The Innovation Ecosystems of Novel Foods: Hype and Incumbent Hijacking or Components of a Sustainable Transition

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Abstract

This article offers an interpretation of the significance and dynamics of current food product innovations, especially those focused on providing alternatives to animal proteins. We first describe the complementary and competing technology routes being explored to develop alternatives for the full range of meat, fish, seafoods, dairy, egg, and generic protein, products. We then draw attention to the original features of current innovation in agrifood and particularly to the nature of its globalization, questioning the dominant focus on the "Silicon Valley" model. The sustainable transitions literature has recently turned its attention to agrifood, and, in the following section, we interrogate its ability to capture the full dynamic of the innovations underway. Political economy approaches, highly influential in both academic and "grey" contributions, which are then discussed, focus on the unsustainability of current innovations and their co-option by incumbent actors. While recognising these possibilities, other authors highlight the modular, decentralized, potential of these innovations with positive impacts for more diversified agricultural development. In the final section, we discuss demand side dynamics with a particular focus on the complex intermediations influencing consumer behaviour, not captured in many of the attitudinal studies. These include retail and food service strategies, labelling and regulatory conflicts, media framing, and the social and cultural factors informing eating practices. In our concluding comments, we provide a brief summary of the principal arguments insisting on the disruptive potential of innovations which propose to radically reduce the various hoofprints of our animal protein diet.

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INTRODUCTION

This article, inspired by the presentations and discussions at the American University of Rome Conference on Novel Foods in March of 2023, first describes current food product innovations, especially focused on providing alternatives to animal proteins. It then offers an interpretation of their significance and dynamics through a critical engagement with the varied academic responses to these innovations. Animal proteins have become a key concern for a combination of health, climate, and animal welfare considerations, to which should be added their centrality in the dietary transitions of many increasingly urban developing countries. The systemic nature of these innovations is highlighted, together with the financial, economic, and political power of the constellation of new actors engaged in their promotion. While initiated in the global North, these innovations are now firmly established in States and regions where rapid economic growth and urbanisation face a grave lack of the traditional natural resources for guaranteeing food security. Given the variety of the intermediations influencing consumers' behaviours – amply documented in the academic literature –, their responses are still uncertain. The underlying factors which have given rise to these innovations nevertheless persist and, with time, have only become more pressing.

A rich and diversified agrifood and innovation literature, both academic and 'grey', has emerged to deal with the many questions which these new protein products pose: the nature of the current innovation process, its implications for the restructuring of the global agrifood system, societal responses, and ethical issues, together with the complexity and variety of intermediating factors influencing demand and consumer behaviour.

The following section first describes the complementary and competing technology routes being explored to develop alternatives for the full range of meat, fish, seafoods, dairy, egg, and generic protein products. Attention is then drawn to the original features of the current innovation ecosystem in agrifood, and particularly to the nature of its globalization, questioning the dominant focus on the 'Silicon Valley' model. The sustainable transitions literature has recently turned its attention to agrifood, and in the following section its ability to capture the full dynamic of the innovations underway is examined. Political economy approaches, highly influential in both academic and 'grey' contributions, which are then discussed, focus on the unsustainability of current innovations and their co-option by incumbent actors. While recognising these possibilities, other authors highlight the modular, decentralised potential of these innovations with positive impacts for more diversified agricultural development. The final section discusses demand-side dynamics, with a particular focus on the complex intermediations influencing consumer behaviour, not captured in many of the attitudinal studies. These include retail and food service strategies, labelling and regulatory conflicts, media framing, and the social and cultural factors informing eating practices. The concluding comments provide a summary of the principal arguments, insisting on the disruptive potential of innovations which propose to radically reduce the various hoofprints of our animal protein diets.

ALTERNATIVE PROTEINS: MANY TECHNOLOGY ROUTES AND MANY PRODUCTS

In 2013, the public tasting of a tiny portion of cell cultured meat, produced at the cost of over US$300,000, was received with the respect and admiration accorded to outstanding scientific achievements (Shapiro, 2018). Ten years later, over 150 cell culture protein companies, only a third of which are in the United States, have emerged out of a finance-driven global innovation ecosystem, comprising startups, individual investors, venture capital firms, investment and sovereign funds which will be discussed in greater detail below. Regulatory approval came first from Singapore (2020), which has adopted high-tech agrifood strategies as its key to meeting food security goals, and then from the US for two chicken products from leading alternative protein firms, Upside, and Just Food (2023). Brazil´s Sanitary Control Agency (ANVISA) has also authorised the production of cell cultivated and fermented proteins (2023). The Netherlands, for its part, permitted public tastings of cultivated meat and fish in 2023 (ATOVA Consulting, 2022; Compre Rural Noticias, 2023; Poinski, 2023; Mridul, 2024).

On the other hand, for many of the Associations representing traditional meat producers, what was once viewed as a scientific achievement is now considered a commercial threat, and livestock lobbies are demanding exclusive labelling rights to traditional animal protein categories (Bollard, 2022). More than this, legislation banning the production and marketing of cell-culture products came into effect in Italy in 2023 (Galbo, 2023), with similar legislative proposals under discussion in most other major livestock producing countries, including Uruguay (Beefpoint, 2023), Brazil (Walendorf, R. 2023) and the United States (Myskow & Hedgepeth, 2024).[1] While meat has been the central focus, all animal proteins, including milk and dairy products, egg products, and all types of fish are currently the object of cell cultivation and initial market launchings.

Cell cultivation is itself only one of the technology routes being explored to provide a protein diet free of animal products. Amy Bentley, in her article in this issue, recounts the historical persistence of vegetarian protein alternatives, whether for religious or secular motives. A multiplicity of now well-documented factors has led to a questioning of animal food consumption in recent decades, creating a potential consumer market beyond the niches of committed vegetarians and vegans. Unlike the latter, potential consumers, 'flexitarians', are considered to be those who are already disposed to reducing meat consumption, and would be willing to adopt alternative proteins to the extent that they are not only nutritionally but also sensorially 'as good as' the animal products they aim to replace (Dagevos, 2021). The convergence of advances in big data digitalisation and genetics have convinced both scientists and the various components of finance capital that make up today´s innovation ecosystem, that these goals are now viable commercial objectives (Shapiro, 2018; Luneau, 2021).

Plant proteins based on new extrusion techniques and biological ingredients identified through big data screening and artificial intelligence have led to the emergence and rapid globalisation of a new generation of food firms. In less than half a decade these firms advanced from product launches to global players: Beyond Meat, Impossible Foods, Eat Just, and Upside in the United States; Omnifoods in Asia; and Fazenda Futuro, plus NotCo in Latin America. Although meats have been the centre of attention since they condense all the factors influencing the shifts in consumer preferences (demography, climate, animal welfare, health), alternatives to milk have achieved greatest market penetration. In seafoods, tuna fish has been the favourite for imitation. The switch to plant proteins breaks down the traditional distinction between protein categories and the same firms are now able to launch products in all the different protein categories (the Chilean company NotCo is a perfect example here in its marketing of alternatives to meats, milk, and fish (Hirtz, F. 2022).

New genetic screening and editing techniques have transformed the traditional fermentation industry, making it possible to tailor microorganisms to produce the desired proteins. The 'heme' produced by Impossible Foods to replicate the visual and sensorial characteristics of meat juices has attracted most attention (Pointing, C., 2023). The same mass screening techniques, however, make it possible and economically viable to identify microorganisms which already possess the desired characteristics, allowing for their large-scale production with traditional methods of fermentation. These varied fermentation processes generally result in a high protein substance which can be transformed through ingredients into various types of meat and fish. Precision fermentation is also being used to reproduce bio-identical milk components which can then be used for a variety of dairy products (Precision Fermentation Alliance, www.pfalliance.org). Perhaps the most original form of fermentation is the production of protein rich flour from naturally occurring bacteria in a culture of the elements of the air, and which, with the help of chosen ingredients, can then be transformed into a wide range of food products.

Except for 'air protein'[2] all these routes imply novel relations with agriculture: animal cells from select breeds in the case of cell culture; a varied assortment of pulses for plant-based meats; or a mix of agricultural ingredients for the different culture mediums. Molecular agriculture introduces a radically new route which,

[1] Now also implemented by the Governors of Florida and Alabama in the USA.
[2] See www.airprotein.com for details of one of the firms producing protein from air.

with the aid of genetic engineering, introduces animal cells directly into plants. Currently tobacco and soy are being tested, and while the production cycle is longer than the fermentation routes, the animal protein, once extracted post-harvest, can reap the benefits of a consolidated global supply chain (Southey, F. 2020).

Proteins from insect sources, a route legitimised and popularised through authoritative international Reports by the FAO-WAGENINGEN (2013) and the World Bank (2021), have attracted significant investments on all continents. Cultural acceptance as a human protein source is globally uneven and it is unclear to what degree animal welfare sentiments extend to insects. Cultivation for human consumption is a tradition in many countries of Asia and Africa and in some regions of Latin America. High protein insect flour, again with recourse to varied ingredients, is mostly transformed into protein snack bars in Northern countries. Production, however, is increasingly oriented to animal feed and petfood where cultural rejection is less evident, although negative sentiments may emerge even there. Large-scale production in this case often takes the form of vertical agriculture with different agricultural sources serving as food, or, as in the case of mega farms in China, food waste from urban consumption creating a circular economy.[3]

Many different questions have been raised in the decade since Mark Post launched the first alternative protein public tasting: marketing projections and consumer trends, carbon footprint, ethical issues, food quality, economic concentration, and implications for the future of agriculture. Academic considerations were preceded by consultancy projections, then quickly accompanied by civil society grey literature, and more recently by lobbying, parliamentary debate, and public regulatory measures. The significance of many of these individual issues becomes clearer once they are situated within an understanding of the originality of the movement which gave rise to these innovations in the agrifood system, and the nature of its globalisation.

THE ORIGINALITY OF CURRENT INNOVATION IN THE GLOBAL AGRIFOOD SYSTEM

The modern agrifood system has periodically been revolutionised by the diffusion of system level innovations: railways, steamships, telephony. Radical agrifood specific innovations, on the other hand, have been led either by public sector agricultural institutions, as in the Green Revolution, or by traditional upstream agrichemical players, as in the diffusion of genetic engineering. In both cases, the issue was the promotion of agricultural productivity, an increase in the existing supply side of the food system.

In the present innovation wave, similar preoccupations prevail (feeding the 'more than 10 billion'), but the perception of and the solution to the problems identified are radically different. The entrepreneurial perspective is distinctively urban, focused on consumption, and oriented to radical food product innovation based on the opportunities of the new technological frontier (Zimberoff, 2021). In fact, urban consumer-driven innovation has become progressively stronger since the last quarter of the twentieth century. The force of demand-side opinion first became apparent in the rejection of genetic engineering in final foods. In a similar fashion, significant refusal of full-cream milk, refined sugar, and trans fats not only led to major adaptations by the established players (corn-derived sweeteners by ADM and artificial sweeteners by Monsanto and others), but also created opportunities for product and process innovations by new entrants: milk from almonds or oats (White Wave Foods, Oatley), plus a whole range of alternative processing techniques for the elimination or reduction of trans fats (Wilkinson, 2024).

[3] In a recent contribution Guthman and Biltekoff, (2023) talk of a third generation of alternative proteins which are characterised by their agnosticism as regards sources and by the ubiquitous availability of protein now liberated from its association with agricultural products. Protein using air or plastics as inputs are certainly outliers but they both use the prevailing fermentation and genetic technologies. Algae are traditionally included in the category of plant-based protein alternatives. Insects are certainly a challenging category from a cultural and perhaps a moral perspective, but they also rely on the same underlying technologies. Rather than generations, we are dealing with different and complementary/competitive technological routes developed within the same innovation ecosystem and often within the same firms.

Health and climate concerns in Northern countries, combined with perceptions of the negative implications of the global dietary transition underway towards animal protein, have transformed animal protein and above all meats into the central target for product substitution. While radical product innovation in the 20th century was primarily the result of isolated individual initiatives and only rarely escaped capture by the incumbent players (Rich Foods, Chobani), the innovation environment for alternative proteins has benefitted from the full force of the Silicon Valley innovation model, which has been researched in depth by Julie Guthman and Biltekoff (2023), and by Alexandra Sexton (2020).

The remarkable profiles of the new entrants – largely individuals at the cutting edges of the scientific and technological frontier and often vegetarians and/or vegans, but with ambitions to challenge the mainstream markets – are vividly captured from widely differing perspectives by Paul Shapiro (2018), Larissa Zimberoff (2021), Gilles Luneau (2021), and Romanos (2022). The speed with which these scientists/innovators created companies, launched products, and reached global markets was made possible once food became the privileged object of a financialised innovation system consolidated through the promotion of successive waves of info, digital, and fintechs. While the future remains uncertain, the four leading startups in plant and cellular proteins – Beyond Meat (2009), Impossible Foods (2011), Eat Just (2011) and Memphis Meats/Upside (2015) – have all become global players and are themselves the vanguard of a universe numbering some 1,800 alternative protein firms according to Protein Directory (https://proteindirectory.com/).

Leading agrifood research has focused on the Silicon Valley model of innovation and extensive fieldwork has been carried out by Guthman & Biltekoff (2023), Fairbairn, Kish & Guthman (2022), and Sexton (2020). The focus here is on agenda setting and discourse analysis. A startup with a project but no product and certainly no product marketable at scale becomes investible to the extent that its narrative can capture investors´ imagination as a point of entry to their pockets. These studies provide a rich sample of interview citations and website promotions showing how problems are framed so that proposed solutions appear plausible. In the absence of eaters, convincing 'fictional expectations' à la Jens Beckert (2017) serve as a proxy for the promised food.[4]

In their most recent work, Guthman and Biltekoff (2023) identify protein as the central actor in these narratives; the only macro nutrient, they claim, to emerge unscathed while carbohydrates and fats have been successively framed as responsible for a range of diet-related illnesses. While this may be true, protein´s main embodiment in meat, and especially red meat, has by no means been immune from critique. On the contrary, more than the products which exemplify the other two macronutrients, meat has condensed dietary, environmental, climate, and animal welfare critiques, which precisely allow for alternative protein routes to be presented as all-embracing solutions (Willet et al., 2019).

Hype is a central component of the 'pitching' game that startups need to play, and the above authors provide perhaps the most detailed account of the discourse framing process. It is nevertheless important to situate the discourse and pitching phase within the broader innovation ecosystem structure equipped with well-defined reality checks that can quickly weed out unfulfilled hype. The initial 'angel' investors, be they family, friends, or wealthy patrons, may be moved mainly by hunch or blind trust, but startups progress only with the help of venture capital firms which establish business plans to negotiate with investment funds. These funds' support is carefully monitored in successive rounds of financing with a view to an eventual public launching or acquisition within a specific timescale of seven to ten years (Lerner & Nanda, 2020).

Innovation driven by finance capital is subject to bubbles of enthusiasm and funding may quickly dry up as

[4] On my reading of Beckert, fictional expectations are intrinsic to capitalism and not restricted to the hype of Silicon Valley-style financialisation since all investment is directed to an uncertain future which needs to be made minimally predictable through framing.

targets are unfulfilled and attention diverted to other investment opportunities, or as funding is negatively affected by macroeconomic factors. Even so, information, digital, and financial waves of startups have all resulted in products, processes and platforms which have radically transformed societal practices, and there is no a priori reason why this should prove not to be the case for food.[5]

Academic studies on alternative foods have focused on the Silicon Valley model of innovation and this has certainly provided the institutional environment in which the leading firms have emerged. While the ideology of Silicon Valley is that of individualism and diversity, Alexandra Sexton´s research has shown how its predominant institutional setting imposes a highly homogeneous trajectory on would-be startups, which marginalises more collaborative open-source initiatives.[6]

INNOVATION MOVES TO THE GLOBAL SOUTH WITH GOVERNMENT POLICY MORE CENTRAL

Less research has been carried out on the diffusion of the Silicon Valley model – broadly understood as a system which integrates research, startups, angel investors, venture capital and investment funds – to Europe, the Middle East and Asia. In each of these regions government policy assumes a much greater role (Wilkinson, 2024). The European Union and individual European Governments (especially Denmark and the Netherlands) invested some US$477 million in alternative proteins in 2022 (GFI, 2024).[7] Israel has declared alternative proteins to be one of its top five priorities for investment and promotion, and the Israeli Innovation Authority has invested heavily in building an innovation hub and promoting a consortium for alternative proteins. Israeli firms captured 15% of global funding but lack of financing for scale-up and the need to access global markets has led their leading firms to set up factories outside of Israel (Buss, 2022). Arab States, by contrast, have focused on attracting the new global players to establish plants in their own territories.

Singapore has become the reference for government promoted alternative proteins as part of an integrated high-tech food security strategy aimed at reducing import dependence, historically at 90%, to 70% by 2030. In addition to promoting finance via Temasek, a State supported investment fund with a portfolio of a little under US$300 billion, the Singapore Food Agency approved the marketing of cell cultivated meats as early as 2020. A range of State Institutions have combined to produce an integrated innovation ecosystem to promote local startups and attract the new global players. All the leading global players – Eat Just, Beyond Meat, and Impossible Foods – are present in Singapore, as is the leading precision fermentation company Perfect Day. Local and regional leaders include Next Gen Foods with its popular brand TINDER, Shiok Meats which despite its name specialises in seafood, and the Hong Kong based Omni Foods. In all, Singapore sports some 60 alt food startups, including 11 cell culture firms, and is now the leading food innovation hub in Asia, if not globally (Stevens & Ruperti, 2024).[8]

Smaller hubs are also being consolidated in Hong Kong, Shanghai and Beijing, complete with startups, venture capital, accelerators, and local dedicated investment funds. Much has been made of Xi Jinping´s declarations in favour of alternative food routes and the inclusion of alternative proteins in China´s most recent five-year

[5] The above authors make the important point that only some 20% of total funding, according to sources such as the Good Food Institute, is dedicated to alternative foods. The vast majority is invested in more predictable digital technologies which are geared to increasing the efficiency of dominant agricultural practices. A large proportion is also directed to food services which are adopting well tried platform technologies, although their impacts are yet to be fully understood. The fact that, even so, most academic contributions have focused on alternative foods points to the radical nature of the questions – cultural, philosophical, economic, geopolitical, and social – that these innovations raise.

[6] The exception she discusses is the Real Vegan Cheese open-source project (Sexton, 2020).

[7] As we have seen above, however, there is also strong organised opposition to alternative proteins in the European Union. For a comparison of EU and EUA ecosystems for cultivated meat, see Schimanietz & Lukacs, 2020.

[8] See also Reis at al., 'The interplay of entrepreneurial ecosystems and global value chains; insights from the cultivated meat entrepreneurial ecosystem of Singapore', Technol. Soc. 71 102116

plan. For Singapore, China, and much of Asia it is not the hype that makes alternative proteins attractive but the evident scarcity of domestic traditional food resources, and the uncertainties and risks of large-scale dependence on imports for basic foods in the case of States whose legitimacy depends heavily on guarantees of food security. The hope of alternative protein leaders such as David Yeung, founder of Omnifoods, is that in the case of alternative proteins the Chinese State will reproduce its promotion of solar energy and electric transport (Yeung, 2022). They argue that only with such levels of State support – a position shared by the global non-profit Good Food Institute (GFI) – can these protein routes provide a viable alternative to the traditional protein sources whose continued growth is widely considered unviable and undesirable (Willet et al, 2019).

Within a decade, alternative proteins have been transformed from a remarkable 'stunt' to a highly integrated network of innovation hubs constituting a global ecosystem, whose centre of gravity is shifting from Silicon Valley to the Middle East and Asia. Over 10,000 food startups had been identified globally by 2022, with 980 angel investors, 3,260 venture capital firms, financed by dedicated investment funds, to which we should add sovereign funds worth many billions of US dollars.[9] In the decade from 2012-2021 some US$170 billion were invested in the agrifood tech sector. Guthman and Biltekoff calculate that some 20%, or over US$30 billion, of this total was directed at the FoodTec sector.

While these figures impress, they pale in the light of the global subsidies for conventional agriculture which a FAO/UN Report (2021) calculated at US$540 billion per year, increasing if unchanged to US$1.8 trillion per year by 2030. Beef and dairy were the sectors identified as receiving the largest shares. Only plant-based alternatives and mycoprotein, with its banner brand Quorn, are currently being marketed at scale and make up around 1% of a global market worth US$1.4 trillion, to which we should add a further US$300 billion for the global fish and seafood market (www.statistica.com). Lack of regulation for products which use precision fermentation, as in the case of Impossible Foods, limits their expansion in Europe and China. Regulation, therefore, will be a key determinant of market penetration, particularly in the case of cultivated animal proteins. The size of the markets targeted also makes clear the limits of this predominantly private-actor dominated innovation ecosystem. The decisiveness of State-supported innovation is starkly apparent when we consider the importance that small States such as Israel and especially the tiny city-State of Singapore have assumed.

ALTERNATIVE PROTEINS AND THE SUSTAINABLE TRANSITIONS LITERATURE

While the academic literature referred to above focuses almost entirely on the specifics of the Silicon Valley model, many researchers have turned to the sustainable transitions literature to understand the broader implications of alternative proteins for the restructuring of the agrifood system. This approach associated with the work of F.W. Geels (2002, 2004, 2007, 2011), which in turn draws on earlier neo-Schumpeterian analyses (Freeman & Perez, 1988), has been influential in interpreting the adoption of renewable energy (Geels and Raven, 2006) and electric vehicles (Krätzig, Franzkowick & Sick, 2020). Based on a threefold, multilevel distinction between niche challengers, regimes (the dominant structure), and the landscape (the broader socio-economic and institutional structure), it explores transitions as the result of engagements and negotiations between the different levels. There is now a considerable literature applying this approach to agrifood (Smith, 2007; Bui, Cardona, Lamine & Cerf, 2016; Bilali, 2019) and to alternative proteins (Janssen, Zunabovic & Domig, 2014; Boukid, 2017; Moraes, Claro & Rodrigues, 2023; Bulah, Tziva, Bidmon & Hekkert, 2023; Dueñas-Ocampo, Eichhorst & Newton, 2023; Mylan, Morris, Beech & Geels, 2023).

Without doing justice to the richness and variety of this literature which has applied the framework to different country contexts, it can be said that the focus of attention has been on the diversity and the

[9] These data were culled from the FoodTech (https://foodtechconnect.com/) and Tracxn (https://tracxn.com/ interactive platforms

complexity of the pathways from niche to mainstream. Interaction and bidirectionality between niche and regime have been highlighted, as has the need to incorporate a range of societal actors seen not to be adequately specified within the niche-regime framework. The global ecosystem supporting alternative protein innovation, as described above, would however suggest the need to go beyond this fleshing out of the transition.

Plant-based proteins have from the outset been directed at the mainstream mass market of burgers, nuggets, and minced meats with the conviction that they could immediately engage the mainstream flexitarian consumer. In this endeavour they found an early ally in large-scale retail which placed their products alongside the existing category offerings. It is not by accident that critics have characterised these products as yet another example of junk food (IPES, 2022), an issue to which we return below. From the outset, these products were also promoted by the dominant sectors of global finance capital, which enabled an unprecedentedly rapid transformation of mission-oriented startups into mass producers and global players.

It is the force of this movement which explains the early entry of the dominant incumbent players into these markets emulating finance capital by acquiring, funding, and promoting the ecosystem of startups. In the 2021 ranking of leading food firms by Food Engineering, all the first 12 had created venture capital firms, a number which rose to 29 in a 2022 survey by Just Food (Costa, 2022). The willingness of retail giants – themselves new entrants, such as Amazon, via Whole Foods – to promote these products led all the incumbent meat producers, which repositioned themselves as protein companies, traders (ADM, Cargill) and final foods (Nestlé, Unilever) to develop plant-based product lines individually or in association on a global scale (Wilkinson, 2024). The notion of a regime, which suggests a considerable degree of stability and coherence, is unable to capture the speed and diversity of the leading actors' responses.

While niche and regime are too schematic for analysing the emergence of alternative proteins, the notion of landscape is difficult to apply to a situation which demands a radical reappraisal of national and global market regulations. In addition, national states and international organisations are increasingly involved in the promotion of research, funding, and the provision of innovation environments on the one hand, and in the redirecting of traditional forms of protein production and consumption on the other (Buss, 2022; Stevens & Ruperti, 2024). Not even the continued predominance of funding for traditional protein production can be interpreted as a landscape effect since it is preserved through increasingly vocal and organised lobbies from regime actors. Most notable, perhaps, is the continued uncertainty regarding consumer disposition. Is the flexitarian hypothesis being confirmed? Is the condition for the adoption of alternative proteins an ability to reproduce the sensorial characteristics of the animal product? Or will the pleasures of eating become emancipated from traditional animal referents?

DISRUPTIVE INNOVATION OR HIJACKING BY THE INCUMBENT PLAYERS?

The early involvement of the incumbent players, the global corporations of the agrifood system, in the development of alternative protein markets, in the acquisition of startups, and in joint ventures or in-house investments in alternative proteins, has already been mentioned. This has been interpreted as co-option by critical think-tanks such as IPES (2022) and ETC (2019), which see it as further reinforcing economic power and concentration in the global agrifood system. Early critiques in this direction focused on plant-based proteins, characterised as reproducing the junk food model of ultra processed foods. While this view misinterprets the strategy behind producing hamburgers, chicken nuggets, and minced meat, which was to reach the mass market with the available technology, initial nutritional comparisons showed higher levels of sodium in early versions of Beyond Burger. Six months after these tests, a 2.0 Beyond Burger was launched with sodium reduced below the level of equivalent traditional meat burgers (Pomranz, M, 2020).[10] This ability

[10] In February 2024 Beyond Meat launched its burger 4.0 https://investors.beyondmeat.com/news-releases/news-release-details/

to redesign food products was captured by the think tank RethinkX (Tubb & Seba, 2019), in the phrase 'food as software', with innovation now focused on the molecular level and readily adjustable.

Cellular agriculture[11] has been analysed in a similar vein by Howard, Ajena, Yamaoka & Clarke (2021) and Howard (2022), focusing on its reinforcement of power asymmetries, traditional feedstock supply chains, and 'centre-of-plate' dietary patterns. These articles includes a detailed figure mapping the extent of incumbent firms in cultivated meat and fish startups. In a recent book, Goodman (2023: 94) concludes in a similar vein: 'The key premise of this book is that the current wave of innovation driven by the convergence of digital and molecular technologies has been contained within the hegemonic industrial model of agriculture and food'. As commented in footnote 5, this would seem to be the case for upstream technologies which are tailor-made to reinforce largescale agriculture. In food services the situation is more complicated, leading to a yet unresolved redefinition of the relative weights of supermarkets, home delivery, and traditional restaurant services.

Alternative foods[12] and especially the animal protein sectors may also become similarly contained. As we have documented, dominant actors throughout the agrifood system are currently investing in alternative proteins, from DuPont upstream to ADM and Cargill in primary processing, to all the leading firms in meats – JBS, Tyson, BRF, Marfrig, Charoen Pokphand Group –, final foods – Unilever, Nestlé –, and even retailers, which not only promote plant-based products but launch their own brands.[13] Given, however, the origin of these innovations outside the traditional actors of the agrifood system, the support they have received from the global resources of finance capital, and the extraordinary speed and scope of their development and diffusion, a more plausible interpretation is that the incumbent players are engaged in 'catching up' strategies faced with a movement which is currently beyond their control. This would seem to be particularly the case in light of the global dimensions of these investments and the increasing involvement of rich States in their promotion, for whom these innovations offer the promise of food security in the face of drastically insufficient domestic conditions for food self-provisioning.[14]

Different actors may well prevail, but it can be argued that the same patterns of economic concentration and power will become consolidated, and these seem in fact to be emerging as the leading new entrants globalise and scale-up, all claiming to be building the world´s largest factories whether for plant-based foods (Beyond Meat), cell cultivation (Upside, Eat Just), fermentation (Quorn), or insects (InnovaFeed/ADM, Ynsect). On the other hand, in each case alternative possibilities are being envisaged. Plant-based proteins hold the promise of dethroning soy as a range of pulses (beans and peas) suited to different edaphoclimatic conditions are being incorporated and promoted. This is particularly the case in Europe where the European Plant-based Foods Association (ENSA) has been formed to promote public policies to increase the continent´s plant protein self-sufficiency. The emergence of shorter supply chains from this endeavour would encourage more decentralised production (Magrini et al, 2018).

A similar argument has been made in the case of cell-cultured proteins as captured in the title of Weele & Tramper´s 2014 article, 'Cultured Meat: Every village its own factory'. Here again it is argued that local crops

beyond-meatr-unveils-its-beyond-iv-platform-fourth-generation/

[11] There is no single agreed definition of cell cultured proteins. Cellular agriculture is a proposed generic definition. See Stephens et al. (2018).

[12] Precision fermentation can in principal produce bio-identical molecules for all kinds of foods and drinks. For coffee see: www.compound-foods.com.

[13] In their efforts to establish themselves rapidly as global players, the alt protein startups also actively negotiate associations with incumbent retail and food services to ensure rapid diffusion, and in other cases have recourse to established food industry players to achieve adequate production scales.

[14] In The Agrifood System in Question: Innovations, Contestations and New Global Players published by Bristol University Press in 2024, the current author argues that as from the 1980s rural and urban social movements, the scientific community and public policies both national and international have converged around a food agenda which has placed the food industry on the defensive, successively adjusting to their varied demands.

could be combined with bioreactors of varying sizes in accordance with local demand. The same model would apply to micro-organism fermentation for protein production. In Europe, the Respect Farms initiative, with prototypes in the Netherlands, Germany and Switzerland envisages the integration of cultivated meats within the dimensions of the traditional family farm (Ettinger, 2023). The farm would have a select herd to guarantee the genetic quality of the meat cells, cultivate feedstocks for the growth medium, and ferment the cells in small-scale bioreactors.

The leading cell culture firms Upside and Eat Just are engaged in or have already constructed huge factories with a view to large-scale production. Serous doubts, however, have been raised about their ability to scale-up to very large bioreactors. Ex-employees at Upside have claimed that the giant bioreactors on show in its San Francisco factory are still not operational. A recent declaration by the CEO of Meatable, Krijn de Nood, reinforces these doubts (Watson, 2023). He argues in favour of small bioreactors, currently at 500 litres, with rapid throughput – as little as eight days in their case. This scale-out rather than scale-up strategy converges with the Respect Farm model and could be integrated into existing decentralised marketing and food consumption practices.

Insect protein would seem to have fewer technical problems for production at scale where the model is similar to that of vertical farming without the same energy (temperature) concerns. Such a model may be more appropriate when the animal feed market is envisaged. On the other hand, where the integration of insects into food consumption practices is customary, more decentralised production is likely to prevail as in many countries of Asia whose insect farms number in the thousands. Protein bars, on the other hand, are tailor-made for the portfolios of the leading snack-food giants.

While the leading new entrants are currently betting on volume and global reach, technical problems of scale, the modular nature of alternative protein processing, and the demand for more diversified protein sources all indicate the persistence of windows of opportunity for more diversified outcomes.

HAVE ALTERATIVE PROTEINS RUN OUT OF STEAM? DEMAND SIDE DYNAMICS.

It might be thought that with all the relevant incumbent players also embarking on alternative proteins, the market at least for plant-based alternatives would be experiencing exponential growth. The sector seemed to be on this track from 2019-2021 but as from 2022 sales have become sluggish, the leading new entrants, Beyond Meat and Impossible Foods, have been cutting back their operations, and references to the Gartner cycle of innovations has suggested that the sector has hit the 'trough of disillusionment' (Terazono & Evans, 2022).[15] These observations are limited to plant-based proteins in Western markets, and the situation in Asia is less clear. Nevertheless, current uncertainties point to the need for a closer look at demand dynamics.

While most studies equate demand issues directly with consumer dispositions and preferences, agrifood studies focus on the intermediation of retail which is regarded to have assumed a hegemonic role in the formatting of food demand. A Brazilian study has examined how the two leading retail firms market plant-based meats in the major consumer centres of São Paulo and Rio de Janeiro (Reis et al, 2023). Its main conclusions are that the plant-based products of the established meat firms tend to have an advantage over the new entrants in terms of price and the range of products on offer. In addition, sales of plant-based products must compete with the promotion of traditional meat products which make up the overwhelming bulk of these meat firms´ sales and corresponding spaces in the gondolas. An earlier study of plant-based products and Canadian retail reached broadly similar conclusions. They found that while retail enabled the availability of plant-based alternatives, these were not actively promoted and consequently were relatively

[15] The Gartner cycle was created by the U.S, consultancy firm Gartner and is used here not for its intrinsic value but because it is used by these authors in relation to alternative proteins and vertical agriculture.

invisible in the gondolas (Gravely & Fraser, 2018).

In her auto-ethnographic study of plant-based meats, Alexandra Sexton (2016) mentions encountering Beyond Meats´ chicken strips in the diet products aisle of Whole Foods, now Amazon, in a Los Angeles retail outlet. The positioning of these alternative protein products has been a central concern of this emerging sector, including also dairy products where market penetration is greater but where less research has been carried out. In their study of plant-based milk within a sustainable transition framework, Mylan and colleagues (2019) draw attention to retail´s positive promotional positioning of alternative milks. The 'non-stuff' (less fats, no fats) of milk, to adapt Sexton´s image (2016), has of course a longer history as a marketing strategy in dairy products, which had established their place in supermarket gondolas prior to the arrival of the new generation alternatives (Oatly, NotCo and others).

Positioning implies messaging, which in turn requires labelling, subject to public regulation. Naming and labelling and have provoked conflicts in the food industry at least since the invention of 'butterine', now margarine. Their importance can be gauged in the current battles to prohibit the use of the words meat, milk, cheese, and yoghurt, for plant protein alternatives, which at one level seems simply to reflect the fears of entrenched lobbies in animal protein producer countries. No-one, it seems, is confused about the origin of the protein when they buy a hot-dog!

In the case under discussion, however, alternative protein firms do claim that their products are meat or milk. Sexton (2016: 67) cites Ethan Brown, Beyond Meats´s CEO, as saying: 'Meat is really made up of five constituent parts: the amino acids, lipids, carbohydrates, minerals, and water. They´re all actually present in plants. What we´re doing is building a piece of meat from those plants, and so the compositions are basically the same. And in that case, we are delivering meat.' Perfect Day, which uses precision fermentation to produce milk components, makes the same affirmation from a different perspective, that of meaning: '"I want the definition of milk to be based on its cultural significance, on the way people use it and interpret it, not on what´s in it necessarily. And the reason is obvious. I mean soymilk is milk, almond milk is milk, cow´s milk is milk' (cited in Jonsson, Linné & McCrow-Young, 2019). To this one could add 'Animal-free Milk', which appears on Perfect Day´s labelling. While the Beyond Meat CEO argues for molecular equivalence, Perfect Day adopts the view that usage leads to various versions of the same product. Oatly, discussed by these same authors, goes even further, and claims that its product is better than milk, in the slogan: 'It´s like milk, but made for humans' (apud Jönsson and colleagues, op. cit.), which recalls here the values attributed to the 'non-stuffs' of Sexton´s analysis.

Research drawing on the social studies of science literature (Stephens & Ruivenkamp, 2016; Kramer, 2016; Jönsson, 2016; Lonkila & Kaljonen, 2021) has exposed the major ambiguities at stake in naming and labelling, and which go beyond, but radically affect, the economic interests of groups with entrenched political clout. In claiming the status of meat, or milk, for plant-based, cell cultivated, or precision fermented alternatives, traditional meanings are being stretched, based on new technological possibilities. Do new knowledges recreate existing realities or forge new realities? In Sexton´s analysis, the bottom line would be 'as good as' in sensorial terms, a route she explores through 'visceral' auto-ethnographic research, and, 'better than' in the values of its 'non-stuffs' (be these, climate, animal welfare, or health externalities).

'Better' in this sense assumes clearly normative connotations, and an important additional line of analysis focuses on the ethical implications of the current wave of protein innovations. Dutkiewicz captures this most provocatively in his title to a 2021 article: 'The Sadism of Eating Real Meat over Lab Meat'. The slaughter of animals and the systematic cruelty involved in mass industrial production might by justified when they can be arguably defended as the only means of ensuring an adequate supply of all the necessary proteins. But once this is no longer necessary, how can the persistence of these practices be justified?

RISING OPPOSITION AND CONSUMER AMBIVALENCE

The closer cultivated meats, fish, and precision fermented proteins reach to market launches, the more juridical, legislative, and ethical and 'defence of traditions' questions come to the fore (Bhat et al., 2019). Even in the case of plant-based alternatives, Jönsson and colleagues´ study of the legal battle over Oatly´s marketing strategies, which lasted some fourteen years, interestingly reveals the uncertain consequences of legal appeals. While the traditional dairy associations won on almost all counts (whether 'equivalence' or 'better than' claims), Oatly repeatedly turned these adverse decisions into marketing opportunities and emerged a much stronger company.[16] It should be remembered that while initially focused on the Nordic markets, Oatly then established itself in the US, and has become a successful global player.

In the case of cultivated meat, opposition has not been limited to court battles over labelling. The Italian Chamber of Deputies passed a law on 16 November 2023, banning the marketing of cultivated proteins, punishable with fines ranging from €10,000 to €60,000. In addition, the use of 'meat' terms in the labelling of alternative proteins was also prohibited. The campaign leading up to this ban was organised by the leading representative farming organisation, Coldiretti, which claimed to have collected 2 million signatures for a petition to ban cultivated meat, with the support of 2,000 municipalities and all the farming regions of the country. The justification in this case was posed in terms of the threat to Italy´s traditional farming products (Galbo, 2023). Other major animal protein producers, Uruguay, the United States, and Brazil, all have similar legislative proposals in the pipeline, but the latter two countries´ regulatory bodies are to date playing an enabling role.

The mass media and social media have also become more 'vocal' as market realities emerge. A review of leading daily papers in Britain suggests that confidence in meat has already been shaken by repeated scandals in recent decades, providing a favourable climate for the introduction of plant-based alternatives, especially given their association with the positive press that veganism has received (Veness, 2023). The reputation of these alternatives however quickly became tarnished by their categorisation as just another round of junk-food. Cultivated meat, by contrast, was presented as 'fake', 'lab', or 'artificial' and this framing coincided with efforts to improve the image of traditional British meats.

Alternative proteins were introduced in the age of social media and several studies have registered their growing presence in on-line conversations (Specht, Rumble & Buck, 2020; Pilarova et al, 2022). A large-scale analysis of X (Twitter) by Ripple Research examined 285 million messages and identified over 400,000 distorted or false claims regarding cultivated meats. Half of these had their origin in a small number of influencers and appeared to be associated with science and climate denial messages, although there was no evidence of an organised campaign by established animal protein interests (Meddah, 2023).

Although there are many intermediations on the demand side before the consumer is reached, social science theory neither reduces demand dynamics to a combination of these intermediations, nor does it attribute 'sovereignty' to the consumer. Alternative proteins have provoked many studies on the consumer in a wide range of countries, aimed above all, and quite naturally, at capturing consumer attitudes and willingness to purchase (Baum, Bröring & Lagerkvist, 2021; Bryant & Barnett, 2019; Liu +4, 2021; Palmieri, Perito & Lupi, 2020; Chriki et al., 2021; Wilks & Phillips, 2017). In general, their conclusions suggest favourable conditions for market growth, but with price emerging as a continual qualifier.

Much social science would question the value of stated intentions as guides to action, particularly in the absence of widely available products. A focus on eating as a social practice (Warde, 2016) would give priority to the way alternative proteins are becoming incorporated into existing eating practices. Alternative milks are

[16] In 2014, Unilever filed a lawsuit against the use of the name Just Mayo by what was then Hampton Creek (now Eat Just), but later withdrew its charges, choosing instead to launch its own 'no egg' mayonnaise.

interesting here since they have been marketed over a longer period. Studies by Mylan et al. (2018) mentioned earlier in our discussion of sustainable transition approaches, and by Buchs, Mylan & Stevens (2023), show that we are not necessarily dealing with a simple product substitution. The latter study found that consumers who bought alternative milks continued to buy traditional milk since the new products did not combine well with hot tea or coffee, although they were excellent substitutes in the case of morning cereals. The innovation strategies of the leading alt protein companies seem to be very much aligned with the notion of eating as a social practice, with its accompanying inertias and rituals. Their stated aim is to reproduce the characteristics of the original meats and other proteins within their habitual eating settings. Hence the relevance of the visceral auto-ethnographic research à la Sexton. The bold flexitarian consumer hypothesis may nevertheless still be faced with the predominance of a reductionist flexitarian argument to simply abstain from meat on certain occasions rather than opt for alternative meat substitutes.

FINAL CONSIDERATIONS

In this article the focus has been on questions directly related to the dynamics of the current innovations in protein food products, and on the academic and 'grey' literature which subjects them to analysis. The analysis has been developed through a critical engagement with this wide-ranging literature. As regards the innovation process itself, the predominant focus on the Silicon Valley model obscures the increasing centrality of new actors as innovation assumes a more global dimension, including States rich in capital but poor in natural resources and for which food security is central. In addition, the brilliant descriptive and interview material, focusing on the hype of the pitching ritual, fails to appreciate the extraordinary results achieved in the space of a decade as startups became global players, and products moved from the lab to the gondola. The hybrid zone between academic and engaged grey literature is dominated by the view that the wave of food startups has been consolidated under the control of the incumbent global players, reinforcing their economic and political power. We have tried to show that this view is at least precipitate, although it is clearly a possible outcome. And while market concentration is being actively pursued by the newly global players, the potential for decentralization is built into the modular architecture of fermentation technologies.

The emerging literature on the myriad factors influencing demand has effectively exposed the inadequacy of much of the consumer literature focused on attitudes and willingness to purchase, and makes vividly evident the depths of the interests and values at stake. It was not possible in the space of this article to do justice to the discussions on the content of the new food products proposed. These have been variously dismissed as junk food, as the reduction of food to nutrition, and as a perpetuation of the meat-centred food plate. These may all be valid observations in themselves, but they forget the central importance of the promise of Sexton´s 'non-stuff': no cruelty to animals, no deforestation, no exhaustion/destruction of natural resources, and no dangers to personal and public health. In this sense, a shift to alternative proteins would indeed be disruptive.

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