.

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

Health concerns linked to alternative proteins, including potential allergies, are seen as a barrier to their widespread use. The long-term effects of these proteins are not fully studied. For instance, certain insects used as protein sources can cause allergic reactions, which could slow market growth. It's crucial to study these trends and ensure regulatory systems can manage potential allergy risks.

4.2.4. Regulatory Challenges

Strong regulations in certain markets pose significant challenges, affecting labeling practices, manufacturing, and marketing. Alternative protein producers should specifically address how these regulations may affect the introduction and expansion of alternative protein-based products. This is another factor that may cause the market to grow rapidly or slowly. The intensity of research and trials to be conducted by entrepreneurs on the

health and environmental impacts of alternative proteins and their verification and validation by independent organizations may accelerate the enactment of appropriate legislation.

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[18], 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.

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 2), 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[11].

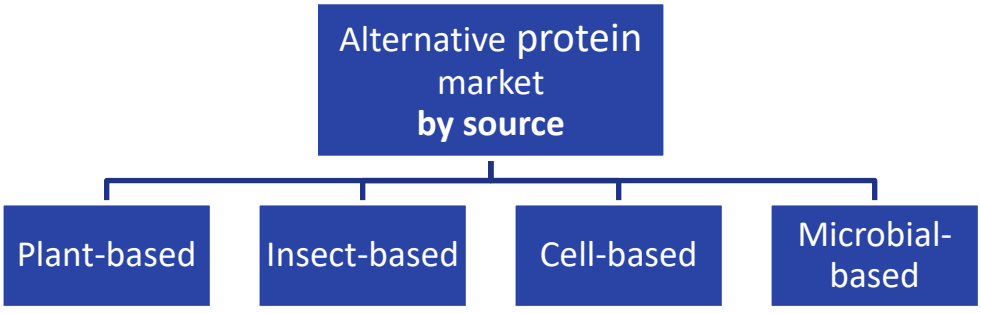


Figure 2. Alternative protein market by source

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[15] 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 2023, the plant protein segment is expected to maintain 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[12].

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 3) acquired a value of US$ 2,987 million in 2022. Changing consumer preferences towards conventional proteins will propel the market to reach a sum of US$ 4,152.2 million by 2033, garnering a CAGR of 3% during the forecast period 2023 to 2033[24].

Table 3 Soy Protein Isolate Market 2022. Source: Future Market Insights

Estimated Market Value (2022)	**US$ 2987 million**
Expected Market Value (2023)	US$ 3106 million
Projected Forecast Value (2033)	US$ 4152.2 million
Anticipated Growth Rate (2023 to 2033)	3% 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 fueled market expansion.

5.1.2. Insect-based Proteins

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[12]. This upward trajectory is further bolstered by the increasing investments 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 fueled by the escalating demand for eco-friendly, protein-rich food options and the surge in investments in edible insect farming.

[24] https://www.futuremarketinsights.com/reports/soy-protein-isolate-market

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 4) 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%[25].

Table 4 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.
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.

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[26].

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,

[25] https://www.futuremarketinsights.com/reports/insect-protein-market
[26] https://www.industryarc.com/Research/microbial-protein--market-research-800203

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 2023, the algae protein segment (Table 5) is anticipated to dominate the microbial protein market[12]. 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 5.5% during the forecast period (2023-2032)[27]. 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 utilization of chlorella in aquaculture diets.

Table 5 Algae Protein Market 2022. Source: Global Market Insights

Algae Protein Market Size (2022)	US$ 750 million
Projected Forecast Value (2032)	US$ 1.3 billion
Anticipated Growth Rate (2023 to 2032)	5.5% 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 stands as a promising avenue to address the mounting global demand for meat in a sustainable and ethical manner. It represents a burgeoning industry with substantial potential for future expansion. Nonetheless, it's crucial to recognize that the market is still nascent, beset by several challenges including regulatory approvals, consumer acceptance, and scaling production to meet global demands.

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[21]. 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 16.5% from 2028 to 2034, projecting to reach USD 1.1 billion by 2034 from an estimated $0.2 billion in 2023[28]. 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

[27] https://www.gminsights.com/industry-analysis/algae-protein-market
[28] https://www.marketsandmarkets.com/Market-Reports/cultured-meat-market-204524444.html

attractive option.

5.2. By application

Segmentation by application (Figure 3) examines how proteins derived from marine sources through microbial fermentation 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.

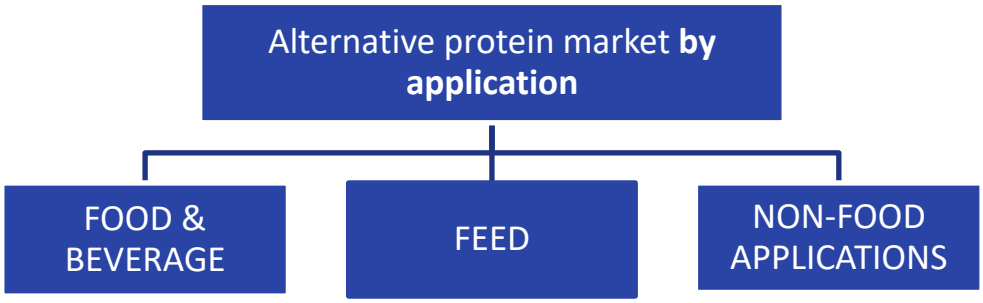


Figure 3. Alternative protein market by application

5.2.1. Food & Beverage

The food and beverage market is positioned for robust growth, with a compound annual growth rate (CAGR) exceeding 17.5% from 2023 to 2032[29]. 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 is 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 projected to hold the largest share in 2023. This segment's dominance 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[30]. 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.

[29] https://www.gminsights.com/industry-analysis/alternative-protein-market-for-food-application
[30] https://www.mordorintelligence.com/industry-reports/protein-ingredients-market2

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 in 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 6) was estimated to be valued at US$ 27.5 billion in 2022. According to Future Market Insights[31], it is expected to witness significant growth, reaching a valuation of US$ 47.4 billion by 2032, with a compound annual growth rate (CAGR) of 5.6% from 2022 to 2032.

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.

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 6 Protein ingredient market 2022. Source: Future Market Insights

Protein ingredient Market Size (2022)	US$ 27.5 billion
Projected Forecast Value (2032)	US$ 47.4 billion
Anticipated Growth Rate (2022 to 2032)	5.6% 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).

[31] https://www.futuremarketinsights.com/reports/protein-ingredient-market

5.2.1.2. Protein supplements

The Protein Supplements Market (Table 7) is estimated to be valued at USD 25.21 billion in 2023, with projections indicating a growth to USD 36.70 billion by 2028, boasting a Compound Annual Growth Rate (CAGR) of 7.80% during the forecast period (2023-2028)[32].

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.

Table 7 Protein supplement market 2022. Source: Mordor Intelligence

Protein supplement Market Size (2023)	US$ 25.21 billion
Projected Forecast Value (2028)	US$ 36.70 billion
Anticipated Growth Rate (2023 to 2028)	7.8% CAGR
Market drivers	Society are being concern 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.

[32] https://www.mordorintelligence.com/industry-reports/global-protein-supplements-market-industry

5.2.2. Feed

The global animal feed alternative protein market is forecasted to reach a value of US$ 3.96 Billion in 2023, with a projected Compound Annual Growth Rate (CAGR) of 7.5%. By 2033, alternative protein consumption is expected to surge to US$ 8.2 Billion, constituting approximately 7.5% of the global market[33].

This rise in demand for alternative proteins is 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.

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,[34] 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 €78,686.7 million in 2020, registering a CAGR of 5.6% from 2021 to 2030, this market is driven by increasing seafood consumption, growing fish farming activities, and the consumer shift towards healthy animal protein alternatives[35].

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 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)[36]. The global nutraceuticals market is expected to witness consistent growth following the outbreak of COVID-19, as these

[33] https://www.futuremarketinsights.com/reports/animal-feed-alternative-protein-market
[34] https://www.mordorintelligence.com/industry-reports/pet-food-market-in-europe-industry
[35] https://www.alliedmarketresearch.com/aquafeed-market
[36] https://www.mordorintelligence.com/industry-reports/global-nutraceuticals-market-industry

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[36]. 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)[37]. 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[38]).

5.2.3.1. Pharma applications

The global protein therapeutics market witnessed substantial growth, reaching a valuation of $283.64 billion in 2020[39]. It is projected to expand further, estimated to reach $566.66 billion by 2030, demonstrating a robust Compound Annual Growth Rate (CAGR) of 7.1% from 2021 to 2030. 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. 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,

[37] https://www.theinsightpartners.com/reports/encapsulation-market
[38] https://www.expertmarketresearch.com/reports/hydrogel-market
[39] https://www.alliedmarketresearch.com/protein-therapeutics-market

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 23.16 billion in 2024, growing at a CAGR of 7.10% during the forecast period (2024-2029), and is expected to reach USD 32.62 billion by 2029[40].

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 2023, North America is anticipated to dominate the global alternative protein market, thanks to a combination of factors[41,12]. These include a growing awareness of environmental issues, ethical considerations related to animal proteins, 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. However, the region's dense livestock population, high meat consumption, and the burgeoning pet food sector also contribute to limit the demand for alternative proteins for feed.

5.3.2. Asia Pacific

The Asia-Pacific region is projected to experience the most rapid growth in the alternative protein market from 2023 to 2030[41,12,15]. 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.

[40] https://www.mordorintelligence.com/industry-reports/hydrogel-market
[41] https://www.feedandadditive.com/global-alternative-proteins-market/

5.3.3. Europe

Europe is another major regional force in the alternative protein market[41,12]. 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. 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 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[42], 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[10]. While only three companies in Europe perform biomass fermentation with yeast: Protein Distillery GmbH (DE), SACCHA (DE) and MOA (ES), yeast single-cell protein (SLF) offers advantages such as suitable bioprocess scalability and desirable protein biomass features.

Despite the potential benefits, there is currently no company 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

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

for animal feed.

However, there is a growing trend towards utilizing protein biomass fermentation in feed production[10]. 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 a 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 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[43]. 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

6.4.1. QUORN FOODS (UK)

It is the pioneer in Europe. It produces Quorn by fermentation with *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[44]: chilled, frozen, vegetarian, vegan and gluten free.

[43] Parhi, R. (2020) Drug delivery applications of chitin and chitosan: a review. Environ Chem Lett 18, 577–594
[44] https://www.quorn.co.uk/products

6.4.2. Contempehrary (DA)

Contempehrary is a young Danish food company[45], 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 [46]of the highest quality, as well as products made from it.

CONTEMPEHRARY

6.4.3. Tempty Foods (DA)

This Danish company [47] performs SSF on starch-rich plant-based sources to generate tempeh-like food products.

TEMPTY FOODS

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 a 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.

6.4.4. Enough Food (Abunda) (UK)

ENOUGH produces ABUNDA® mycoprotein[48], a complete food ingredient containing all essential amino acids as well as being high in dietary fiber.

ENOUGH®
Sustainable protein

[45] https://contempehrary.com/
[46] https://contempehrary.com/en/nordic-tempeh
[47] https://www.tempty-foods.com/
[48] https://www.enough-food.com/what-is-it

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 a 1 billion chickens and reducing more than 5 million tons of CO2 emissions[49].

6.4.5. Mycorena (Promyc) (SE)

Since its founding in 2017, Mycorena has become one of the fastest-growing companies in the food industry and is recognized as one of the leading Foodtech start-ups in Europe.[50]

They use protein-enriched extracts from SLF on cereal-based substrates or agri-food by-products (i.e., vegetables, alcoholic beverages, pastries, confectionaries, dairy side-streams), respectively.

The flagship product Promyc[51] is a vegan mycoprotein ingredient produced through biotechnology with the fermentation process as a core. Their production process allows them to be a lot more efficient than traditional farming in terms of time, cost and feedstock, with much less environmental impact. It also enables the decentralization of food production, making it possible to produce Promyc wherever needed.

6.4.6. Protein Distillery GmbH (DE)

Relying on biomass fermentation, Protein Distillery has created Prew:tein[52], 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.

[49] https://www.enough-food.com/sustainable
[50] https://mycorena.com/about-us
[51] https://mycorena.com/promyc
[52] https://proteindistillery.com/#product

6.4.7. 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[53].

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.

6.4.8. eniferBio (FI)

Enifer is a biotech start-up based in Espoo, Finland, founded in 2020[54]. They harness the power of fungal fermentation to upcycle agrifood industry byproducts into nutritious mycoprotein ingredients.

- 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[55].
- PEKILO®: [56]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[57]: Is the premium source of sustainable pet food protein, that is highly digestible and 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[58]: 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.)

[53] https://www.moafoodtech.com/aboutus
[54] https://enifer.com/about
[55] https://enifer.com/products
[56] https://enifer.com/products/pekilo
[57] https://enifer.com/products/pekilo-pet
[58] https://enifer.com/products/pekilo-aqua

- Axiom Foods Inc. (U.S.)
- Cargill Incorporated (U.S.)
- BENEO GmbH (A Part of Südzucker AG) (Germany)
- DSM-Firmenich (Netherlands and Switzerland)
- Armstrong Cricket Farm Georgia (U.S.)
- Ÿnsect (SAS) (France)
- 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

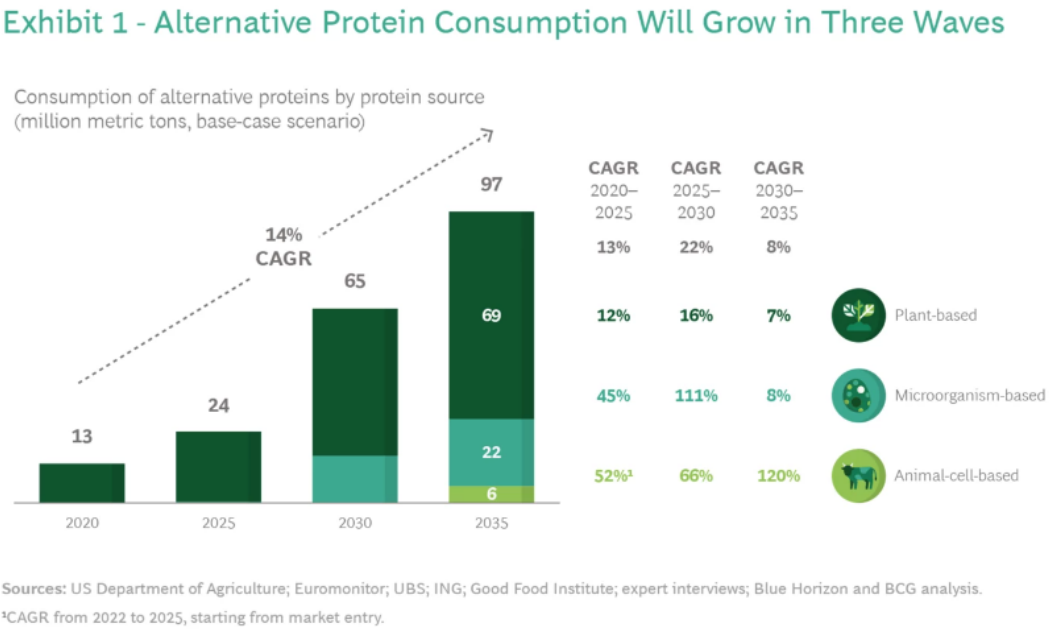
7.1. Forecast of Trends:

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[59].At this point, it is anticipated that alternative proteins, across the three types, will account for approximately 11% of the overall protein market[59].

Based on an assumption of average revenues of $3 per kilogram, this translates to a substantial market size of around $290 billion[59]. This projection underscores the growing demand and adoption of alternative proteins as consumers increasingly seek sustainable, ethical, and healthier protein sources.

[59] https://www.bcg.com/publications/2021/the-benefits-of-plant-based-meats

Figure 4 Alternative Protein Consumption. Source: Boston Consulting Group



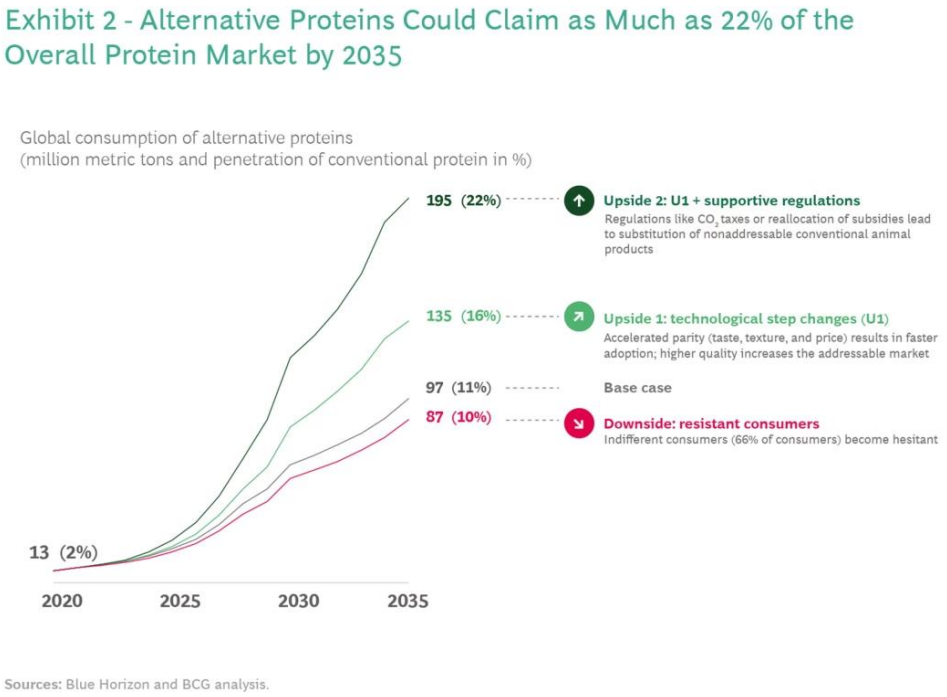
Achieving parity with animal proteins in taste, texture, and price is crucial for the widespread adoption of alternative proteins.:

- **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[59], these changes are expected to have a mostly positive effect on market growth, particularly on the upside (see Figure 4).

Figure 5 Alternative Proteins. Overall protein market by 2035. Source: Blue Horizon and Boston Consulting Group.



On Figure 5:

- **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[59].
- **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[59].
- **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[59].

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

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 are also emphasizing 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.

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.