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RESEARCH ARTICLE

Plant-based protein products in the news: Mind the gap between innovation and public discourses

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Data Availability Statement: This research uses data from a third-party, the LexisNexis database (LexisNexis, 2022), which is not publicly available. Particularly, through the database we accessed the online archives of the print version of the Guardian (London) and the Times (London) and the online version of the Telegraph (telegraph.co.uk) in order to compile articles relevant to plant-based diets and plant-based protein products. A detailed description of the data collection method is included in the paper. Other researchers are able to access the same data, following the same method,

Abstract

Markets for plant-based protein products are experiencing unprecedented growth. However, the extent to which the wider diffusion of plant-based protein products is beneficial to human and planetary health is still a contested issue in public discourses. The study of media frames for plant-based protein products can serve as a basis for approaches of technology assessment, which aim to inform actors involved in innovation processes of important aspects of diffusion, including controversy and unexpected risks regarding societal reactions. In this paper, we conduct a frame analysis of three U.K. broadsheet newspapers (the Telegraph, the Guardian, and the Times) between 2010–2020 to explore how media frame plant-based protein products. The results show that overall media coverage for plant-based diets has adopted a positive stance. However, there is variation in how plant-based protein products and particularly meat and dairy substitutes are portrayed. The biggest stumbling block appears to be potentially adverse health implications associated with the consumption of meat and dairy substitutes. We therefore argue that the scope of strategic choices regarding product design should also focus on the development of products more analogous to whole plant-based foods. Moreover, we argue that the long-term resilience of the plant-based protein sector will require strategies that convincingly align with policy goals for food security and broader food system sustainability.

Author summary

In this paper, we explore how media discuss plant-based diets and plant-based protein products, food products that aim to substitute livestock consumption. We analyze articles in three U.K. broadsheet newspapers (the Telegraph, the Guardian, and the Times). The results show that overall media coverage for plant-based diets has adopted a positive stance. However, there is variation in how plant-based protein products and particularly meat and dairy substitutes are portrayed. The biggest stumbling block appears to be potentially adverse health implications associated with the consumption of meat and dairy substitutes. We therefore argue that the scope of strategic choices regarding product

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design should also focus on the development of products more analogous to whole plant-based foods. Moreover, we argue that the long-term resilience of the plant-based protein sector will require strategies that convincingly align with policy goals for food security and broader food system sustainability.

1. Introduction

Achieving food system sustainability is one of the most pressing contemporary challenges. Global food production and consumption, particularly of meat and dairy products, have significantly contributed to climate change and ecosystem degradation [1,2]. At the same time, all forms of malnutrition, including obesity and the associated noncommunicable diseases, have been estimated to constitute some of the most important risk factors for the global burden of disease [3]. Consequently, the importance of diets in determining food system sustainability has become a widely recognized topic [4,5]. The recently authoritative EAT-Lancet Commission report on "healthy diets from sustainable food systems" highlighted the interlinkages between environment and human health and called for diets rich in plant-based foods and fewer animal source foods [5].

Plant-based protein innovation and the diffusion of plant-based protein products can contribute to accelerated change in consumption patterns towards plant-based diets and to wider transitions in the broader food system [6–8]. In response to concerns about health and sustainability, markets for plant-based protein products are experiencing unprecedented growth. According to research from [9], retail sales of plant-based protein products in the EU and the UK have grown by almost 10% per year between 2010 and 2020 and are expected to be able to maintain their growth. However, despite high growth rates, for the time being, meat and dairy remain the dominant protein source in Europe [9]. Therefore, the question is how to foster a broader transformation in which plant-based protein products acquire a larger market share and eventually replace a consequential share of global meat and dairy consumption, as well as capture some of the anticipated growing demand for protein [10].

In this context, media can play an important role. Media frames for emerging technologies and products, such as plant-based protein products, not only reflect broad public discourses and societal expectations but also shape them [11,12]. The study of media frames for plant-based protein products, then, can inform actors involved in innovation processes, such as technology developers, government agencies and civil society groups, of important aspects of diffusion, including controversy and unexpected risks with regard to societal reactions [13,14]. A media frame analysis can serve as a basis for approaches aiming to evaluate the broader dynamics of innovations and their trajectories [14–16]. The study of media frames can also inspire interventions that broaden technology development according to societal expectations and contribute to the embeddedness of innovations in society [16].

This is especially important in the case of plant-based protein products, which, despite the market growth noted earlier, have also been the target of critique. Indeed, whether the diffusion of plant-based protein products is beneficial to human and planetary health is still a contested issue [17,18]. First, recent advances in food science and manufacturing processes have led to an emphasis on the development of meat and dairy substitutes, plant-based products which mimic the taste and texture of livestock products [19]. However, currently, there is still uncertainty as to whether the replacement of livestock products with meat and dairy substitutes offers comparable nutritional or chronic disease reduction benefits, as with whole plant-based foods, such as legumes [20].

Hence, dominant innovation trajectories for the development of meat and dairy substitutes might contradict calls for a transition to "healthy" plant-based diets. Likewise, the environmental footprint of the various different meat and dairy substitutes, as well as their manufacturing processes and ingredients, can vary significantly [21]. Finally, adding to these critiques, there has been controversy over the legal definition of meat and dairy substitutes, which has led to a number of proposed measures that would ban substitutes from being referred to by the names of livestock products [17,18].

Previous studies have not systematically explored media frames for plant-based protein products. Scholars have investigated narratives employed by academics and industrial firms [17,18,22,23], sustainability transition dynamics in the food system [7,19], and consumer acceptance and practices [24–26]. Little is known regarding how plant-based protein products have been framed in media and what can be learned from these frames to further the development of plant-based protein products.

In this paper, we conduct a frame analysis of three U.K. broadsheet newspapers (the Telegraph, the Guardian and the Times) between 2010–2020. We identify frames for plant-based protein products to conceptualize the current broader dynamics of technological development and articulate recommendations for actors involved in plant-based protein innovation, in order to contribute to the embeddedness of innovations in society. Our research questions are formulated as follows:

Which frames can be identified in media discourses regarding plant-based diets and plant-based protein products?

What can be learned from media frames about future plant-based protein innovation?

In the following section, we briefly discuss media frames and their potential role in the development of plant-based protein innovation. We then describe the method employed for the collection and analysis of data. Subsequently, we present the results of the study. Finally, we discuss the results, and articulate recommendations for future plant-based protein innovation.

2. Media frames and plant-based protein innovation

The concept of framing originates from discourse theories, which are rooted in interpretive or social-constructivist traditions [27]. Such theories assume the existence of multiple realities and put emphasis on how language is used to socially construct those realities [27–29]. Frames in general are seen as structures through which people perceive physical and/or social phenomena and the way they communicate about them [30,31]. Hence, frames provide different socially constructed meanings to particular phenomena.

Frames in media are seen as the construction of the meaning of problems and solutions [29,31,32]. While making sense of particular issues, media take on a certain perspective against other alternatives [32]. They communicate selected meanings to problems, as well as their cause and solutions [32] This has been defined as framing "to select some aspects of a perceived reality and make them more salient in a communicating context, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described" [33]. Media frames reflect broad public and political discourses, shaped by a heterogeneous set of actors [34,35]. Because they influence perceptions, media frames significantly impact ongoing public understandings of issues, by making certain facets seem more important [12,34,36,37].

This is especially relevant in the adoption of new technologies and products, which is contingent upon societal interests and expectations [16,38]. People may reject technologies, redefine their functional purpose, customize them or assign meaning to them and thus, contribute

to a process of social appropriation [39,40]. However, there is an "asymmetry" of timing, knowledge and/or power, between actors involved in innovation processes and outsiders involved in social appropriation processes [38,41,42]. Actors aiming at technology development may foreclose certain options at a moment when knowledge regarding societal expectations is missing. This is because with increasing investments during R&D, lock-ins emerge, such as sunk investments [43]. As a result, new technologies and products may not live up to their potential in terms of becoming part of society.

Therefore, the study of media frames can inform technology developers on which issues and facets around technologies and products are highlighted in public discourses, as well as offer an indication of societal expectations and/or potential reactions. By employing insights from media frames analysis design and development processes can already comprise some kind of social evaluation, such as information on preferred forms of deployment of a technology. In general, such insights can be valuable for reflexive technology development approaches in which actors aim to navigate uncertainties regarding new technologies and products and develop interventions that potentially contribute to the embeddedness of innovations in society [14–16].

In the next section, we present the method of this paper. First, we introduce how we collected data and then, we discuss how we analyzed them to identify media frames for plant-based protein products.

3. Method

3.1 Data collection

Data from three U.K. national newspapers, the Telegraph (telegraph.co.uk), the Guardian (London), and the Times (London), were gathered. We chose to focus on one country, the UK, because demand for meat substitutes has expanded substantially in recent years. The UK market for meat and dairy substitutes has doubled in worth between 2016–2020 to $840 million each [44]. Therefore, we expect extensive media coverage regarding this development. We selected among the most widely read "broadsheet" newspapers due to their high circulation, as well as because of the popularity of their websites and frequent reproduction of articles online and in social media. Additionally, we chose three news outlets that are perceived as embodying diverse political ideologies to avoid merely exploring media frames employed from a single perspective. To study the development of public discourses over a decade (2010–2020), we accessed the online archives of the print version of the Guardian (London) and the Times (London) and the online version of the Telegraph (telegraph.co.uk) through the Lexis Nexis Database.

Terms used to identify plant-based protein products vary significantly [22]. To identify relevant material, we used a set of seven predefined keywords, including plant-based product/food, meat substitute, plant protein product, meat-free product/food, protein transition. Data were collected between 2010–2020 in order to accurately reflect the development of present-day discourses. We included both opinion pieces and reported material, such as articles found in news, environment, business, and health sections. We chose to include both articles referring to meat and dairy substitutes and articles referring to plant-based protein products that do not necessarily aim to substitute livestock products; this allowed us to more comprehensively explore relevant frames. We excluded articles focusing on products other than food, such as bioplastics, articles on cultured meat and articles featuring food and restaurant reviews, recipes, or simply mentioning plant-based protein products. The complete dataset of articles studied in this paper included 574 items (Table 1).

Table 1. Materials for the study gathered from three U.K. newspapers between 2010–2020.

Data source	Number of items included
The Telegraph	205
The Guardian (London)	234
The Times (London)	135
Total	574

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3.2 Data analysis

In this paper, we employed an inductive approach in order to identify media frames regarding plant-based protein products. We conducted a frame package analysis, which facilitates the identification of a "cluster of logical organized devices that function as an identity kit for a frame," which is also referred to as a package [29]. Thus, frame package analysis offers a heuristic tool of variables, framing devices, and reasoning devices that indicate the presence of a frame [31,45].

Building on [29–31], first, we focused on exploring *reasoning devices* that reveal the argumentation of the articles. We studied each article to identify problem definitions, proposed solutions and non-solutions, as well as concepts that were deemed not possible, not desirable, or both. We explored the broader premises upon which each article proposed "to act" (e.g., environmental sustainability, health, animal welfare) and whether research items were characterized by an overall positive, negative, or ambivalent tone toward the transitions to plant-based diets and plant-based protein products. Moreover, in line with [30], we identified *framing devices*, key concepts, and phrases used repeatedly, as well as metaphors used to support arguments, to better identify linguistic elements that indicated the presence of a frame. After the classification of reasoning and framing devices, we investigated the dataset in order to identify patterns that signified frames. We developed an initial code-book of 13 frames. Afterwards, we studied each article again in order to determine which frame it employed. A single article could have involved more than one frame. Finally, we evaluated the initial frames and arrived at 15 individual frames (a detailed description of all frames can be found in the results section).

To facilitate the analysis and presentation of results, we grouped frames under the three broader scientific discourses around plant-based protein products: 1. Health, 2. Environmental sustainability, and 3. Innovation trajectories. First, regarding health, studies explore whether and how plant-based protein products can mitigate the prevalence of certain chronic diseases and potential public health risks associated with the (over-) consumption of meat [20,46,47,48]. Second, research focusing on meeting the rising global demand for livestock products with minimal environmental impacts, often exploring the development and diffusion of plant-based protein products as more efficient alternatives to livestock products [24,46,49,50,51]. Third, more recently, scholars explore current innovation trajectories in plant-based protein products as well as debated their broader economic and social implications [52,53].

Inductive qualitative frame analysis inevitably requires interpretations by the researcher, which might be interfered with by the researcher's own mental constructs. To limit such interference, the researcher scanned and compared the data multiple times [54]. The frame package analysis approach benefits the reliability of results because it offers a heuristic to analyze data systematically. Additionally, an independent researcher analyzed 25 research items. Differences in interpretations were evaluated and resolved through the formulation of additional coding instructions. A limited number of research items was used to illustrate the results of

this research. Each item was given a specific reference code (i.e., #1). S1 Table lists the reference codes for illustrative research items.

The next section starts by briefly presenting the overall media coverage for plant-based protein products from the Telegraph, the Guardian (London), and the Times (London) between 2010–2020. It continues by describing the frames identified for plant-based protein products with regard to: health, environmental sustainability, and innovation trajectories. The discussion follows in the subsequent section.

4. Results

4.1 News coverage for plant-based protein products

Media attention for plant-based protein products increased during 2010–2020 (Fig 1). The majority (79%) of articles included in this study were published between 2017–2020, reflecting the recent interest on topics relevant to plant-based food. More than half (64%) of the articles studied referred to meat and dairy substitutes, products which mimic the taste and texture of meat and dairy products. The rest of the articles referred to plant-based diets or plant-based products that do not necessarily aim to substitute meat and dairy products, such as legumes and nuts. Media coverage towards the transition to plant-based diets was mostly positive (Fig 2). From the articles studied, 71% were characterized by a positive tone, 14% were neutral, and only 10% were characterized by a negative tone. However, 5% of the articles, while supporting the transition to plant-based diets in general, explicitly cautioned against the consumption of meat and dairy substitutes, mostly due to health reasons.

Most articles included health (44%) and/or environmental sustainability-related arguments (39%) when discussing the need for a transition to plant-based diets and/or plant-based protein products. The argumentation of several articles (28%) was based on the unprecedented, soaring demand for meat and dairy substitutes. A few articles discussed arguments regarding animal welfare, cost and accessibility of food products, the rising demand for meat, and truthful labeling. Finally, other arguments were related to business and investment, farmers' livelihoods, and issues of broader ethics.

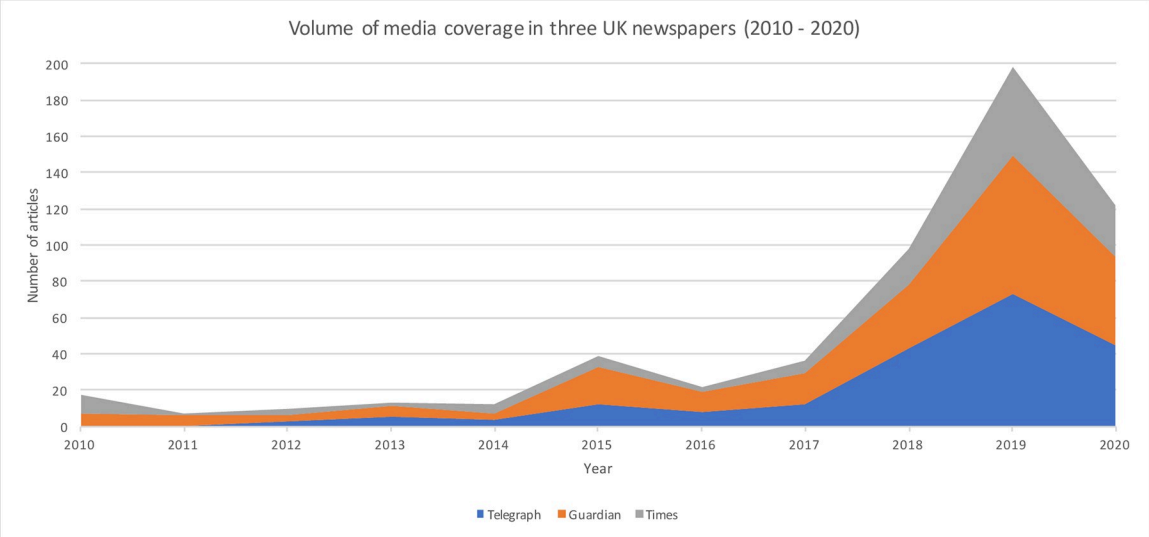

Fig 1. Number of articles about plant-based protein products in the Telegraph, the Guardian (London), and the Times (London) between 2010–2020.

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We identified 13 different frames for plant-based protein products. One article could include more than one frame. We continue by discussing the individual frames in detail under the three broad themes of heath, environmental sustainability and innovation trajectories.

4.2 Health

We identified 5 different frames about the broader theme of health. Overall, frames under the theme of health identified problems regarding maintaining a healthy diet for individual and/or public health. However, each frame adopted a different reasoning and proposed different solutions ranging from discouraging to promoting the consumption of livestock products. Table 2 describes each health-related frame according to the identified proposed problem definitions and solutions. The relative share of each individual frame in the health theme is illustrated in Fig 3 and discussed in detail below.

The largest part (62%) of the newspaper coverage with regard to health focused on the potentially positive impact of (mainly) plant-based diets on public and individual health. As part of this frame, articles mainly presented scientific studies that examined various alleged health benefits of plant-based diets or research results on adverse health impacts of meat and dairy overconsumption. Thus, these articles adopted a positive stance toward the transition to plant-based diets and commonly suggested that individuals limit consumption of livestock products. Often these articles emphasized the importance of choosing a healthy, balanced diet, including "whole" and "unprocessed" plant-based protein foods.

However, many articles (30%) adopted a frame which included arguments from a health perspective but did not discuss environmental sustainability and explicitly criticized the nutritional value of popular meat and dairy substitutes. For example, one article [#1] elaborates on the health benefits of vegetarian and vegan diets, employing the following quotes of experts to caution against the consumption of processed substitutes: "*A well-planned vegan or vegetarian diet that includes plenty of whole plant foods (in contrast to processed vegetarian foods) is likely*

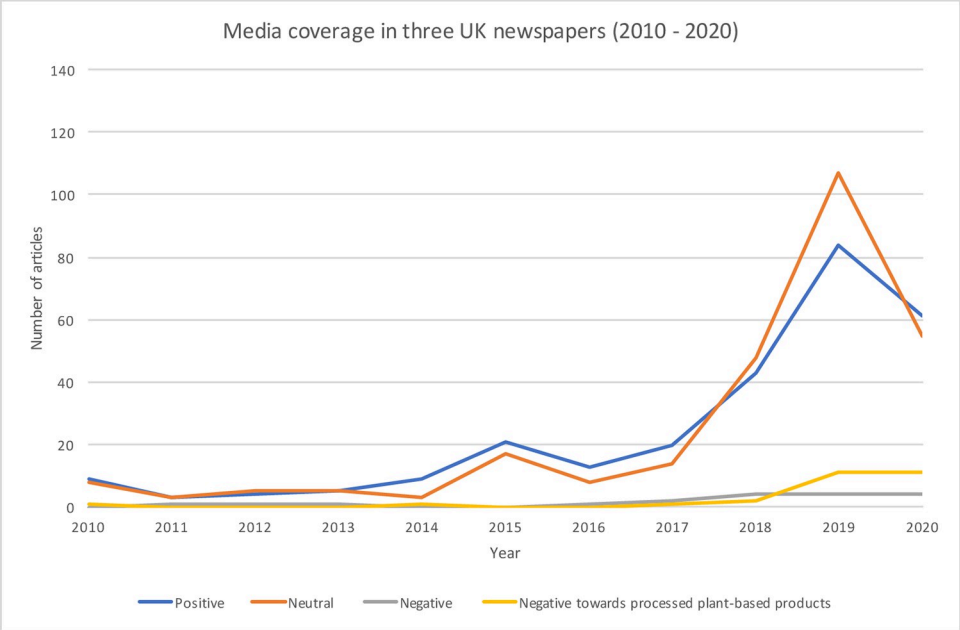

Fig 2. Analysis of articles about plant-based protein products in the Telegraph, the Guardian (London), and the Times (London) between 2010–2020.

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Table 2. Frames for plant-based protein products regarding health.

Frame	Problem definition	Possible solutions
Plant-based diets are healthier	Adverse impacts of meat and dairy overconsumption for public and personal health/ Positive impact of (mainly) plant-based diets on public and personal health / Increase global consumption of meat and dairy as a health risk/ Food safety risks (e.g. outbreak caused from zoonotic transmission)	Limited consumption of livestock products/ Promotion of plant-based diets through hard and soft regulation
Meat and dairy substitutes vs whole plant-based foods	Adverse impacts of meat and dairy overconsumption for public and personal health/ Positive impact of (mainly) plant-based diets on public and personal health/ Nutritional value of highly processed meat and dairy substitutes	Maintenance of healthy, balanced diet, including "whole" and "unprocessed" plant-based protein foods/ Removing processed meat and dairy substitutes from diet
Meat and dairy are also important in a healthy diet	Prevention of nutrient deficiencies caused by vegetarian/vegan diets	Acknowledgement of the nutritional value of livestock products in public discourses/ Credible information from experts to maintain a balanced diet
The quality of the dietary intake of vulnerable individuals and populations must be safeguarded	Food security/Undernourishment in low-income countries/ Cost of plant-based products	Safeguarding of the dietary intake of people in low-income countries/ low-income population groups in high income countries
Save money with plant-based diets	Cost of maintaining a healthy diet/ Adverse impacts of meat and dairy overconsumption for public and personal health/ Positive impact of (mainly) plant-based diets on public and personal health	Limited or no consumption of livestock products

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to be lower in saturated fat" and *"Those opting for a plant-based lifestyle should also steer clear of unhealthy, greasy foods that are marketed as healthy."* Therefore, these articles were also characterized by an overall negative tone toward the consumption of meat and dairy substitutes.

A few articles (25%) stressed that meat and dairy products have important nutritional benefits or that unbalanced plant-based diets can lead to adverse health impacts, such as nutrient deficiencies. For example, one article [#2], entitled "*Vegans could be lacking crucial nutrient for brain health, warns expert,"* reported on research regarding a nutrient commonly found in meat and dairy products and included a scientist's call for attention to potential nutrient

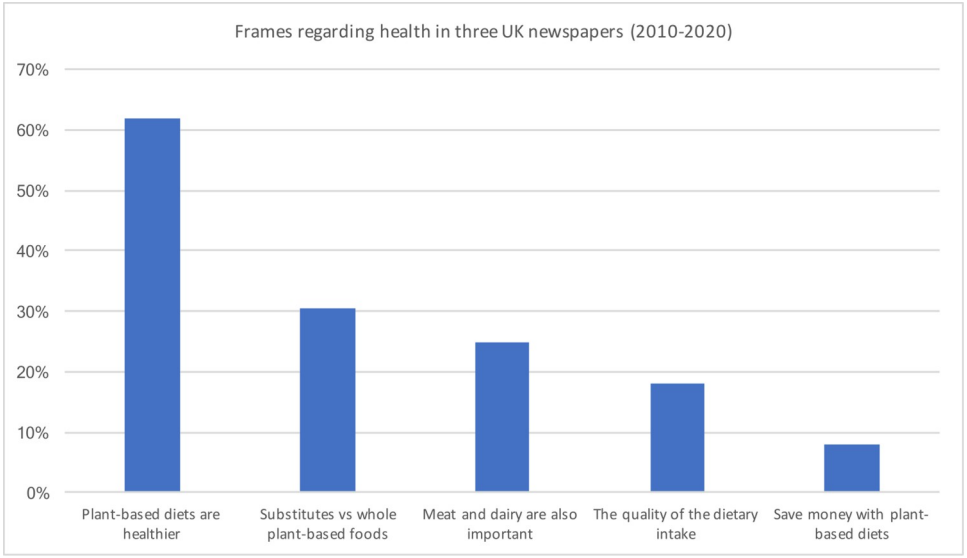

Fig 3. Frames for plant-based protein products regarding health from the Telegraph, the Guardian (London), and the Times (London) between 2010–2020.

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deficiencies because of the popularity of plant-based diets. In one quote, the expert argues: *"This is now more important than ever given that accelerated food trends toward plant-based diets/veganism could have further ramifications."* A few of these articles were produced as a response to high-impact policy reports supporting plant-based diets or discussed the viewpoint of the meat and dairy industries' interest groups. For example, one article [#3] reported the following opinion from an expert: *"Meat and dairy have known health benefits, and consumption of animal-based food during early life has been linked with lower levels of malnutrition and improved health outcomes. . .High-profile movements such as EAT-Lancet and Veganuary gain widespread press coverage, yet the fact that the World Health Organization rejected the EAT-Lancet recommendations was largely unreported*."

Another frame under the theme of health, found in 18% of articles studied, discussed the quality of dietary intake of people in middle- and low-income countries, or of vulnerable individuals and population groups in high-income countries. For example, [#4] discussed a letter from experts urging governments around the world to introduce "peak meat by 2030," a peak in livestock production, as a climate change mitigation option. In regard to health, the article includes the following quote: *"But the transition will need to be managed fairly. . . In poor countries, where over 800 million people are still undernourished, priorities obviously differ."* A similar argument with a more negative undertone is found in [#5]: "*The war on meat has begun, and there are many reasons to join the resistance."* This article argues against calls to urgently reduce the consumption of livestock products and claims: *"Throughout the developing world, when people get access to dairy products and meat, their stature and IQ tend to shoot up. Denying this opportunity to the many people who are vegetarians through poverty rather than choice would be grotesque. The United Nations posturing about meat abstinence sounds like 'let them eat cake.'"*

Articles in regard to the quality of dietary intake of vulnerable individuals and population groups in high-income countries criticized the high price of healthy food products, including plant-based protein products. For example, the article [#6] *"A meat tax need not to hit the poor"* argued: "*The revenue from such a tax [referring to a future tax on meat products] could be used to make nutritious plant-based food more affordable. To the extent that higher prices might still be necessary, welfare and wages will need to increase. We need a food system where the price of food reflects the true cost of production, and an economic system where everyone can afford a healthy diet."* Similarly, the article [#7] *"The shock of redundancy: 'Food is a massive issue'"* explored the viewpoint of a low-income British family that could not afford to purchase food products they perceive as healthy, such as the popular meat substitute "Quorn," and relied on cheaper livestock products instead.

Finally, opposing the aforementioned frame, 8% of articles employed a frame which discussed the cost of diets and proposed adopting a (mainly) plant-based diet as a cost-saving measure. For example, [#8] argues that "However, this research proves there is actually a lot of money that could be saved by making a veggie or vegan commitment. I believe in showing people how to make delicious, affordable food, and meat-free options are just the same; it doesn't need to be expensive or fancy to be satisfying and tasty."

4.3 Environmental sustainability

We identified 3 different frames regarding the broader theme of environmental sustainability. Frames under the theme of environmental sustainability discussed the adverse environmental impact of livestock agriculture and the projected increase in meat consumption. However, the three frames differ in the proposed solutions and particularly their perspective on meat and dairy substitutes. Table 3 describes each frame according to the identified proposed problems

Table 3. Frames for plant-based protein products regarding environmental sustainability.

Frame	Problem definition	Possible solutions
Plant-based diets are more efficient for environmental sustainability	Adverse environmental impact of meat and dairy production / Increasing global demand for meat and dairy	Limited consumption of livestock products/ Promotion of plant-based diets through hard and soft regulation
Upscale innovations to meet growing global demand for protein	Rising global demand for meat and dairy/ Adverse environmental impact of meat and dairy production	Development of novel plant-based protein products/ Introduction of novel protein ingredients/ New or improved manufacturing methods/ Scale up and commercialization of innovative meat and dairy substitutes
Sustainable meat and dairy agriculture is part of the future	Rising global demand for meat and dairy/ Adverse environmental impact of meat and dairy production/ Environmental footprint of plant-based protein products/ Greenwashing	Promotion of sustainable livestock agriculture through hard and soft regulation/ Promotion of 'better' produced meat and dairy products through hard and soft regulation/ Development and promotion of plant-based products with relatively low environmental footprint

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and solutions. The relative share of each individual frame in the broader environmental sustainability theme is illustrated in Fig 4 and discussed in detail in the text below.

The most common frame (93%) regarding environmental sustainability included articles which presented scientific studies arguing for plant-based diets as means to mitigate the adverse environmental impacts of livestock agriculture. Sustainability arguments were often complemented with health-related arguments to argue for the promotion of "healthy and sustainable diets." For example, [#11] summarized suggestions for maintaining sustainable and healthy diets by employing one quote from the journalist Michael Pollan: "*Eat food. Not too much. Mostly plants.*" However, a few articles promoted specific plant-based products as options that were more sustainable, healthy, or both, compared to other products. For example, one article discussed the qualities of lupin over soy products, arguing: "It's vegan, gluten-free, high in protein, and said to be more sustainable than soy" [#12]. Therefore, multiple and sometimes conflicting pieces of advice about what food products should be part of a sustainable (and healthy) diet were found.

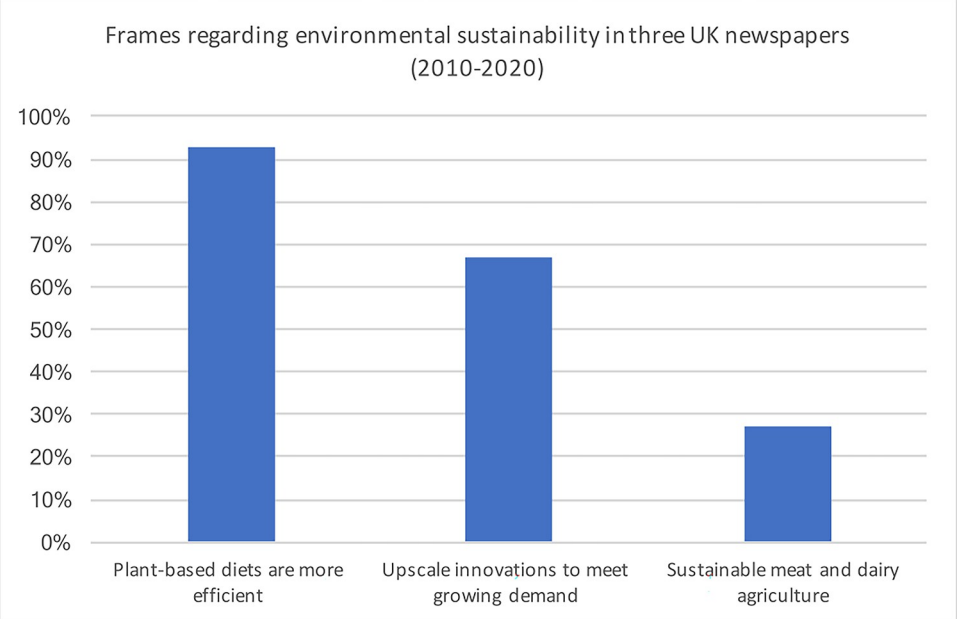

Fig 4. Frames for plant-based protein products regarding environmental sustainability from the Telegraph, the Guardian (London), and the Times (London) between 2010–2020.

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A second common frame (67%) discussed the rising global demand for meat and proposed the development of innovative meat substitutes as more efficient. Articles that fell under this frame discussed ways in which firms have attempted to find novel ingredients, improve manufacturing methods, scale up production, and commercialize innovative meat substitutes. These articles often adopted the perspectives of food firms, which have argued that the development and diffusion of innovative products have become an undisputable solution for a sustainable food system. For example, [#13] quotes the CEO of Impossible Foods, arguing: *"Meat production is a 'ridiculous' and 'inefficient' industry which is causing global ecological collapse. Weaning consumers off meat was a 'no-brainer,' calling it 'the absolute most important task in the world.'"* Additionally, this frame often describes meat substitute firms as technology businesses that develop innovative sustainable products, rather than merely food firms. For example, [#14] reports on an event that showcased new gadgets and included Impossible Foods' burger, "Burger 2.0," in a list of 10 standout gadgets.

A small number of articles (27%) included a counter frame, which opposed the need to transition to plant-based diets, as well as the development and diffusion of meat and dairy substitutes. These articles argued that the development of substitute products can also involve adverse environmental impacts. For example, one article [#15] described the benefits of free-range livestock agriculture: *"Free-range livestock fertilize the soil, and the pastures they graze on soak up surplus water and prevent soil erosion"*; furthermore, the article argued: *"In the process of squaring up to the challenge of climate breakdown, we seem to have forgotten that plant foods too can be either badly or well produced. [. . .]. It's a pity that the public food discourse has become so binary: animal foods bad, plant foods good."* Similarly, another article [#16], when comparing livestock and plant-based protein products, claimed: *"A switch from beef and milk to highly refined livestock product analogues such as tofu could actually increase the quantity of arable land needed to supply the UK."*

Other counterarguments in this frame discussed the perspectives of supporters of livestock farming. These articles questioned the sustainability promises of meat substitute firms. For example, one article [#27] discussed a campaign launched by European Livestock Voice, an interest group for livestock farming, which aims to raise awareness for the overall benefits of livestock farming. In this article, the European Livestock Voice group is quoted: "*The consequences of a drastic reduction on consumption of animal products by replacing them with 'meat substitutes' or other activities could well be worse than the benefits of meat consumption, without leading to a significant environmental or health improvement*." In an opinion article [#10], a farmer questioned the motives of plant-based protein firms, arguing: *"Rather than being seduced by exhortations to eat more products made from industrially grown soya, maize and grains, we should be encouraging sustainable forms of meat and dairy production [. . .]. We should, at the very least, question the ethics of driving up demand for crops that require high inputs of fertilizer, fungicides, pesticides and herbicides, while demonizing sustainable forms of livestock farming that can restore soils and biodiversity, and sequester carbon."*

4.4 Innovation trajectories

We identified 5 different frames regarding the broader theme of innovation trajectories, covering frames that discussed the broader economic and social implications of the diffusion of meat and dairy substitutes. Proposed problems and solutions varied and were mainly related to the political economy of the food system. Table 4 describes each frame according to the identified proposed problems and solutions. The relative share of each individual frame in the broader innovation trajectories theme is illustrated in Fig 5 and discussed in the text below.

Table 4. Frames for plant-based protein products regarding innovation trajectories.

Frame	Problem definition	Possible solutions
Incumbents need to make plant-based the easy choice for consumers	Fast-growing demand for meat and dairy substitutes/ Adverse environmental impact of meat and dairy production / Increasing global demand for meat and dairy	Wide diffusion of plant-based protein products in regime structures e.g. fast-food chains, retail shops, menus at events, cookbooks/ promotion of plant-based meat and dairy substitutes by prominent individuals/Investments in plant-based protein firms
Labels for substitutes	Truthful labelling for meat and dairy substitutes/ Misleading advertising	Regulation the names of meat and dairy substitutes/ Regulating nutrition facts labels
The livelihoods of livestock farmers must be safeguarded	Adverse environmental impact of meat and dairy production/ Diminishing livelihoods of livestock farmers	Promoting sustainable livestock agriculture through regulation and fiscal policies/ Policies to compensate livestock farmers
Meat and dairy consumption is unethical	Adverse environmental impact of meat and dairy production/ Increasing global demand for meat and dairy/ Adverse impact of meat and dairy production on animal welfare / Ethical concerns regarding meat and dairy consumption Unequal power structures in current food regime	No consumption of meat and dairy products/ promotion of plant-based diets through hard and soft regulation/Civil disobedience actions e.g. protests, blockages etc.
The corporate food regime is not the answer	Greenwashing strategies of incumbents (e.g. biochemical firms, fast-food chains etc.)/ Unequal power structures in current food regime/ Health impact of meat and dairy substitutes	Broader considerations for sustainability in the food system/ new business models/ sustainable livestock agriculture

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The largest part (70%) of the news coverage regarding innovation trajectories for plant-based protein products discussed the visibility of the fast-growing demand for meat and dairy substitutes in the U.K. market and globally. These articles mainly reported the ways in which incumbent food firms, retailers, and food service providers responded to changing consumer demand patterns by modifying their assortment of products, menus, or both. For example, [#19] discussed the strategies of the retailer Tesco and the food service firm, Pret a Manger: *"Tesco says demand for vegetarian and vegan ready meals and snacks has soared 40% in the past year, prompting the UK's biggest supermarket to introduce new labelling to flag up all its vegan products. [. . .] Pret A Manger, the London-based coffee shop chain, has just opened its second veggie-only outlet after double-digit percentage rises in sales of vegetarian food."*

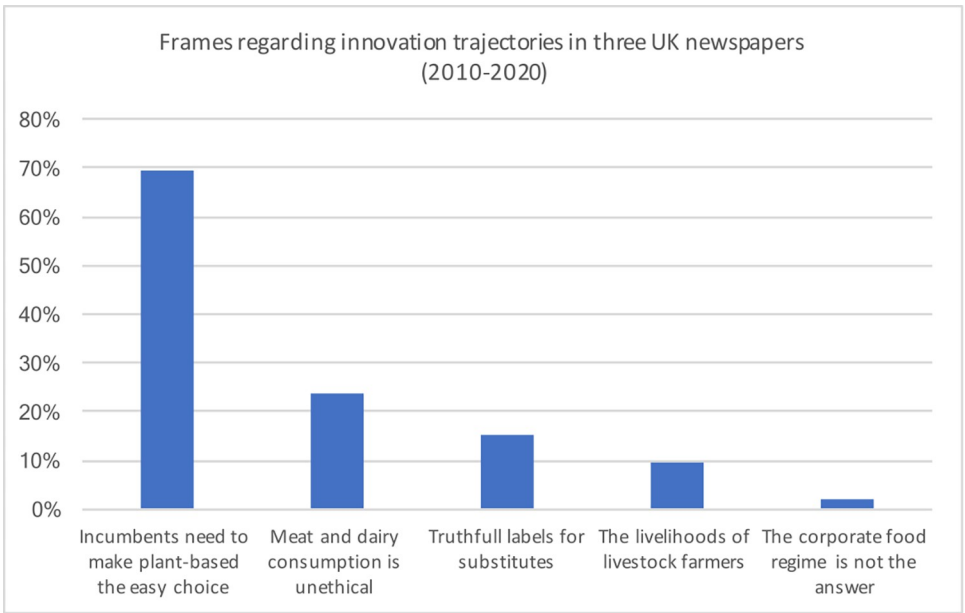

Fig 5. Frames for plant-based protein products regarding innovation trajectories from the Telegraph, the Guardian (London), and the Times (London) between 2010–2020.

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Such articles argued that the wide diffusion of plant-based protein products in regime structures would contribute to making the adoption of plant-based diets "the easy choice" for consumers and thus, accelerate the transition toward sustainability. They were characterized by an overall positive tone toward incumbents increasingly adopting plant-based protein products. For example, in [#20], entitled *"Laugh if you want, but the 'McPlant' burger is a step to a greener world,"* the author explained the rationale behind this supportive position by quoting an animal protection organizer, who argued that "*by making humane and sustainable proteins affordable and accessible, initiatives like the McPlant could contribute to a reduced market for factory-farmed meat*." Another article [#21] reflected on the transformative potential of this development versus more "radical" efforts of civil society groups, arguing: *"The paradox here is that the heroes of the story are science and capitalism—normally seen by the green-minded as the arch-villains. [. . .]. In the end the big food giants' muscle (after they buy some of the upstarts) will be what turns niche products into mass-market ones. The militant vegans of Animal Rebellion aim to disrupt London for two weeks, starting today, under the slogan 'Kill capitalism, not animals.' They are ordering from the wrong menu."*

Under this frame, articles also often discussed the role of celebrities or prominent individuals (e.g., Bill Gates) in promoting plant-based diets and plant-based protein products. These articles argued that the involvement of celebrities and prominent individuals constituted an indication that the transition to plant-based diets has been accelerating. For example, [#22] claimed that: *"While once vegans were viewed as largely Guardian-reading sandal-wearers, they have now gone almost mainstream. [. . .]. There are also plenty of glossy celebrities shunning all animal products, from Pamela Anderson, [. . .]. Tennis star Novak Djokovic has his own vegan restaurant."* Another article [#23] described Oatly, a popular plant-based milk firm that sold a 10% stake to investors including celebrities, such as Oprah Winfrey, Jay-Z's entertainment company, and Natalie Portman. The firm's chief executive argued: *"We are a grassroots brand and wanted to bring in people who are generational voices."* The article continued: "*Jay-Z and Beyoncé have encouraged fans to try plant-based foods, as has Winfrey, while Portman is a high-profile advocate of veganism."* Other articles under this frame discussed ways in which the diffusion of plant-based protein products in regime structures, e.g. cookbooks, popular events, television programs, can facilitate dietary change towards sustainability.

A few articles (24%) adopted a frame which discussed ethical concerns related to the meat and dairy industry, such as animal welfare, and supported the adoption and promotion of plant-based diets. For example, one article [#18] argues that: *"For both the billions of animals raised and killed each year and for ourselves, that day cannot come soon enough. There is nothing natural or inevitable about factory farms, which have transformed human agriculture into a monstrosity which would be unrecognizable to previous generations."* Some of these articles featured the activities of grassroots civil society groups advocating for food system transformation and as a result brought in governance considerations, such as procedural justice and participation in the food system.

Another frame, identified in 15% of articles, focused on labelling issues regarding meat and dairy substitutes. Articles mainly discussed recent EU proposals to regulate the use of meat and dairy names to prevent plant-based protein products from being described as milk or burgers, for example. Out of these articles, most took a positive or ambivalent stance toward the plant-based protein industry. Proponents of the plant-based protein products industry, such as nongovernmental organizations promoting vegetarianism and veganism, have argued that proposals to regulate the use of names are motivated by vested interests of the meat and dairy industry and aim to hamper a growing movement toward more sustainable and ethical food consumption. One article, [#24], discussed the viewpoint of a "green" member of the European Parliament (MEP), who argued: "*The suspicion is that this has come from the meat industry out*

of panic at the fact that young people are moving away from eating meat. It is a clear indication that they are worried about their market being undercut–and that's quite a good sign." Moreover, a few articles claimed that a regulation against the use of meat and dairy names could comprise an opportunity for the plant-based protein industry. For example, in the previous article, the same MEP hoped that a regulation against the use of meat names from plant-based protein products could lead food producers to abandon attempts to mimic livestock products. Particularly, the MEP argued: "*you can have a very nice cuisine that starts with vegetables and not a meat substitute. I think this could unlock a lot of creativity."* A small number of articles adopted the position of livestock agricultural lobby groups and argued that regulations against the use of "meat and dairy names" from substitute products should be introduced to protect consumers from untruthful labeling. Other labelling issues regarding plant-based meat and dairy substitutes discussed vegetarian and vegan labels and the accurate identification of ingredients and nutritional value of products.

A different frame identified in a small number of articles (10%) discussed the rising popularity of plant-based diets and plant-based protein products in relation to the future of the meat and dairy industries and particularly the livelihoods of livestock farmers. Articles under this frame questioned the socioeconomic impact of policies promoting the transition to plant-based diets for livestock farmers. For example, in an opinion article [#6], entitled "*A meat tax need not hit the poor,"* a green politician recommends the introduction of a meat tax but nevertheless argued: *"There is no single magic bullet for avoiding climate catastrophe while improving people's health and securing farmers' livelihoods. . . Any tax would need to be phased in, and give farmers the financial support and time to transition to more sustainable methods of rearing animals*."

Finally, only very few articles (2%) questioned the fast reorientation of incumbent food firms towards substitutes. For example, one opinion article, [#25], questioned the degree to which public discourses have embraced the diffusion of plant-based protein products, arguing: *"Supermarkets, global food manufacturers and biotech and chemical companies have enthusiastically embraced Veganuary. Fast-food enterprises, formerly seen as seen as the nemesis of public health and the environment, have recast themselves as their saviors."* Articles under this frame proposed embracing new business models for the provision of food, such as firms creating short supply chains. For example, article [25] continues by arguing that '*The sausage that sits on your full English platter at a motorway service station is, excuse the pun, quite a different animal to that which arrives in your box from a company such as Riverford, which sells food to consumers direct from its producers."*

5. Discussion

A clear majority of the articles that were studied from the three UK newspapers, the Telegraph, the Guardian (London), and the Times (London), were in support of the need to promote a transition towards plant-based diets. This overall positive coverage signals that plant-based diets have been widely assumed to be beneficial and their mitigation potential, primarily for health and sustainability, has been taken for granted. Nonetheless, the results also illustrate that while plant-based diets have found widespread acceptance, plant-based protein products, including meat and dairy substitutes, are portrayed through different and often conflicting frames with regard to health, environmental sustainability, and innovation trajectories.

To start with, regarding health, we find that support for plant-based protein diets both for individuals and public health is high in most articles. At the same time, it appears that the consumption of meat and dairy substitutes is not necessarily required to support a shift to a healthy diet. Instead, whole plant-based protein foods, such as legumes, are considered

superior in that respect. This is an important finding of this study because, in part, favorable health-related perceptions have been driving the increasing consumer demand for plant-based protein products [17]. In turn, firms producing meat and dairy substitutes position their products in contrast to livestock ones as "healthier" [19]. However, there is still high ambivalence and uncertainty in the public debate on what constitutes a healthy plant-based diet, which may influence consumer attitudes towards meat and dairy substitutes.

Therefore, we argue that to realize the envisioned association of substitutes with "healthy and sustainable diets," actors involved in their development should broaden the scope of strategic choices regarding product design. Product developers should not only focus on mimicking the taste and texture of meat and dairy, but also invest in activities for the development of products that are more analogous to whole plant-based foods. This direction can also satisfy normative concerns regarding the appropriateness of consuming substitutes, e.g. due to the propagation of the conceptualization of animals as food products. Thus, it can resonate with new segments of consumers who hold such ethical considerations and broaden the market for plant-based protein products.

We also find that questions of inequality in nutrition are important, which is a current focal topic within the sustainable development goals of the [55]. Scholars have emphasized that transitioning to plant-based diets should involve food justice considerations [56]. We argue that the accessibility and affordability of plant-based protein products will likely become increasingly important, particularly regarding meat and dairy substitutes which are often perceived as expensive or elitist. Therefore, actors involved in the plant-based protein innovation should try to address such questions on equitable access to food products.

The adverse environmental impacts of meat and dairy production is one of the most important problem definitions in public discourses for plant-based diets. The benefits of the transition to plant-based diets and adoption of plant-based protein products, including meat and dairy substitutes, for environmental sustainability is a very common framing. Articles under this frame mostly characterized plant-based protein products as more sustainable and efficient compared to livestock products. In addition, the majority of these news articles, champion product innovation and technological advancements for the development of substitutes. This technological fix frame has been identified in broader discourses regarding sustainability in the food system [57]. However, a few articles criticized the potential contributions of plant-based protein innovation to sustainability and raised issues, particularly regarding the large environmental footprint of crops used in the development of substitutes. Moreover, articles contesting the environmental friendliness of substitutes often raised equity questions about the impact of the transition to plant-based diets on food production at the farm level, especially as it pertains to the livelihood of farmers. What can be learned is while environmental sustainability is one of the main selling points of meat substitutes, there is evidence suggesting that contestation might surface in the future.

Thus, we argue that in order to address environmental sustainability and equity concerns, the focus of research and development in plant-based protein products, particularly in the UK and EU countries, should increasingly be laid on the adoption of protein ingredients with transparent and local supply chains. This direction also holds a competitive advantage in terms of societal acceptance. It is also aligned with visions for food security that have emerged in recent agricultural policy domains and can be important for the long-term resilience of the plant-based protein sector [58]. Relevant strategies could involve the promotion of cross sector initiatives between e.g. actors in the food processing industry and farmers for the development and promotion of plant-based protein crops.

Regarding innovation trajectories, media discourses largely revolve around the recent reorientation of food regime actors towards the promotion of meat and dairy substitutes. This

development has overwhelmingly been framed as positive. However, a few articles have emerged which contest this frame by arguing against the appropriateness of supporting the current corporate food regime. Overall, such articles bring together normative, health, and food security objections against the current corporate food regime. In general, as innovations diffuse, their potential market expands, and they are then brought into the mainstream [59]. However, this mainstreaming process, particularly regarding the food system, can reinforce existing unequal power structures [60] and thus, lead to contestation. We expect that as the plant-based protein industry grows and substitutes increasingly become part of the existing food regime, these products may also face more resistance [61]. Therefore, we argue that the lasting appeal of plant-based protein firms may involve a balancing act between growth and protection of their mission and representativeness.

Finally, the frames identified in this study, which touch upon several important topics in the food system, such as health and equity, show that the regulation of the transition to plant-based diets should not only be left on private actors. Public actors and civil society organizations, which hold the mandate and legitimacy to work on such topics, should increasingly become involved in this unfolding transition and attempt to address and regulate emerging controversies and concerns.

6. Recommendations for the future of plant-based protein innovation

To sum up, based on this study we propose three key points for the future of plant-based protein innovation. First, this analysis of media frames highlights that the potential health implications associated with processed meat and dairy substitutes comprise the main criticism toward the plant-based protein industry. We argue that to maintain public acceptance and avoid further controversy, product design should necessarily entail health considerations, such as the development of products that are more analogous to whole plant-based foods. Second, while the environmental friendliness of meat substitutes is a better embraced topic in public discourses, there is evidence suggesting future contestation, particularly regarding the footprint of protein crops. We suggest that the utilization of plant-based protein ingredients with transparent and local supply chains should become a strategic priority for the sector. This can also contribute to aligning substitutes with emerging EU and UK policies for food security. Finally, the remarkable growth of the plant-based protein industry has understandably led to the acquisition of plant-based protein firms by incumbent food firms, as well as the involvement of other actors from the corporate food regime, such as retailers and fast-food chains. Nevertheless, the unfolding discourse in media, which frames the fast diffusion of plant-based protein products as a negative development, mainly due to normative considerations, indicates that there is a potential trade-off between mainstreaming and legitimacy. Therefore, we argue that in order to maintain their acceptability, plant-based protein firms should continuously reflect on whether their growth strategies are in line with normative considerations of consumers.

Supporting information

S1 Table. Reference codes of selected research items used in the results section.
(DOCX)

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