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RECENT MARKET ANALYSIS OF PLANT PROTEIN-BASED MEAT ALTERNATIVES AND FUTURE PROSPECT

A. Samad[1], S. Kumari[1], Md J. Hossain[1], A. M. M. Nurul Alam[1], So-Hee Kim[1], Chan-Jin Kim[1], Eun-Yeong Lee[1], Young-Hwa Hwang[2*], and Seon-Tea Joo[1, 2*]

[1] Division of Applied Life Science (BK21 Four), Gyeongsang National University, Jinju 52852, Korea
[2] Institute of Agriculture and Life Science, Gyeongsang National University, Jinju 52852, Korea
*Corresponding authors: Seon-Tea Joo (Tel) +82-55-772-1943 (E-mail) stjoo@gnu.ac.kr
Young-Hwa Hwang (Tel) +82-55-772-1943 (Email) philoria@gnu.ac.kr

ABSTRACT

Food shortage is a primary challenge as the human population is increasing rapidly. Therefore, the world is looking for ways to establish sustainability in the food system to generate nutritious food with better sensory qualities. To fulfill the animal protein requirements of the world, different meat alternatives are available in the market, like cultured meat, mycoprotein, and insects, but from a sustainable point of view, plant-based meat alternatives are the most suitable. However, in producing these alternatives, industrialists need to be aware of particular challenges and opportunities in production and marketing while manufacturing. The major challenge for industrialists is the consumer acceptance rate, which depends on plant-based products' physical appearance and taste. They can improve the marketing of plant-based meat products by improving plant-based meat alternatives' physical and sensory characteristics. The focus of this paper is to discuss the technologies necessary for the production of plant-based meat alternatives. The current findings suggest that the market scenario will change for plant-based meat producers, in which customer preference and beliefs will have a massive role in the acceptance and marketing of this meat. The development of plant-based meat alternatives is the first step to achieving the goal of sustainable food; more innovations are needed to establish a healthier and sustainable food system as this type of food has a low carbon footprint compared to other products available.

Keywords: Plant-based meat, sustainability, food shortage, consumer preference, opportunities, challenges.

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INTRODUCTION

The adoption of plant-based diets is of paramount importance in promoting environmental sustainability, safeguarding human health, and ensuring the welfare of animals. However, meat consumption continues to grow and is anticipated to increase to 377 metric tons by 2031 (OECD, 2022). Three approaches can be employed to counter this increasing meat consumption. (i) The reduction in total meat consumption, i.e., decreasing the portion sizes or consuming cultured and hybrid restructured meat products (Samad *et al*., 2024) (ii) The total meat replacement is made using traditional plant- and animal-based proteins such as eggs, cheese, legumes, mushrooms, tofu, insects, and seaweed. (iii) The consumption of plant-based meat alternatives only (PBMAs) (Dagevos, 2016; Verain *et al.,* 2015). The primary target and significant consumer base for plant-based meat alternatives are undeniable flexitarians, a diverse and expansive dietary group. As the flexitarian diet involves the voluntary reduction or avoidance of meat consumption to varying degrees, the individuals following this diet actively seek and have a keen interest in meat substitutes.

The current trend in the food market is to create plant-based foods that closely resemble conventional meat. This includes replicating the taste, texture, mouthfeel, appearance, and nutritional content such as iron and vitamins. The industry uses meat-related language to name these products. The goal is to cater to the dietary preferences of flexitarians, vegetarians, and vegans who want to consume plant-based foods that imitate real meat. However, some individuals in these groups might hesitate to consume plant-based meat alternatives due to their close resemblance to meat. The extent to which consumers adopt and accept PBMAs. This review explores the primary obstacles and prospects related to the manufacturing and utilization of PBMAs products while considering the factors involved in their development. The primary focus of this review is to bring to light the PBMAs as one of the sustainable food resources. There is limited data available on the current scenario of PBMAs, so this review aims to highlight the current and future prospects for improving PBMA manufacturing technology. This review also highlights market challenges and opportunities that are necessary to understand for the betterment of PBMA marketing.

Technology for the Production of Plant-Based Meat Alternatives: Vegetable protein products, such as tofu and tempeh derived from soy and seitan, have historically served as early meat substitutes, predominantly in Asian nations (Singh *et al*., 2021). Regrettably, the current range of foods available cannot accurately mimic the sensory characteristics of meat products, which is a challenge for Western customers who desire plant-based alternatives to closely mimic meat in terms of texture, flavor, and taste. In modern meat substitutes, the crosslinking potential of soy proteins, rooted in Asian culinary heritage, has garnered attention. This phenomenon manifests under specific conditions. Currently, soy remains the primary raw material for crafting meat replacements in contemporary settings, as emphasized by Zhang *et al*. (2021). The dominance of this particular protein undeniably hinges on the accessibility of the primary substance and its technological and functional characteristics. These attributes encompass its solubility, capacity to absorb water and oil, and ability to form gels and emulsify substances. Collectively, these factors play a crucial role in determining the overall quality of the final product (Nishinari *et al.,* 2014). However, there is a growing trend in scientific study and industry to explore new alternative materials instead of soy (e.g., pea protein raw and wheat gluten) (Bakhsh *et al*., 2024). This change is driven by concerns about genetically modified organisms (GMOs), allergies, and unsuitable climatic conditions for soy agriculture, followed by the need to conserve and promote biodiversity.

New studies have used proteins derived from other sources, such as peas, fava beans, rapeseed, and hemp. These protein isolates were examined alone or with soybeans (Grossmann and Weiss, 2021). Protein isolates, irrespective of their botanical origin, are widely utilized as primary ingredients, typically with a protein level over 75% and often approaching 90% (Schutyser *et al.,* 2015). Isolates are commonly generated by wet separation methods, frequently characterized by their time-consuming nature, high costs, inefficiency, and lack of sustainability. These drawbacks typically arise from the substantial quantity utilization of water, alkalis, acids, or enzymes (Schutyser *et al.,* 2015). Standardizing the technological features of protein isolates is also tricky due to the considerable variation in protein functionality resulting from different process conditions during isolation (Grossmann and Weiss, 2021). Protein isolates are frequently substituted with protein concentrates, which typically have a protein content ranging from 50% to 65%. However, this substitution does not overlook the structural quality needed in the final product (Zahari *et al.,* 2022).

Dry separation techniques are utilized to produce high-protein fractions. This method is more environmentally friendly than wet procedures due to its lower usage of water or solvents, lower energy consumption, and ability to maintain the protein's original structure. Unlike their wet procedures, dry separation techniques do not produce protein aggregates, preserving their technological functionality (Grossmann and Weiss, 2021). The underlying premise of air classification is based on the varying densities of flour particles, which exhibit differing levels of starch or protein content. The centrifugal and gravitational forces exerted throughout the operation facilitate the segregation of the flour into two distinct fractions: a finely textured fraction abundant in protein and a coarsely textured portion abundant in starch. Hence, the protein ingredients obtained from air classification, which are less refined, may contain other constituents, such as lipids and fibers. These constituents are frequently incorporated in the formulation of products based on protein isolates (Schutyser *et al.,* 2015).

The optimization of air-classification conditions is necessary due to the potential variability in the lipid and fiber contents of protein concentrates, which can be attributed to the source and processing circumstances. There are limited instances, albeit with promising outcomes, wherein high-protein fractions derived from legumes using air separation have been employed in manufacturing meat analogs (De-Angelis *et al.,* 2020). This indicates the need for additional investigations that encompass diverse sources as well. To broaden the selection of raw materials appropriate for the manufacturing of meat substitutes while preserving the desirable attributes of the final product, a variety of colorants (such as leghemoglobin, red beets, red cabbage, etc.) and flavorings (including herbs and spices) have been suggested because preservation can improve the overall shelf life of the product (Talib *et al*., 2024). These additives aim to replicate the color and flavor characteristics of meat while also concealing any undesirable tastes associated with specific legume proteins.

The desirable sensory characteristics of meat-like products, including juiciness and softness, can be achieved by incorporating various fats and oils, such as coconut oil, butter, sunflower oil, canola oil, and sesame oil. Nevertheless, there is a growing trend in the utilization of binding agents such as oleogels, starches, hydrocolloids, or fibers as substitutes for fat (Zahari *et al.,* 2022). It is worth noting that excessive quantities of fat, functioning as a lubricant, may impede the process of protein denaturation, which is the initial step needed for proteins to acquire a texture similar to that of meat. The meat-like shape is attained by converting the inherent globular structure of pulse proteins into a fibrous structure characterized by elongated and well-organized proteins (Grossmann and Weiss, 2021). Various technologies can fabricate this structure, such as extrusion, flow-induced structuring using a shear cell or a Couette cell, 3D printing, wet-spinning, and electrospinning. (Boukid, 2021) has provided a comprehensive overview of the merits and drawbacks of each technique.

Extrusion has emerged as the predominant technology for producing meat analogs due to its notable attributes, such as high productivity, cost-effectiveness, adaptability, energy economy, and potential for scalability. The raw materials undergo hydration throughout this procedure and are exposed to heat and mechanical strains applied during extrusion. Ultimately, the resulting product is cooled to achieve ambient temperature (Wittek *et al.,* 2021).

Plant-based Meat Industry: The world's meat usage is increasing daily, as shown in Figure 1. The figure shows the enhancement of meat consumption from 2022-2030 (Shahbandeh, 2023). The rise in global protein demand, inadequate protein consumption among specific population segments, and the health and sustainability benefits associated with plant-based protein have collectively spurred the emergence of novel plant-based protein products and stimulated consumer preferences toward plant-based products and diets. In recent years, there has been a growing interest among producers and consumers in the utilization of plant proteins (Lonnie *et al.,* 2018). This trend has been observed throughout the last decade, with a noticeable evolution in the plant protein market (Springmann *et al.,* 2018). There is a growing level of governmental and consumer endorsement, as evidenced by the allocation of research program funding toward sustainable and alternative proteins (Euromonitor International, 2019).

Here is an overview of two essential consumer trends that are contributing to various attitudinal and behavioral shifts and encompassing emerging consumer interests. This review focuses on the supply side, presenting product innovations and sales information. Furthermore, we will delineate the specific matters primarily involved in policy and regulation. Consumer trends refer to the patterns and shifts in consumer behavior and preferences within a specific market or industry. Plant proteins have been referred to as "freedom foods" due to their ability to be consumed without the same environmental problems, food safety issues, and health risks associated with animal-based protein consumption.

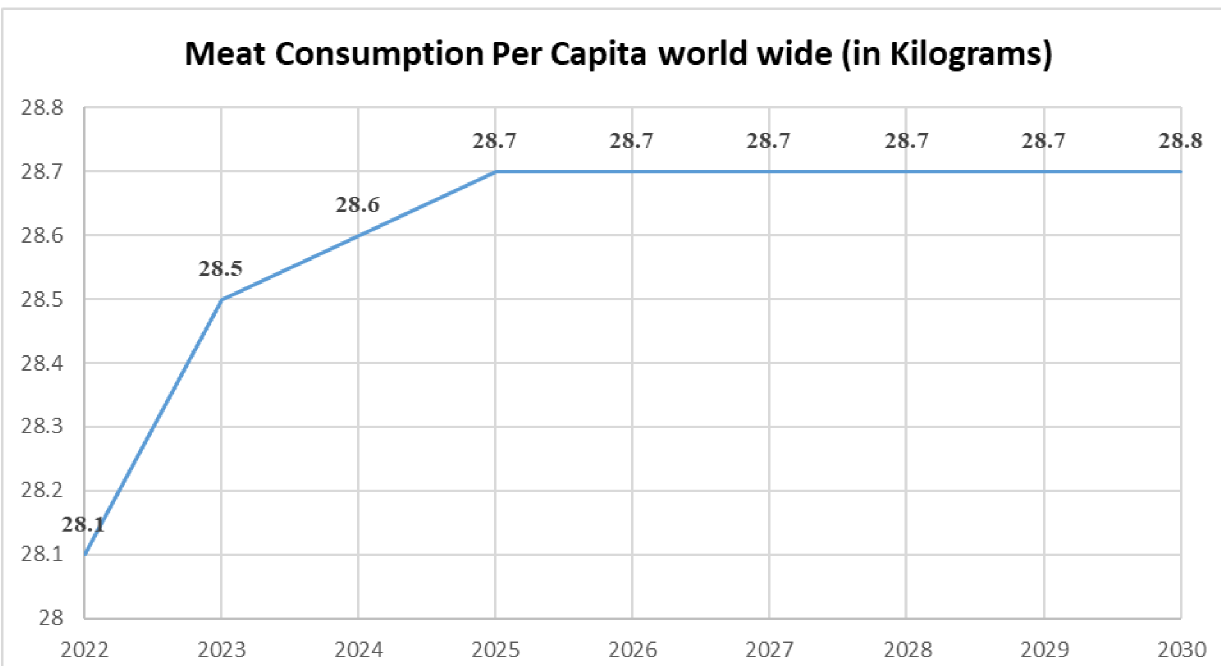

Fig. 1. Projected per capita meat consumption (2022-2032) (Shahbandeh, 2023)

The rise in the adoption of plant-based diets in recent years can be attributed, in part, to the recognition of the health-related expenses linked to the intake and excessive consumption of animal-derived protein (Landbrug and Fødevarer, 2017). Recently, there has been a discernible increase in the significance attributed to environmental and sustainability-related factors and concerns about animal welfare. This trend has been particularly pronounced among the younger demographic. Furthermore, a significant concept to consider is "clean label" foods (Noguerol *et al*., 2021). These foods lack chemical additives, feature ingredient lists that are easily comprehensible, and are manufactured using traditional methods with little processing (Edwards, 2013). Labeled foods exclusively utilize components that consumers universally accept (Ingredion, 2014).

Consumers perceive items as 'clean' based on two factors: their expected cleanliness, either assumed due to the inherent cleanliness of the product category or explicitly claimed by the producer and their observed cleanliness upon inspection, which can be influenced by the presence of any seemingly unclean substances. (Asioli *et al.,* 2017). The favorable reception of plant proteins can be attributed to consumer perception. Nevertheless, this observation also highlights a potential concern about the impression of processed plant-based commodities, such as milk and meat alternatives, if the constituents are viewed as lacking in purity

Market value of PBM and other plant-based products: The European market has witnessed a significant surge in the introduction of plant-based products over the previous several years, as reported by Euvepro in 2019. According to a report by Landbrug and Fødevarer (2017), Denmark had a twofold increase in a specific timeframe, specifically from 2011 to 2015. An example is the Danish maker of plant protein-based products, Naturli Foods. According to Food Supply DK (2018), there has been notable growth in sales and a significant acquisition of market share. According to Food Supply DK (2018), natural foods export their products to several regions, including Europe, New Zealand, Australia, and Singapore. Furthermore, the company is in the process of expanding its operations to enter the American market. This serves as a manifestation of the worldwide need for increased availability of plant-based food alternatives.

The sales of meat substitutes in Germany have experienced significant growth, positioning the country as a prominent global leader in adopting meat-free dietary choices, particularly vegan options. According to Euromonitor International (2019), the sales volume of these alternatives has risen from 14,000 tonnes in 2014 to 20 tonnes in 2018. In 2016, European enterprises accounted for 39% of the global market share in plant-based products. According to The Vegan Society (2018), Germany is recognized as a notable contributor to the production of plant-based products. The use of plant-based alternatives is increasing day by day. Figure 2 shows the usage proportion of different plant-based alternatives.

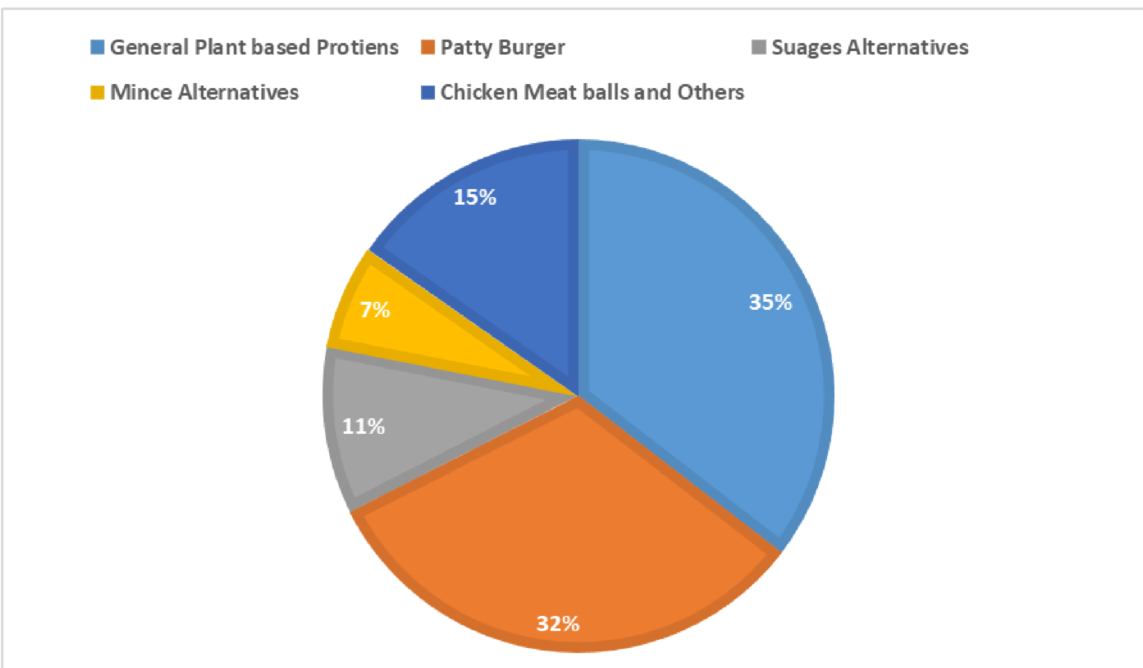

Fig. 2. : Different Plant-based Alternatives and proportion of their usage (Andreani *et al*., 2023)

Consumer Choices and Intentions Toward Plant-based Meat: The rise in demand resembles other statistical indicators demonstrating a growing inclination toward plant-based dietary patterns among the global population. The prevalence of vegetarianism and veganism is increasing in many European countries, as reported by the European Data Journalism Network (2019) and Plant Protein. According to a global consumer study conducted in 2019, which aimed to investigate the attitudes of individuals worldwide toward plant-based diets and worries over climate change, 40% of respondents indicated their active efforts to decrease their consumption of protein derived from animals. Furthermore, 10% of participants claimed complete avoidance of red meat. According to data from 2015, the prevalence of individuals adhering to vegan and vegetarian diets was estimated at 1%. The majority exhibited an upward trend in 2016; by 2017, it surpassed the 2% mark. In contrast, it is worth noting that a significant proportion of the respondents, precisely 60%, indicated that they do not encounter any limitations or constraints about the consumption of animals (Euromonitor International, 2019). According to the Vegan Society, Italy had a substantial 94.4% growth in the vegetarian demographic from 2011 to 2016.

According to The Vegan Society (2018), there was a notable rise in the proportion of individuals in Germany who predominantly adhered to a plant-based diet. Specifically, the percentage increased from 1% in 2015 to 7% in 2018. A significant proportion of Danish individuals, precisely 51% in 2017, indicated their adherence to a dietary practice wherein they abstain from consuming meat for at least one day each week. According to (Videnskab. dk, 2019), there was a reported increase in the number of individuals who claimed to have reduced their meat consumption by 30% within the past five years. The suitability of a plant-based diet cannot be universally generalized. There have been concerns over ultra-processed plant-based food products' nutritional value and health implications. However, there is currently limited empirical evidence available to support or refute the health benefits of these items. This is primarily due to their novelty and the fact that they have yet to be included in many dietary assessments. The primary contention pertains to the degree of cognitive processing and its influence on consumption behaviors.

Health-promoting plant-based diets have been found to offer protective benefits. However, it is essential to note that plant-based diets that are characterized by the consumption of convenience foods and ultra-processed foods do not appear to vary significantly from diets of animal origin in terms of their impact on health (Gomez-Donoso *et al.,* 2019; Hu *et al.,* 2019). The data presented above highlight a remarkable observation: Although the proportion of individuals identifying as vegans or vegetarians reaches a maximum of 10% of the population, there is a significantly larger section, approximately 30-40%, consisting of consumers who consider themselves flexitarians or express an interest in lowering their meat consumption. The antibiotics which are being used in animal production can be the opportunity for plant based meat to alter the real meat as some consumer will prefer to eat antibiotic free meat because antibiotics can cause resistance in human body (Samad, 2022; Atique *et al*., 2024)

Changes in Meat Sale: According to market data conducted by COOP, a Danish store, there has been a 5% decrease in fresh meat sales since 2015. This occurred after a significant surge in meat consumption between 2010 and 2015, coinciding with the rise in popularity of a paleolithic-inspired dietary pattern that emphasizes the indispensability of meat (COOP, 2019). In addition, it is worth noting that plant-based minced beef alternatives account for a mere 2% of the total sales of minced beef, as reported by Dansk Vegetar Forening in 2019. Consumers contend that the inclination toward adopting a predominantly plant-based consumption pattern is primarily attributable to the influence of global market dynamics. Given the anticipated rise in policy and consumer attention toward sustainability challenges, there is expected to be increased consumer interest in plant-based foods as a viable alternative to animal-sourced protein. This trend is likely to favor the growth of the plant-based food market (Euromonitor International, 2019).

Regulation and Policies: Policy and regulatory concerns are relevant in developing the plant-based product market and the growing customer inclination toward plant-based options. Various countries have discussed environmental considerations, including in official nutritional guidelines. The correlation between healthy eating and sustainability has been previously emphasized by the BCFN Foundation (2020) through the “double pyramid” model. Additionally, Sweden implemented corresponding changes in 2015, as reported by the FAO (2020). These policies favor plant-based diets while diminishing the significance of meat and dairy, potentially influencing consumer demand. Moreover, in alignment with global efforts to combat climate change, the climate targets set by governments and various organizations may lead to initiatives that bolster the demand for plant-based food and meat substitutes. The European Union, as highlighted by the European Commission in 2020, and numerous nations worldwide have established ambitious climate objectives. For instance, Denmark’s food and agricultural industry has pledged to achieve climate neutrality by 2050, aligning with the global goal of limiting temperature increases to below 2 degrees Celsius above preindustrial levels, as outlined in the Paris Agreement. These targets could increase livestock farming expenses or, more significantly, crop investments catering to plant-based diets. Consequently, this may lead to alterations in the supply or demand structure. For instance, if public canteens implement initiatives such as meat-free Mondays or expand their meat-free meal choices, it could further impact the demand for meat. Nevertheless, the existing policy frameworks may be biased toward promoting meat and dairy commodities.

The agricultural policy of Europe, known as the Common Agricultural Policy (CAP), has been relatively stable over several decades. In several nations, there exists a prevailing scenario where subsidies and taxes incorporate components that favor the promotion of meat and dairy foods while potentially neglecting the advancement of plant-based technologies. An example can be seen in Denmark, where a distinction is made between the taxation of cocoa drinks and cocoa milk. Specifically, cocoa milk is exempted from a specific tax imposed on chocolate, whereas plant-based cocoa drinks do not enjoy the same exemption. A producer of plant-based beverages recently had a favorable outcome in their efforts to influence politicians to alter the existing state of affairs (Aschemann-Witzel *et al*., 2021). A topic of ongoing discussion is the nomenclature of meat substitutes. Meat and dairy industry stakeholders express a vested interest in safeguarding the exclusive usage of terms such as milk, meat, sausage, burgers, and similar designations solely for animal products.

On the other hand, proponents of plant-based alternatives contend that including these terms in their product packaging is justified to inform consumers about the nature of their offerings as substitutes. The resolution of this issue in France has been inclined toward the interests of meat producers (BBC, 2018). However, it is anticipated that subsequent deliberations regarding the terminology employed for plant-based alternatives may ensue.

Challenges and Opportunities: Over the past half-decade, scholarly literature delving into consumers' preferences and constraints regarding reducing meat consumption and embracing plant-based diets has highlighted various challenges hindering enterprises aiming to promote animal protein substitutes or plant-based food products (Kumari *et al.,* 2023). However, amid these obstacles, promising opportunities warrant exploration in understanding consumer behavior and fostering positive responses. The following section offers an overview of the primary obstacles and motivators.

Challenges: The primary obstacle is to provide more convenient meatless meal options. Consumers often perceive the preparation of such meals as notably more challenging (Graca *et al.,* 2019; Malek *et al.,* 2019; Mullee, 2017; Pohjolainen *et al.,* 2015; Reipurth *et al.,* 2019) and encounter difficulties in finding readily available alternatives for meatless meals. (Clark and Bogdan, 2019; Mackenzie and Shanahan, 2018). Additional obstacles associated with the habitual nature of meat intake have been highlighted by several scholarly sources (Grac¸a *et al.,* 2019; Mackenzie and Shanahan, 2018; Malek *et al.,* 2019; Pohjolainen *et al.,* 2015; Stoll-Kleemann and Schmidt, 2017). Numerous individuals possess knowledge and experience with meat-based dishes, and a prevailing notion exists that meat is an essential element of a complete and satisfactory meal (Austgulen *et al.,* 2018; Mackenzie and Shanahan, 2018). This perception is primarily rooted in the belief that meat offers indispensable nutritional benefits (Boer *et al.,* 2017; Mullee *et al.,* 2017; Pohjolainen *et al.,* 2015; Reipurth *et al.,* 2019). However, it is noteworthy that there remains a dearth of understanding regarding the detrimental health and environmental implications linked to the intake of beef (Austgulen *et al.,* 2018; Malek *et al.,* 2019; Pohjolainen *et al.,* 2015; Stoll-Kleemann and Schmidt, 2017).

Furthermore, it is widely acknowledged that there is a prevalent negative perception of the taste of plant-based dishes (Clark and Bogdan, 2019; Grac¸a *et al.,* 2019; Malek *et al.,* 2019; Reipurth *et al.,* 2019). A study demonstrated that this phenomenon is particularly evident in the context of plant-based protein products that serve as substitutes for meat. Clark and Bogdan (2019) argue unfavorable attitudes and apprehensions regarding these substitutes' elevated sodium content and extensive processing. Additional barriers that are not well recognized include the assumption that a diet centered on meat is more cost-effective (Clark and Bogdan, 2019) and the perception that meals containing meat are more satisfying (Reipurth *et al.,* 2019). In addition to the issues above, it is essential to acknowledge that social conventions provide numerous obstacles to decreasing meat consumption. Several research studies have indicated that individuals may encounter or perceive social resistance from their peers and family members when they choose to follow a plant-based diet (Grac¸a *et al.,* 2019; Mackenzie and Shanahan, 2018).

On the other hand, it is worth noting that vegetarians and vegans face significant social pressure due to the stigmatization they encounter (Grac¸a *et al.,* 2019; Markowski and Roxburgh, 2019). However, previous research examining individuals' attitudes toward vegetarians and vegans has failed to uncover any substantiated indications of social stigma associated with these dietary choices (Judge and Wilson, 2019; Ruby *et al.,* 2016).

There are several challenges in plant-based meat product manufacturing, e.g., color, texture, and taste, and more work is still required to improve these characteristics (Tyndall *et al*., 2024). This is necessary to improve the physical and sensory characteristics of PBMAs for consumer adaptation (Kumari *et al*., 2023). Currently, the taste of PBMAs is not the same as that of original meat. So, these sensory and physical characteristics should be addressed in future studies.

Opportunities: The primary and commonly recognized factor motivating the adoption of plant-based diets is the perception that these diets are associated with improved health outcomes (Apostolidis and McLeay, 2016; Mullee *et al.,* 2017; Schenk *et al.,* 2018; Birch *et al.,* 2019;

Circus and Robison, 2019). The second most significant factors are the moral and ethical issues of environmental effects and animal welfare (Apostolidis and McLeay, 2016; Schenk, Rossel, and $ Scholz, 2018; Circus Robison, 2019). For instance, Schenk *et al*. (2018) conducted a study that revealed that ethical advantages associated with animal welfare had a limited impact on individuals' decision to abstain from consuming meat.

Apostolidis and McLeay (2016) and Mullee *et al*. (2017) have identified other factors that motivate consumers to incorporate more plant-based foods into their diets. These factors include curiosity to explore novel flavors and the intention to diversify meal options. Various demographic characteristics correlate with the propensity to abstain from meat consumption and embrace a plant-based diet. Research conducted by (Pohjolainen *et al*., 2015; Ruby *et al*., 2016; de Boer *et al*., 2017; Mullee *et al*., 2017; Mackenzie and Shanahan, 2018; Schenk *et al*., 2018; Circus and Robison, 2019; Grace *et al*., 2019; Judge and Wilson, 2019) has consistently shown that there is a greater inclination among female individuals to avoid meat consumption and instead opt for meat substitutes. Furthermore, this inclination is more pronounced among younger individuals (Pohjolainen *et al.,* 2015; Clark and Bogdan, 2019) and those with higher levels of education (Pohjolainen *et al.,* 2015).

According to Pohjolainen *et al*. (2015), individuals residing in rural areas and those with children exhibit a lower propensity to adhere to plant-based dietary patterns. Consequently, urban dwellers without children are likely to adopt plant-based eating practices.

SWOT (Strengths, Weaknesses, Opportunities, and Threats analysis) is an analytical framework that allows companies to systematically outline their internal capabilities and limitations and align them with external factors in the market environment, including prevailing conditions and trends (Kotler and Keller, 2015). Utilizing this methodology in the context of plant-based food and protein, a SWOT analysis is performed by incorporating the framework of global drivers, industry trends, market data, and pertinent consumer behavior elements. This study analyzes the food industry's existing consumer behavior drivers and barriers, explicitly focusing on their implications for food businesses. Consumers perceive plant-based food and proteins as conducive to good health and exhibiting greater environmental sustainability, constituting advantageous factors for the present business landscape. This emerging phenomenon is widely perceived as advantageous, considered novel, and offers diverse options. However, certain limitations persist in consumer perception and behavior under the present circumstances since habits, familiarity, and entrenched ideas about meat significantly hinder the widespread adoption of plant-based alternatives.

There is a perception that plant-based foods and meals are less convenient and flavorful, and there remains a dearth of understanding regarding their positive effects on health and sustainability. The macroenvironment of global trends and regulatory support shape enterprises' prospects to invest in plant-based products. There is a prevailing belief that plant-based diets possess superior health benefits and are comparatively less associated with various issues. The preference for dairy and animal-based food and diets regarding habits, tradition, familiarity, and view of what constitutes a "proper" dish or meal is evident. Plant-based diets are commonly perceived as being more ecologically sustainable and positively impacting the climate. Within certain circles, there is a prevailing idea that meat consumption is nutritionally essential and has a greater capacity for satiety. Plant-based meals are often preferred because they offer diverse nutritional options. Additionally, they are currently experiencing a surge in popularity. However, there is a common perception that plant-based foods may lack taste.

The perception exists that cooking and consuming plant-based meals is somewhat less convenient. A lack of knowledge remains regarding animal-derived food products' health and sustainability ramifications and the comparative influence of plant-based alternatives on health and sustainability. The subject matter under consideration pertains to opportunities in the food sector, where sustainability challenges have spurred heightened consumer awareness and demand, along with policy support for implementing mitigating measures. Conversely, the subject matter also relates to potential hazards or dangers. The concerns revolving around processing and components in plant-based foods, linked to the clean-label food trend, can potentially foster a negative perception.

The BRICS countries may experience a possible surge in meat demand while simultaneously witnessing the emergence of a global trend toward plant-based food consumption. This shift can enhance the export potential of knowledge, ingredients, and food products. The emergence of health-related apprehensions over plant-based diets or the possibility of consumer uncertainty on associated health hazards may contribute to a negative response toward plant-based food options. Insufficient protein intake among older people can prompt endeavors to enhance the prevailing circumstances, thereby resulting in an increased demand for protein. The quality of protein in colder climates experiences enhancement as an inadvertent consequence of climate change.

There is an opportunity to improve the taste by Nano coating to improve the taste of PBMAs (Vishvakarma *et al*., 2023), while myoglobin can also improve the color of PBMAs (Ryu *et al*., 2023), but this review suggests that further studies are required to improve these characteristics for creating more opportunities in the industry of PBMAs

Implementation: Food industry stakeholders must consider the favorable market backdrop and global macro environment while evaluating the obstacles and opportunities associated with investments in plant-based food and protein trends. Consumers who exhibit a partial reduction in meat consumption constitute a noteworthy consumer sector, and several regulatory parameters and trends support the growing popularity of plant-based diets. Nevertheless, the further transformation in consumer attitudes, perceptions, and comprehension is essential for the business's potential to expand on a broader scope. Furthermore, it is crucial to address the paradoxical nature of customers' inclination toward health and clean labeling while simultaneously harboring cynicism toward food processing. This requirement can be addressed by offering a more comprehensive range of plant-based food options catering to consumer preferences. For instance, more emphasis should be placed on ensuring that the development of meat substitutes includes using uncomplicated ingredients devoid of excessive amounts of unhealthy additives such as sugar and salt. Additionally, it is advisable to avoid incorporating components that customers may be unfamiliar with or harbor skepticism toward. PBMAs can be customized according to the needs of consumers by using restructuring technology because this technique can provide a product with a specific nutritional composition (Samad *et al*., 2024). Restructuring technology can minimize fat and sodium intake and make PBMA according to consumer demand.

Conclusion: PBMAs are sustainable food resources as they allow vegetarians to have a taste similar to the one they are meeting. This review is about plant-based meat alternatives. Which briefly explains plant-based alternatives, their product technology, and the market scenario. At the same time, this review also highlights the challenges and opportunities in PBMAs. This review concludes that sustainable food production through plant-based food (e.g., plant-based meat) is necessary to fulfill the world's food needs, which are also listed in UNO's SDGs. This review concludes that there is a need to improve the physical and sensory qualities of PBMAs by adding different functional ingredients and binders to improve the texture. This review provides an overall scenario of plant-based meat development and current issues with the PBMAs market. Further studies are required to enhance the overall quality of PBAs.

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