Meat alternatives compared: their pathways of change and sustainability

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Extended abstract

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1. Introduction

Over recent years, the sustainability of meat consumption and production has increasingly come under scrutiny. The production of meat has been criticised for, inter alia, poor conversion of plant-based proteins into meat-based protein and the ensuing land requirements for feed production; environmental impacts from local to global scale of emissions into air, water and soils, in particular methane and manure; animal welfare concerns about lack of space, inhumane treatment and direction of breeding (Gill, Feliciano, Macdiarmid, & Smith, 2015). At the same time, meat consumption and production have become a major driver of global environmental change (Steinfeld et al., 2006) and are expected to further increase at global scale, partly replacing plant-based sources of protein such as pulses.

The societal concerns over meat consumption and production have stimulated a search for alternatives. These include high-technology ways to produce meat proxies such as cultured meat or plant-based meat alternatives, animal based meat alternatives, such as insects, and the traditional, low tech alternatives like pulses. Discussions about the potential success of these alternatives have addressed their technological feasibility and production costs as well as their economic viability and resonance with cultural and behavioural patterns of consumption.

Several studies propose that a transition or transformation is needed to tackle the trade-offs between meat production issues and to counter the trend of increasing demand for meat (Aiking, 2011; Packwood Freeman, 2010). A transition perspective emphasizes interlinkages between different levels of organisation: niche innovations, socio-technical regimes (or ''systems') and macro-structures. The suggested pattern is that local initiatives and small-scale innovations (niches) interact with incumbent (sub)regimes that tend to resist and suppress change unless macro-developments crack open the established structures and open opportunities for niche innovations to be taken up or scaled up (Elzen, van Mierlo, & Leeuwis, 2012; Geels, 2002; Kemp, Loorbach, & Rotmans, 2007; Smith, 2007). A transition towards regime change involves intertwined changes of technology, consumer preferences and practices, suppliers' practices and relations and policy.

Studies on meat provision from a transition perspective identifying barriers, opportunities and preconditions are still rare. In a handful of more integrated transition studies, several fundamental barriers for a transition based on meat alternatives developed in niches have been identified, in particular regarding relations between niche and regime actors, among niche actors as well as technological, organizational and institutional aspects. Human minds as well as human societies are prone to various ways of lock-in, and inertia in attitudes and social systems might create an "efficiency trap" which slows down societal responses to new problems – until eventually an avalanche of shifts occurs when a threshold is reached, which then leads to a sudden transition (Scheffer, 2009).

This raises the question under which conditions the developments around these issues might be more conducive to each other. Overall, this calls for a wide-ranging study from an interdisciplinary perspective to compare the known meat alternatives, the socio-technological changes required for an upscaling of each and the possibilities for them to develop into a supportive relationship. In this way, it can be assessed whether and under what conditions high-tech alternatives can help the transition towards a sustainable system. This raises the first question to be addressed in this paper: Can sufficiently strong coalitions be assembled to support each an alternative through lengthy processes of technological and social innovation?

From a technological point of view, a more sustainable food production would imply i) reduction of the use of fossil energy sources, ii) reduction of the use of clean water, iii) a more efficient use of raw materials (resources). The inefficiencies related to meat consumption originate from the fact that plant materials, especially proteins are decomposed and restructured again into proteinaceous materials. To produce meat, animals consume protein-containing feed, which they decompose into amino acids, which are then converted into new proteins (amongst others muscle tissue). Depending on the animal species, the ration between fed protein and protein suitable for human consumption ranges from 4 to 26 (Sebek & Temme, 2009). Meat production is optimized in an economical manner. The price of meat is low, suggesting that the production of meat does not require much processing or handling. In other words, meat production is not efficient in resources, but efficient in terms of economy. This indicates that replacing meat by alternative products will not always be more sustainable, especially if much bio-refining and other processing is involved. The second question for the comparison of the meat alternatives hence relates to the desirability of the meat alternatives from an environmental sustainability point of view: What are the potential sustainability gains from each alternative, i.e., would their eventual success significantly reduce the use of scarce resources compared to current best practice? In other words: Is it worth the effort, and which alternatives are most promising?

To contribute to this discussion, this paper adopts an interdisciplinary perspective on alternatives for meat provision and use. Being an interdisciplinary team ourselves, we will develop a conceptual framework – the Reflexive Integrative Comparative Heuristic (RICH) – to conceptualise plausible pathways for the production and consumption of five widely discussed meat alternatives and surrogates: cultured meat, algae, insects, plant-based meat surrogates and pulses. Aided by the RICH heuristic, we will estimate their environmental sustainability potential and comparatively appraise the level of complexity regarding the needed technological and social-institutional innovations. This approach resonates with the recent call for a changing role of science in the Anthropocene by contributing to societal goal clarification, exploration of supporting or obstructing trends and analysis of "factors that might propel or impede transformations towards desirable futures" (Bai et al., 2015).

This approach allows us to compare the environmental sustainability potential of the known meat alternatives, the socio-technological changes required for an upscaling of each and the possibilities for them to develop into a supportive relationship. In this way, it will be assessed whether and under what conditions the advocated high-tech alternatives can help the transition towards a sustainable system.

In the following sections, we first introduce our methodology and provide a few comparative overviews before drawing conclusions for the research and action agenda of a meat transition and reflects on whether and how the RICH heuristic provides a more robust and complete analysis of sustainable transitions pathways addressing relevant issues of choice than the current approaches of analysing transitions (cf. Turnheim et al., 2015).

2. Methodology: Reflexive Integrative Comparative Heuristics

To better understand the preconditions and implications of the alternatives to meat production and consumption, we conceptualise likely development pathways for five options, which are currently widely debated: cultured meat, algae, insects, plant-based meat surrogates and pulses. These protein transition alternative-pathways (PTAPs) are constructed following a set of guiding questions (see

Table 1) designed to integrate current knowledge from a wide range of disciplines (here: food and nutrition science, environmental science, social sciences, philosophy) and publicly available knowledge and to reflect on the differing rationales and imaginations about the future behind each alternative. The alternative-pathways are then systematically compared with regard to their preconditions and implications. Here we focus on (a) the required level of technological, organisational and institutional innovation, which are assessed by mapping the respective challenges for safe and large-scale production and consumption, and (b) the potential sustainability gains of each alternative. The potential environmental efficiency is evaluated by reviewing current literature, regarding the processing of each alternative compared to the production of poultry meat.

Our Reflexive Integrative Comparative Heuristics (RICH) does not aim to generate predictions, but to explore and compare the societal, food health and environmental implications of technological alternatives. It has been inspired by the "4C heuristic" for the cooperative conceptualisation of complex controversies (Burns & Ueberhorst, 1988; Feindt et al., 2008). It resonates with recent debates about the changing role of science in the Anthropocene by contributing to societal goal clarification, exploration of supporting or obstructing trends and analysis of "factors that might propel or impede transformations towards desirable futures" (Bai et al., 2015).

Table 1: Reflexive Integrative Comparative Heuristic: Guiding questions

	Dimension	Guiding questions
Background information	Origins, history and technical operation	Where did the alternative emerge, how did it develop, who was involved and what are the technical principles?
	Nutritional value	What quality of protein and other nutrients does the alternative provide?
	Attention and cultural resonance	How much attention does the alternative receive and how does it resonate with cultural values around food, nutrition and lifestyle?
	Consumption and production rates and patterns	What are the levels and trends of consumption and production?
	Position as meat alternative	How is the alternative positioned to (partially) replace meat as part of consumption patterns?
Current practice and situation	Technological	What is the technical state of the art?
	Consumption and lifestyle	How is the alternative positioned in current consumer markets?
	Supporters and opposition	Which actor coalitions have arisen for and against the alternative?
	Legal and institutional framework	How is the alternative legally treated and which are the relevant institutional frameworks for regulatory oversight and potential legal amendments?
Future outlook: Preconditions and implications	Environmental sustainability potential	What is the potential of the alternative to realise environmental sustainability gain in comparison to poultry meat production?
	Technological	What are the main technological challenges (including breeding) and implications?
	Organisational and institutional	What are the main organisational and institutional challenges and how will they be likely addressed?
	Potential future supporters and opposition	What actor coalitions are likely to emerge for and against the alternative?

3. Comparative evaluation and discussion

The aim of the paper was to compare different pathways for alternatives to meat production and consumption in regard to the necessary changes and the potential sustainability gains. We do so systematically, following our RICH heuristics.

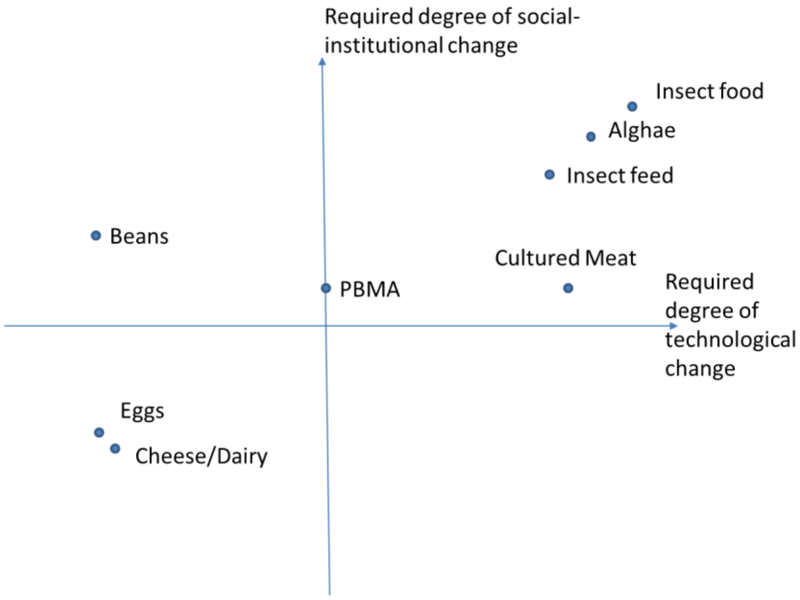
The comparison of the environmental sustainability of the alternatives shows a *robust trend*: The more transformation and processing a meat alternative requires, starting from plants, the more uncertain its potential sustainability gains. Meat is criticised for inefficient transformation of plant protein into animal protein, which becomes unsustainable if the production of animal feed competes with other scarce land uses. In contrast, algae-based and plant-based products require various degrees of technological processing that lead to sustainability losses. For insects and cultured meat, transformation from plant to animal protein needs to be added, although for insects this loss is smaller.

When matched against the level of technological innovation needed to realise the sustainability potential, we find a stark discrepancy (see Table 2). The only alternative that requires neither industrial processing nor technological innovation are pulses. The technological innovations entailed in the other meat alternative-pathways mostly pertain to energy-intensive processing and transformation of raw materials that reduce any potential sustainability gains.

Sustainability gains	**Required technological innovation**		
	Low	**Moderate**	**High**
High	Pulses		
Moderate		Plant-based meat alternatives	
Uncertain			Cultured Meat Algae Insect Food
Low	Cheese/Dairy Eggs		

Table 2: Sustainability gains and required technological innovation of meat alternatives

Furthermore, our analysis demonstrates that the meat-alternatives differ not only in the level to which they require technological, but also societal and institutional change for a successful transition (see **Error! Reference source not found.**). Meat is deeply institutionalized in Western societies. While on the one hand eggs, dairy and potentially also cultured meat conform to present dietary patterns, consumption of insects and algae would come with considerable change, while pulses and plant-based alternatives are existing and institutionalized options but have become (pulses) or remain (PBMA) niche products because of low societal appreciation. Consequently, the alternatives that best conform to present social-institutional consumption patterns are not the most sustainable ones. The most sustainable option, pulses, does not require major technological or societal change apart from improved attractiveness for farmers and consumers. The most technologically challenging alternatives also require high to moderate levels of social-institutional change, rendering the general assumption that with technological advancement we can maintain our consumption practices obsolete.



PBMA – plant-based meat alternatives

Figure 1: Level of social-institutional and technological change required for meat-alternatives

On reflection, our analysis has conceptualised each alternative pathway in isolation. In reality, they are part of a complex and interacting field. On the one hand, the wealth of alternatives that are being developed, discussed and promoted contribute to a broader discourse about societal change, which might benefit all alternatives. On the other hand, there is clearly competition among the alternatives for attention, inspiration and investments. In these respects, novel, surprising or high-tech alternatives such as cultured meat and insects have an advantage. Innovative entrepreneurs are attracted by the technological challenges and imaginative engagements such as future-oriented cookbooks aim to stimulate disruptive thinking about our protein future. In contrast, the traditional, low tech alternatives will need additional efforts to draw attention and resources.

5. Conclusions

Current levels of meat consumption exceed the dietary protein requirements in many countries. Continuation of the current pathway of meat production has unsustainable environmental implications at global scale. According to environmental studies, the obvious solution is to replace meat consumption by other food products from plant origin. In contrast to more traditional calls for increased cereals consumption, vegetarian or vegan diets, novel technological developments suggest other alternatives. In particular cultured meat, algae and insects have received much scientific, public and financial attention. Our analysis suggests that the level of technological, organisational and institutional innovations required to make these novel alternatives viable require a high level of societal coordination, while the potential sustainability benefits are limited due to energy loss from necessary processing or transformations of raw material. At the same time, alternatives such as pulses and PMBA would allow immediate and significant sustainability gains, but are less attractive to consumers and producers. They also lack a powerful actor coalition that could propel them on the agenda, instigate the required social-institutional change and stimulate investments. Hence, the most sustainable alternative (pulses) is not further developed while many resources (attention, money, scientific capacity) are spent on technologically advanced options with very limited sustainability potential. These findings suggest that the (un-)sustainability of meat consumption and its alternatives is not just a problem of technological optimisation of production systems, but also a second order problem of problem framing and specification. The focus on high-tech alternatives such as cultured meat and algae is based on deep-seated assumptions about the feasibility and desirability of high levels of control over natural conditions (and intellectual property), and highly integrated models of industry organisation.

Overall, we need to develop integrated approaches to overcome lock-in, and find transition mechanisms and tipping points. This question pertains to research agendas and policy. To make the most sustainable options for a protein transition viable, we have to look for their attractiveness to relevant players and answer questions such as this one: How can you become famous as a bean researcher?

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