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Plant-Based Meat as a Low-Carbon and Biodiverse Food Solution in the Anthropocene

Baoqing Yang

Guangzhou New Channel-Zengcheng Experimental Middle School, Guangzhou, Guangdong, 510000, China
2120070810@qq.com

Abstract:

Global food systems, particularly conventional livestock production, are among the key sources of climate change, resource degradation, and loss of biodiversity, which jeopardize planetary stability in the Anthropocene. This paper will be addressing the potential of plant-based meat as a sustainable low-carbon food that can be applied to mitigate environmental pressure and to support biodiversity conservation. This research is conducted through systematic review and synthesis of the current scientific literature, contrasting data on environmental effects of plant versus animal meat production, comparing socioeconomic barriers to uptake, and comparing proposed governance strategies. Analysis confirms plant-based meat has significant climate and resource benefits, including much lower greenhouse gas emissions, negligible land and water usage, and higher resource efficiency compared with traditional meat. Besides, it decreases ecosystem pressure via deforestation reduction, habitat loss, and pollution, thus fostering biodiversity and ecological resilience. However, adoption is constrained by socioeconomic variables such as higher cost, low consumer acceptability, and low public awareness. To the study, there is a requirement for a cooperative multi-stakeholder response including enabling government policies, business technological and marketing innovations, and civil society-led education initiatives to overcome these challenges. Plant-based meat thus provides a pragmatic and disruptive path towards building a more resilient, equitable food system for the world.

Keywords: plant-based meat, anthropocene, sustainable food systems, biodiversity conservation, socioeconomic barriers

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1. Introduction

Plant-based meat is a groundbreaking development in the global food system, which is designed to mimic traditional animal-based meat products as a substitute protein source. Its primary objective is to replicate the sensory characteristics of meat, including taste, texture, and appearance, without relying on animal agriculture. Plant-based meat is primarily composed of plant proteins and, more recently, fungal proteins produced through fermentation. The plant proteins commonly used include soy, wheat, pea, and rice, which are often blended to optimize both nutritional value and functional properties [1]. Fungal proteins, produced through fermentation processes, provide a sustainable and scalable alternative to conventional plant proteins [2]. The production process involves several steps. Initially, proteins are extracted from raw plant or fungal materials. This is followed by extrusion or other structuring processes that create a fibrous texture that resembles meat. Flavorings and fats, such as coconut or canola oil, are then added to give the product the taste and juiciness of real meat [3]. These steps demonstrate the advanced technology that allows plant-based meats to closely match the sensory and nutritional properties of animal-based products. But most of the available literature tends to address the issue from the technological aspects of plant-based meat production or its potential environmental consequences in an abstract fashion. There is still an important gap in understanding how to fully assess both the climate and ecological benefits and the socio-economic challenges, as well as the regulatory frameworks needed for wider adoption. This study addresses this gap by examining how plant-based meat can become a low-carbon, biodiversity-friendly food in the Anthropocene and what strategies are needed to overcome the related challenges. For this, it uses a systematic literature review and policy analysis to bring together scientific evidence, examine existing challenges, and propose a multi-dimensional action framework. Accordingly, this study provides policymakers, industry leaders, and scholars with an overview of how plant-based meat can support food production and sustainable food systems.

2. Plant-Based Meat and Climate and Resource Benefits

Plant-based meat holds implications that reach beyond nutrition and consumer preference. Besides, it is intrinsically connected to several of the most urgent environmental challenges of the present era, including climate change, sustainability, and the stability of the Earth system. Livestock production, particularly ruminant species such as cattle, goats, and sheep, constitutes a significant contributor to global greenhouse gas emissions. Through enteric fermentation, ruminant livestock release methane, a greenhouse gas distinguished by its elevated global warming potential. Based on the Food and Agriculture Organization (FAO) of the United Nations, livestock accounts for approximately 14.5% of total global greenhouse gas emissions, with more than half of this being methane [4]. In addition, livestock production contributes to the release of carbon dioxide and nitrous oxide through land-use changes, feed crop cultivation, and manure management [5]. By replacing conventional meat with plant-based alternatives, it is possible to markedly reduce the overall greenhouse gas footprint of the food system, hence lessening the contribution of animal agriculture to global warming.

Furthermore, plant-based meat can indirectly curb emissions by reducing the need for extensive livestock supply chains, including transportation and cold storage. Besides, reduced dependence on livestock lessens the environmental burden of veterinary care, antibiotic administration, and feed crop production, reducing the total carbon emissions from the food system. In addition, plant-based meat addresses the escalating demands on land, water, and energy resulting from population growth and increased food consumption. The production of plant-based meat is far more resource-efficient than traditional livestock rearing, with lower land and water use and lower energy output [6]. This efficiency results from the direct consumption of plant proteins, which bypasses the energy losses inherent in animal digestion. Through improved resource efficiency, plant-based meat production fosters sustainable and resilient food systems while while encouraging crop diversity.

3. Plant-Based Meat and Ecological and Biodiversity Benefits

Historically, the expansion of feed crop cultivation and intensive livestock farming has resulted in substantial deforestation, habitat loss, and reductions in biodiversity. The transformation of natural landscapes into extensive cropland and grazing areas disrupts ecosystems and reduces the resilience of terrestrial and freshwater habitats. In this context, plant-based meat provides a viable alternative by

lowering the demand for livestock and their feed crops, thereby easing pressure on forests and other essential habitats [7]. By constraining agricultural land expansion, plant-based meat indirectly supports biodiversity conservation and sustains ecosystem services crucial to both humans and the environment.

In addition to mitigating habitat loss, the production of plant-based meat reduces the reliance on fertilizers and minimizes animal waste, which are major sources of soil and water pollution. Lower fertilizer application decreases nutrient runoff into waterways, while reduced manure output limits nitrogen and phosphorus loading, fostering improved soil health and aquatic ecosystem balance [8]. By reducing the demand for livestock and feed crops, plant-based meat alleviates pressures on land, forests, and freshwater systems, thus enhancing ecosystem stability and resilience. This shift helps maintain key ecological processes, like nutrient cycling and habitat connectivity, which are critical for species persistence and ecosystem functioning. These observable effects highlight the ways in which alterations in food production practices impact biodiversity conservation and the resilience of Anthropocene ecosystems.

Moreover, the conservation of natural habitats through plant-based meat production preserves key carbon sinks, such as wetlands and forests, which are essential to global climate regulation. By avoiding extensive land conversion for feed crops or grazing, plant-based meat protects biodiversity while reinforcing ecosystem functions that support climate mitigation. These ecological advantages exhibit that plant-based meat transcends its role as food, thus serving as a strategic tool to sustain biodiversity, conserve natural habitats, and strengthen ecosystem resilience in the Anthropocene.

4. Socioeconomic Challenges and Constraints Facing Plant-Based Meat

Even with the demonstrable ecological and environmental gains of plant-based meat, its extensive adoption is limited by multiple socioeconomic challenges. While the capacity to lower greenhouse gas emissions, preserve resources, and promote biodiversity is considerable, these benefits alone are inadequate to ensure widespread consumer adoption. And the identification of these barriers enables strategies that convert environmental benefits into actual consumer adoption.

Specifically, one key barrier is the elevated price of plant-based meat compared with traditional animal-based foods. The use of expensive raw materials, advanced processing technologies, and ongoing research and development contributes to a higher market price, which limits accessibility, particularly in low- and middle-income regions [9]. This economic barrier can slow the expansion of plant-based meat in global markets and restrict its role in sustainable food systems.

Meanwhile, consumer acceptance presents a major barrier. Though technological advancements have enhanced the taste, texture, and appearance of plant-based meat, some consumers continue to find it less satisfying than conventional meat [10]. The attainment of sensory parity plays a crucial role in driving habitual meat eaters toward plant-based alternatives, highlighting the importance of aligning technological improvements with consumer expectations.

In addition, public awareness and education remain limited. The prevalence of misconceptions regarding protein quality, processing methods, and food safety, combined with limited awareness of the environmental benefits of plant-based diets, constitutes a barrier to adoption [11]. Consequently, the deployment of targeted communication and educational initiatives is essential for enhancing knowledge, boosting responsible consumption, and bridging the divide between science and public action.

5. Strategies for Fostering the Growth of Plant-Based Meat

The coordination of governance to address socioeconomic challenges is essential for promoting the adoption of plant-based meat, commonly framed as a “governance triangle” involving governments, corporations, and civil society. And effective coordination of policy, technological advancements, and public participation facilitates addressing cost, acceptance, and awareness barriers, supporting large-scale adoption of plant-based meat as a sustainable dietary option.

At the governmental level, supportive policies, legislation, and fiscal incentives play a key role. For example, regulatory frameworks, such as labeling requirements implemented by the European Union (EU), enhance market transparency and protect consumer choice [12]. Economic measures, including subsidies and grants, mitigate production costs and encourage investment in plant-based meat technology [13]. By creating a favorable policy environ-

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ment, governments lower market barriers and provide the necessary conditions for industry and consumers to transition toward more sustainable food options.

At the corporate level, technological innovation and market development bridge the gap between production capabilities and consumer expectations. Innovations such as the use of heme protein by Impossible Foods or texture enhancement techniques by Beyond Meat demonstrate that advanced technological approaches are required to produce large-scale, consumer-accepted meat analogs [14]. In addition, strategic marketing efforts, such as fast-food chains offering plant-based alternatives like the Impossible Whopper, increase accessibility and normalize plant-based diets in mainstream consumption patterns [15]. Through corporate initiatives, plant-based meat is positioned to compete with conventional meat in terms of sensory quality and convenience.

At the community level, civil society actors can enhance government and corporate strategies by increasing public awareness and fostering responsible dietary behaviors. In particular, educational campaigns and outreach initiatives inform consumers about the environmental impacts of livestock production and the benefits of plant-based alternatives, helping to bridge the gap between scientific evidence and public behavior [16]. Through sectoral coordination, socioeconomic barriers can be addressed while promoting the environmental, ecological, and sustainability goals discussed earlier.

6. Conclusion

Plant-based meat is a transformative innovation for creating a climate-resilient, sustainable food system in the Anthropocene. Research shows it can significantly reduce the environmental impacts of conventional livestock by cutting greenhouse gas emissions and using land and water much more efficiently. Moreover, by reducing the need for feedstuffs and grazing land, it has the direct impact of reducing deforestation and habitat loss, supporting biodiversity preservation and improving the resilience of ecosystems. However, the study notes that socioeconomic barriers limit this potential. High costs, taste and texture differences, and low public awareness hinder wider adoption. These threats underscore that environmental benefits by themselves are insufficient to trigger a large dietary transition. In order to surmount these threats, there must be a coordinated, multi-stakeholder governance framework. Healthy diet promotion requires synergistic effort: governments must craft supportive policy contexts and fiscal tools; business must invest in technological innovation and strategic communication to improve product quality, prices, and access; and civil society must bridge the awareness gap via education and advocacy. In general, this research stresses that the successful integration of plant-based meat hinges on strategically addressing the interaction between its proven environmental potential and the multidimensional socioeconomic realities. It is more than a substitute protein; it is a realistic and necessary component of a strategic vision for building a more equitable, flexible, and low-carbon food future. With concerted action, plant-based meat can be made to play its highest possible role to determine positive climate and ecosystem directions for generations ahead.

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