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The transformative innovation potential of cellular agriculture: Political and policy stakeholders' perceptions of cultured meat in Germany

Jana Moritz [b,c,*], Hanna L. Tuomisto [a,c,d], Toni Ryynänen [b,c]

[a] Department of Agricultural Sciences, Latokartanonkaari 7, 00014, University of Helsinki, Helsinki, Finland
[b] Ruralia Institute, Lönnrotinkatu 7, 50100, University of Helsinki, Mikkeli, Finland
[c] Helsinki Institute of Sustainability Sciences (HELSUS), Yliopistonkatu 3, 00100, University of Helsinki, Helsinki, Finland
[d] Natural Resources Institute Finland, Latokartanonkaari 9, 00790, Helsinki, Finland

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ABSTRACT

The current animal-based food systems are being challenged by environmental, social and economic sustainability issues. A systemic transformation from conventional agriculture to a more sustainable cellular agriculture utilising cell-cultivation technologies to produce animal products has been proposed. The aim of this study is to explore the political and policy stakeholders' perceptions about cellular agriculture; how they perceive of the current food system and its potential transformation into a cellular agricultural system. The qualitative data comprises 13 interviews conducted with representatives of German stakeholders. The data were analysed with the Transformative Innovation Policy approach. Perceptions of the transformative potential of cultured products were classified into drivers and bottlenecks that either advance or hinder the progress of cellular agriculture in Germany. The results show that the political and policy stakeholders are aware of the changes that are needed, but anticipate that large-scale transformation to the cellular agriculture system may not be a plausible solution in the near future.

1. Introduction

Current food production systems will confront challenges in a world in which population is predicted to grow to 9.5 billion by 2050 (Willett et al., 2019). In addition to growing demand for food, current livestock production is associated with sustainability challenges such as increasing deforestation, climate change, land usage, pollution of water bodies, human health issues and the ethical aspect of rearing and eating animals (Poore and Nemecek, 2018; Steinfeld et al., 2006; Thornton, 2010). Addressing these global challenges by developing only the existing livestock food systems appears insufficient, which has led to the emergence of potential future solutions. One of them is cellular agriculture, which refers to a novel food-production sector and the post farmed-animal bioeconomy as a model for organising its economic activity.

Cellular agriculture is defined here as a selection of technologies to manufacture livestock products with cell-culturing techniques (Stephens et al., 2018), although in practice, cellular agriculture can also be used for production of other than livestock products (Rischer et al., 2020). One product of cellular agriculture is cultured meat that is produced by cultivating animal cells in a nutrition medium in a bioreactor (Post, 2012). Cultured meat is an example of the tissue-based cellular agriculture, whilst another form of production is fermentation-based where no animal cells are used but products are fermented by using bacteria, algae or yeast (Stephens et al., 2018). We consider specifically cultured meat in this paper. Since the introduction of the first cultured hamburger in 2013, more than 60 start-up companies have been established and they have attracted more than 450 million US dollars in investments for bringing cultured products to the market (Swartz and Bomkamp, 2021). Until the end of 2020, just one company has been successful in introducing cultured chicken nuggets to the market in Singapore (Lucas, 2020).

The development of cultured meat and other cell-cultured food products encounter technical and societal challenges such as scalability of production, currently high production costs, social and cultural challenges as well as issues of consumer acceptance (Stephens et al., 2018; Post et al., 2020). Natural scientists and engineers have addressed the challenge of the scalability of culturing meat (Moritz et al., 2015). These large-scale production issues and anticipated high end-product price compared with conventional meat are still unsolved challenges

* Corresponding author. Faculty of Agriculture and Forestry, Latokartanonkaari 5, room C222, 00014, University of Helsinki, Finland.
E-mail addresses: jana.moritz@helsinki.fi (J. Moritz), hanna.tuomisto@helsinki.fi (H.L. Tuomisto), toni.ryynanen@helsinki.fi (T. Ryynänen).

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(Hocquette, 2016). The life cycle assessment studies have concluded that the energy use of producing cultured meat is substantially higher than producing conventional meat, whereas environmental impacts such as water usage or climate impact are lower for hypothetical cultured meat production when compared to beef production (Tuomisto, 2019). A recent study has shown that the production of cultured meat is anticipated to have lower environmental impacts than conventional meat production if sustainable energy sources can be used (Sinke and Odegard, 2021). However, the current knowledge of cellular agriculture is fragmented and uncertainties that surround cultured meat are related to social and political acceptance and technical obstacles.

To evaluate the transformative potential of cellular agriculture and particularly cultured meat, we have drawn on the transformative innovation policy (TIP) approach (Schot and Steinmueller, 2018). TIP builds on the idea that implementing new policies based on novel innovations such as cellular agriculture could radically transform existing systems. Current systems tend to have bottlenecks represented by missing policies, existing policies and practices that hinder innovation, financial hurdles and barriers developed by stakeholders or big lobby industries repressing sustainability transitions for their own benefit (Gliedt and Larson, 2018). The aim of this article is to explore German political and policy stakeholders' perceptions of cellular agriculture using TIP to investigate future directions of food systems when products such as cultured meat are considered.

The German food system has purposely been chosen for the study since half of land area in Germany is used for agricultural purposes (Federal Statistical Office, 2020). Out of 82 million inhabitants in Germany, only 4% follow a vegetarian diet (Weinrich et al., 2020). Moreover, the German agricultural traditions are deeply rooted and partly reflected by the current meat consumption, which accounts for almost 60 kg of meat per capita in the year 2020 (Weinrich et al., 2020; Bryant et al., 2020; Statista, 2020).

This paper proceeds by reviewing the literature about cellular agriculture and the TIP approach. After presenting the interview data and the analysis method, results are discussed according to TIP principles of directionality, goal, impact, degree of learning and reflexivity, conflict and inclusiveness of cellular agriculture. The paper concludes with an overview of the transformative potential of cellular agriculture based on the political and policy stakeholders' interviews.

2. Cellular agriculture and transformative innovation policy

2.1. Cellular agriculture in social sciences

The social science studies on cellular agriculture have mainly focused on cultured meat and different stakeholders' perceptions and their potential acceptance of this novel food (Sharma et al., 2015; Bryant and Barnett, 2018; Bryant et al., 2020). It is suggested that once people know all the benefits of cultured meat, willingness to try and acceptance levels will increase (Hocquette et al., 2015; Verbeke et al., 2015). However, consumers are concerned about the healthiness and naturalness of products grown in a laboratory (Laestadius and Caldwell, 2015; O'Keefe et al., 2016; Wilks and Phillips, 2017; Siegrist et al., 2018). The socio-economic and socio-political factors of cultured meat have also been studied, concluding that younger, male, higher-income class, highly educated, environmentally aware and politically liberal people tend to be more willing to taste and eventually to consume cultured meat (Wilks and Phillips, 2017; Slade, 2018).

A survey of German consumers found that 57% were willing to taste cultured meat, whereas 30% were willing to eat it regularly and about the same proportion would recommend cultured meat to people eating conventionally produced meat (Weinrich et al., 2020). Furthermore, the results show that ethical advantages associated with cultured meat such as improved animal welfare or environmental benefits have the highest importance for Germans and hence the highest impact on their willingness to eat cultured meat, followed by negative emotional objections such as feelings of unnaturalness and the potential for reducing global warming (Weinrich et al., 2020).

A comparative study of consumers' dietary preferences and attitudes to cultured meat show that the overall acceptance is higher in Germany than in France (Bryant et al., 2020). Moreover, Germans tended to prefer cultured meat to plant-based meat alternatives and German people working in agriculture or in meat production facilities tend to have a more positive attitude towards cultured meat than the others. Results about the attitudes of the German participants show that the highest motivator for cultured meat acceptance in Germany is the assurance that cultured meat is free from antibiotics, followed by the importance of food safety, environmental benefits and animal welfare (Bryant et al., 2020).

In addition to consumer acceptance studies, research has been conducted on the ethical aspects of growing alternative proteins. Some of the negative ethical aspects associated with cultured meat include the disconnection from humans to nature and hence being alienated from animals as well (Hopkins and Dacey, 2008; Van der Weele and Driessen, 2013; Schaefer and Savulescu, 2014). Development of products such as cultured meat could result in an extinction of livestock animals and make growing human flesh possible, bring up ethical concerns (Hopkins and Dacey, 2008; Van der Weele and Driessen, 2013; Schaefer and Savulescu, 2014). Although these ethical concerns perceived by the study subjects in several studies are psychologically real to them, the potential benefits of cultured meat mentioned in the introduction tend to outweigh the ethical objections mentioned above.

Newton and Blaustein-Rejto (2021) conducted 37 semi-structured stakeholder interviews in the United States to explore potential threats and opportunities of the plant-based and cultured meat sectors to rural communities and farming regions. The stakeholders anticipated opportunities for farmers who could grow feedstock for cultured meat production or produce it themselves at a farm-level (Newton and Blaustein-Rejto, 2021). The stakeholders perceived that cultured meat production sector could create new employment opportunities, improve food security and provide health benefits. Moreover, the stakeholders identified threats such as the loss of income for livestock producers or the exclusion of farmers by transitioning into the cultured meat sector, since a few large companies were anticipated to overtake cultured meat development (Newton and Blaustein-Rejto, 2021). Helliwell and Burton (2021) identified similar threats and called them narrative silences by pointing out destructive silences that are under-addressed, such as the discussion of what happens to rural communities or who cares for the countryside when cultured meat replaces most of traditional farming. Agricultural employment and consolidation of food production (Bryant 2020) are key questions when the impacts of cellular agriculture are evaluated from the rural perspective. The stakeholders in Newton's and Blaustein-Rejto's (2021) study further identified opportunities for government agencies, which could incentivise land transitions by reducing subsidies for animal farmers to create a just competitive environment for cellular producers.

One key contribution that we will use later has been made by Chiles (2013) who studied the ideologies of political stakeholders and the potential political consequences of ambiguous goods such as cultured meat. The findings suggest that stakeholders rely upon stable institutional ideologies to judge and understand new food products. The study identified the Techtopian, Green Luddite and Work Machine ideologies that explain choices for or against cultured products (Chiles, 2013). The Techtopians or technology utopians perceive technology as the path to societal well-being and assume that consumers are not aware of the cellular agriculture development; they only become aware once it is on the market, which makes this the key political arena for social change. The Green Luddite is the classical environmentalist trying to maintain the natural order, biodiversity and traditional landscapes. The controversy with the Green Luddite is that they are usually also against unsustainable conventional meat production and tend to prefer local small-scale farming solutions. The Work Machine ideology draws from

economic growth achieved through productivity and wealth. Contrary to the Techtopian emphasising well-being, the Work Machine relies on business-as-usual methods, which in this case could mean conventional meat production.

The vision of innovators and other expert stakeholders of cultured meat has been analysed and compared in the expert interviews in Germany to contribute to the German national research policy (Böhm et al., 2018). In the innovators' vision, cultured meat was perceived as the most sustainable and efficient way to produce meat (Böhm et al., 2018). The results show that the other stakeholders associated challenges and other opportunities for realising sustainable food production (Böhm et al., 2018). For instance, the alienation from animals was perceived as a challenge and they proposed other options such as reducing the current meat intake and raising more awareness among consumers about current livestock problems (Böhm et al., 2018).

Stephens et al. (2018) summarises challenges and prospects based on 70 social science expert interviews of people working with cultured meat. Their results suggest that consumer acceptance studies and ethical challenges have been overemphasised and that regulatory and political challenges need to be addressed in future research settings. Specifically, the pathway for introducing cultured meat to the European market is not clear yet. These products can be considered within the Novel Food Regulation framework of the European Union if cultured products are free from genetically modified foods or under the regulations relating to genetically modified foods that allows the use of genetically modified ingredients (Stephens et al., 2018).

In addition, the political uncertainties include how existing political systems may have to be reconfigured to include cellular agriculture, and asks questions about who will be the beneficiaries and sufferers of this development and deciding the policy landscape of cultured meat (Stephens et al., 2018). Moreover, their study critically assessed the current investment cycles in the cellular agriculture sphere, which mostly comes from private capital ventures rather than public government funding. Stephens et al. (2018) concluded that cultured products will probably have a small-scale impact on society and the environment and are unlikely to keep the promise of a large-scale impact of reducing climate change issues.

2.2. Transformative innovation policy

The Transformative Innovation Policy (TIP) is a framework for research and innovation policy development (Steward, 2012). Earlier government-led single-purpose growth policies and the later innovation policies aiming at increasing competitiveness with research and development activities within certain systems were seen as being inefficient for addressing global-level challenges such as urgent social justice issues and climate change problems (Schot and Steinmueller, 2018; Diercks et al., 2019; Molas-Gallart et al., 2020). The establishment of the Sustainable Development Goals (SDGs) by the United Nations (UN) in 2015 (United Nations General Assembly, 2015) helped to develop the transformative policy approach further, which distinguishes itself from past policies with more radical goals. This frame is usually suitable for a range of policy mixes to achieve socio-technical transitions (Molas-Gallart et al., 2020).

The TIP approach is practical for exploring how a system should be transformed with innovative and radical policies to reach sustainable goals, to advise policy makers and to address current system failures. The approach has been developed to expedite solving the grand challenges (such as climate change) by emphasising the need for transformative policies that address the societal aspect of a new technological innovation (Steward, 2012). The focus of TIP is on a novel approach to science, technology and innovation in reaching the SDGs and building on socio-technical transitions (e.g., Geels, 2011, 2012; Geels et al., 2016).

The TIP approach has been used by scholars to analyse political and socio-economic systems and to address sustainability issues such as energy transition in Germany (Hölsgens et al., 2018) and waste management in Ghana (Akon-Yamga et al., 2021). Hölsgens et al. (2018) show how social innovations are important for a successful energy transition. They use the multi-level perspective (MLP) in analysing various social innovation projects that are aimed to accelerate the energy transition in Germany. The results show that a successful social innovation in the MLP framework must lead to a system change or have a competing or symbiotic relationship with an existing regime (Hölsgens et al., 2018).

3. Research data and methods

3.1. Interview data

The research data comprise 13 thematic semi-structured interviews with the informants representing German stakeholders with an official political, policy, regulative or personal political agenda (see Appendix 1). The first author conducted the interviews: 11 were held in person in Berlin and two via telephone. Choice of the informants was based on their backgrounds in agriculture, animal welfare and consumer protection. The interviews were conducted between January 28, 2020 and March 18, 2020 and lasted from 30 to 60 min. A similar set of questions were addressed to each of the informants (see Appendix 2 for the interview structure). The German food culture, current agricultural practices, political agendas, prospects, and challenges of cultured meat were discussed during the interviews. The informants received a background information letter on the topic before the interviews (see Appendix 3). The interviews were audio recorded, verbatim transcribed in German and translated into English by the first author.

The political and policy stakeholders' perceptions analysed in this study represent the views of significant groups that can influence both the development of and general attitudes to cellular agriculture and cultured meat. Eventually, politicians reflect the needs of their voters and policy organisations' representatives reflect their supporters' views (e.g. Chiles, 2013). These stakeholders set societal agendas, act as ambassadors for various endeavours and partly steer the usage of public funding. They are also able to start or advance development and assessment projects for or against cellular agriculture. Representatives of these stakeholder groups occupy a vantage position in societal processes such as law and regulation drafting on a regional, state and European Union levels. In addition, their work includes advancing group's interests through direct and indirect lobbying as well as negotiating or bridging the views of disagreeing stakeholders. These characteristics make political and policy stakeholders into influential groups in employing identified drivers and transformation bottlenecks to the potential of cellular agriculture in their activities.

3.2. The TIP as an interpretation theory and content analysis of the interviews

The analysis followed a theory-led approach. The interview data were coded according to the six TIP principles presented in detail in subsections 4.1–4.6. The six principles associated with the TIP framework include directionality, goal, impact, degree of learning and reflexivity, conflict and inclusiveness (Cele et al., 2020). These principles were used in analysing transformative potential of cultured meat from the informants' perspective. The informants' perceptions of cellular agriculture and cultured meat are understood here as socially constructed (Berger and Luckmann, 1966). The interviewees had not tried cultured meat or other products of cellular agriculture and therefore they co-constructed the meanings of cellular agriculture with the interviewer.

The analysis proceeded in four consecutive phases. First, the data were read through several times to obtain an overall conception of the data. This phase included an identification of the nuances regarding cellular agriculture and cultured meat. Based on the first phase, it was

decided that a sentence would be the unit of analysis: classification of singular words tended to miss the contextual meanings and paragraph-level analysis turned out to be too abstract as the informants expressed issues that were related to the several TIP principles. Second, relevant parts of the data addressing cellular agriculture and cultured meat were classified according to the six principles for further analysis purposes. Third, the sorted data were content analysed (Mayring, 2000; Schreier et al., 2012; Schreier, 2014) to identify how the informants perceived each of the TIP principles separately. Fourth, the findings describing each TIP principle were compiled together and the informants' perceptions about cellular agriculture were constructed. In this phase, the authors' constructed 22 themes (see Fig. 1).

To assess the transformative potential of cellular agriculture, the 22 themes were further classified into aggregate themes of hindering bottlenecks (*current practices, unfavourable prospects* and *threats)* and advancing drivers (*diversity and transparency, supply and retail, and external benefits)* of cultured meat development.

4. Results: the political and policy stakeholders' representatives perceptions of cultured meat

All the interviewed stakeholder representatives had heard about cultured meat, yet each perceived a transformative potential of cellular agriculture differently. Everyone indicated that their organisations did not have an official stance or a clear position about cellular agriculture or cultured meat. Therefore, they communicated personal views openly as the agreed policy formulations regarding cultured meat are not yet decided and agreed upon in the political parties or informants' organisations. In addition to expressing their personal views, all the informants based their perceptions regarding cultured meat to the mission, goals and values of their political party or background organisation (e.g., Chiles, 2013).

No clear consensus across the interviewed representatives could be identified. Even though the informants could have been grouped according to similarities in their political or policy agendas, it was not sensible to do so, because the perceptions about cultured meat tended to vary significantly. For instance, none of the informants were exclusive in their opinions: each of them agreed on some points that one would classify as "typically conservative" but also to "typically progressive" views. The informants acknowledged the positive externalities of cellular agriculture for environment, animal welfare and public health but most of them also expressed concerns about this new food technology, regardless of their political or policy agendas.

4.1. Direction of the food system's future development

Directionality focuses on alternative futures and is associated with technological design choices in the TIP framework (Cele et al., 2020).

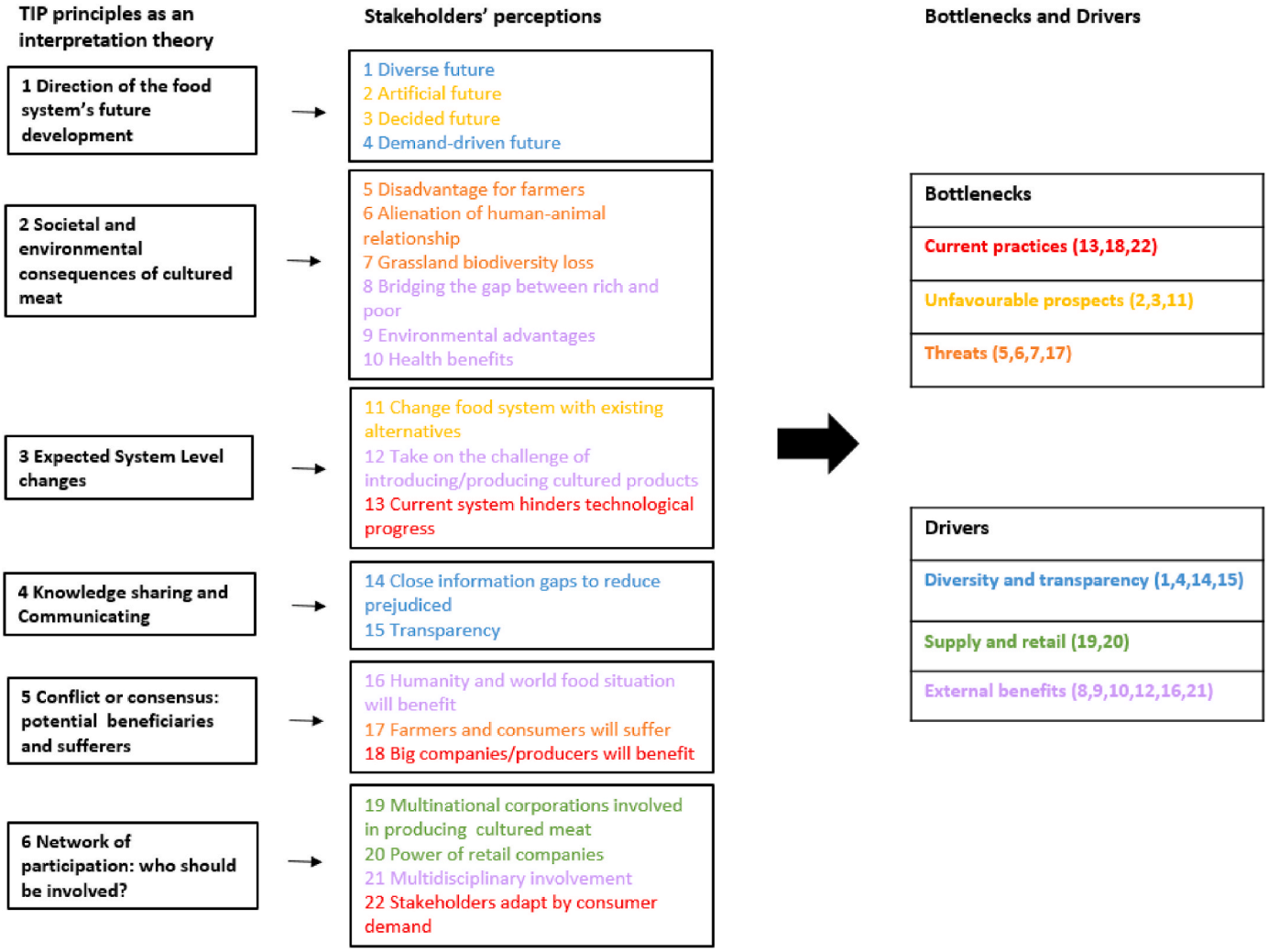

Fig. 1. The data structure: the TIP as interpretation theory, the political and policy stakeholders' perceptions and transformative potential of cellular agriculture in terms of hindering bottlenecks and advancing drivers. The colours indicate specific bottlenecks and drivers. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Questions on how the representatives conceive the development of the current food system and their perceptions of cultured meat were discussed during the interviews. The informants argued that the current food system is already developed in a direction where the product range will be more diverse, and that cultured meat would not make a notable difference. They recognised that the current meat production system cannot be sustained in the future and that alternative systems are necessary:

> "We are looking at how the meat market is going to change, and I expect that in 20 years, at least half of what is eaten will not be protein from conventionally produced meat where the animal is slaughtered. The other half will come at least either from cell cultures or from plant- based proteins." (F)

Next to the more diverse future with products of cellular agriculture described above, concerns about the artificiality of cultured meat were also discussed since food relates to supporting life and is closely linked with German agriculture:

> "I do not know if it is good for a country to feed its people with artificial products. Food has much to do with life." (B)

One informant canvassed a future in which cultured meat will have entered the market and whether grocery stores will still have a meat counter or if it will have been replaced by or called a protein counter (H). Some of the informants (D; H; J; M) tended to believe that cultured meat will not replace conventional meat and will hardly contribute to the human nutrition in the future. These informants seemed rather unimpressed: they tended not to believe in the viability of cellular agriculture.

In addition, the anticipated higher price of cultured products compared with conventionally produced foods were discussed. One informant concluded that the future will be decided by the market based on external factors such as price or regulations:

> "I honestly believe that if it simply comes onto the market in addition, it would be more likely to compete with the somewhat more expensive, ecologically and socially produced meat products [instead of factory farming]. The big question mark is how cheaply it can be produced. If you can offer it for €3.40 a kilogram, it is competition for the cheap meat products, then I would like it. Otherwise, it would be redundant." (D)

The role of markets was perceived as an important factor, having an impact on whether cultured meat or other cellular agricultural products will be successful in the future. Some of the informants foresaw that the market would regulate itself and that demand will be met one way or the other (A; C). Others anticipated an active participation of politicians in the regulation processes of cellular agriculture. The informants came up with ideas such as independent research on cellular agriculture or research funded by the state and steering the future direction of the food system development (D; I; M). One example of this "demand driven" future was anticipated by an interviewee emphasising the role of consumer choices:

> "Many things are up to the consumers. If the consumer has a certain demand, then politics is well advised to meet that demand." (A)

The informants anticipated that the future of cellular agriculture can follow various paths. Most of the informants, independent of their backgrounds, assumed that the future with cellular agriculture will be more diverse offering novel and additional food products but not replacing the conventional food production methods or the current food system. The informants also identified the future as more artificial with cultured products when compared to conventionally produced foods. In addition, the informants anticipated that the future can be decided upon in which case the regulation processes, political will and independent research would steer the development of cellular agriculture. The future with cellular agriculture was also perceived as demand driven when the consumers and markets will steer the development and acceptance of cultured meat.

4.2. Societal and environmental consequences of cultured meat

The second TIP principle addresses the preferred goals of development with the focus on societal, economic and environmental challenges (Cele et al., 2020). The societal benefits of a product such as cultured meat should entail the provision of affordable food that is environmentally and socially sustainable. The informants focused particularly on the potentially negative consequences of cellular agriculture: what might happen to the farmers, rural areas and livelihoods:

> "What do we do with farmers is an incredibly social question. What do we do with rural areas? In that case, we virtually no longer need farmers, and in Germany, we have several million of them. They can grow other things, but many things will change abruptly. And of course, we will make ourselves dependent on a food industry." (G)

Both the agricultural or traditional landscape and grassland biodiversity in Germany would be negatively impacted if livestock animals were no longer needed (F). Moreover, the informants mentioned that it is practically impossible to produce food in means other than livestock farming in the low mountain ranges:

> "Whoever thinks they could do agriculture with grassland where no animals graze any more […] we will have a humus [i.e. soil organic matter] problem sometime. That is this short-term thinking of people who have no idea about agriculture and only have their eye on climate. To see the whole thing as a technocratic operation is critical." (J)

Some of the informants acknowledged that the potential consequences of cellular agriculture will be more economic than social for farmers in rural areas. They anticipated that small and specialised farms producing high-quality products will not disappear but co-exist next to cellular agriculture (C). Moreover, positive societal consequences were mentioned by an informant who pointed out the gap between rich and poor countries that could be bridged with the development of cellular agriculture products:

> "From a global perspective, the discrepancy in meat consumption between richer and poorer countries could be bridged [provided that the prices for laboratory meat will decrease]." (I)

Several informants (G; A; E) acknowledged that the development of cellular agriculture could be generally beneficial for the environment. More specifically, freshwater protection (F) and positive effects on the human-animal relationship (K; I) were mentioned. In addition, public health benefits were discussed:

> "I believe that we need to talk more to people about the [health] benefits of this development. Because we talk a lot about why this product is good for the planet and the animals but never about if it is healthy or not. It would be great to have one document that lists all the potential benefits of producing meat in the lab. Because in the end we could even add nutrients and create 'super meat' for people who want it." (K)

The anticipated societal consequences of cultured meat were discussed in terms of farmers' and the livestock future roles in the food system, development of rural areas and livelihoods and the changing roles of the rich and poor countries. In addition, the informants emphasised the impacts of cellular agriculture to conventional agriculture, the potential landscape changes in Germany and a range of environmental and public health benefits.

4.3. Expected system-level changes

The third TIP principle considers the impacts and expected changes (Cele et al., 2020) that cultured meat could have at the food system level. In addition to food and meat supply perspectives, a systems level examination considers how and why meat is consumed, and what social practices are associated with meat. The informants' interest in the food system focused on the current agricultural practices in Germany, which were perceived as export-oriented, globally focused and politically sustained (J).

Considering cultured meat and its integration into the existing food system, responses were critical but also solution oriented and partially consensual. The informants pointed out that the need for climate action is obvious and that the current system is slowly moving towards plant-based alternatives:

> "The whole food system has to be reconsidered. This probably includes more plant-based already today. We must come up with new concepts to change agriculture today. If we make an environmentally friendly [transition] within the [current] food system, meat consumption will decrease [automatically]." (F)

In addition, some of the informants anticipated that a change would happen with or without products of cellular agriculture such as cultured meat:

> "[A future with cultured products] will bring changes. That is one of the things that I find exciting. How far the current systems can change? Agriculture is in the transition process anyway and I also believe that [conventional meat producers] should not see this as a threat, but as a challenge." (E)

Several informants (I; G) pointed out the concern of a monopoly or oligopoly entering the market in the wake of cultured meat development. The proposed solution would be to take on the challenge by introducing novel practices that use an open-source approach and are accessible for all interested:

> "Whenever a monopoly is created, we have to deal with massive consequential problems. If there is a misguided development, which means that states can be blackmailed again and therefore there is a need for many corporations. In the face of the 21st century, I believe that we have to work more with open source and that the knowledge should be shared by many brands." (I)

From another perspective, the informants criticised the fact that bureaucracy in Germany hinders system-level innovations (C) and that the current food system tends to be protective and reactive:

> "In Germany, we have to realise that we still have a lot of catching up to do and meat consumption needs to be reduced. In Germany, meat is extremely cheap. And this is very depressing for us as agricultural politicians, that meat is partly traded as junk." (A)

The informants rarely discussed an expected change in the food system but rather about challenges of the current system such as bureaucracy-related problems in Germany. They tended to emphasise how the current agriculture system hinders adoption of progressive technologies. Some of the informants acknowledged the challenges in the current system and were willing to address them by proposing solutions as a more open access approach to sharing technological innovations. Others anticipated that enough meat alternatives are already available for changing the food system: the current system is being forced to change towards more sustainable practices already with current policies.

4.4. Knowledge sharing and communication

The fourth TIP principle highlights learning and reflexivity as a process in which political stakeholders create spaces for experimentation and recognise the problems of operating routines (Cele et al., 2020). Cellular agriculture and cultured meat were recent or unknown concepts to many of the informants: although some of them are food experts, the technical processes of cellular agriculture are largely unknown to most of them. To keep up with the development of cellular agriculture, the informants argued that information needs to be communicated clearly and early enough to everyone:

> "The process of producing cultured meat is largely unknown. Information on this and the reasons for it should be communicated to consumers. Especially in the development phase, when companies and researchers are in the process of organising and starting the production process, it is important to involve consumers to close information gaps or to reduce prejudices." (I)

One informant was especially concerned that communications from the cultured meat companies is creating false hope and thus not being transparent enough:

> "One of the biggest problems is the communication because some start-ups say that their product is already available in two years and then if it does not happen, the people might lose their trust. Then investors start losing their trust and discontinue funding them." (K)

A need for clear and simple communication was mentioned by the several informants (D; G; C; H; M). They were generally concerned about the consumers' right to know what they are offered. Whilst some of them perceived proper informing as a part of consumer protection, the others considered overall promotion of cultured meat to the public. Moreover, the informants tend to appreciate sharing the information about cultured meat development and are interested in taking proactively part to the communicating processes so that the key stakeholders such as farmers are informed early enough (C). Another informant mentioned that the communication should originate from the market and that politicians should not be involved in communication measures (B).

In addition to communication actions aimed at consumers, transparency was mentioned as an important factor in the development of cellular agriculture:

> "It is important to have strict food controls, produce clear guidelines as to what may be added in such products and to exercise a high degree of transparency so that the consumers can evaluate what they are eating." (A)

Providing consumers with clear and simple communication seemed to be of particular importance for the informants. The communication could be used to educate consumers about the benefits of new products of cellular agriculture, keep them updated regarding the development of cellular agriculture and to filling in the potential information gaps that might cause unsubstantiated prejudices. The communication from the start-up companies must be up to date in preventing the creation of false hope. Transparency was also emphasised by the informants as consumers are entitled to know what they are offered and eating.

4.5. Conflict or consensus: potential beneficiaries and sufferers

Different views about what is at stake in a systems transformation can lead to conflicts but also to consensus about needed measures (Cele et al., 2020). The fifth TIP principle suggest that a disruptive change such as the food system transformation about cellular agriculture is a controversial topic and opinions about the preferred development will probably be conflicting. Most informants agreed that the development of cultured meat has a potentially positive outcome for the humanity in the future:

> "The big beneficiaries are humanity and the world food situation. I do not think there will be any sufferers, because the total amount of

protein consumption can increase dramatically. The trend of alienation [from conventional livestock products] is already here and will increase." (C)

While the previous statement seems favourable from the consumers' perspective, some informants mentioned them as being on the losing side in the cellular agriculture development. In addition to adverse impacts to current factory farming, another negative side effect would be consumers' alienation from the conventional food products perceived as natural:

"The sufferers will be the factory farms. Another side effect is that consumers are increasingly alienated from natural food production. The beneficiaries will be the companies that produce it." (J)

Some of the informants agreed that small food businesses and farmers will be in an unfavourable position if cellular agriculture products enter the markets. As most of the informants have an agricultural background, their reactions were oriented towards the farmers and the extant agricultural production system: some of them wanted to protect the small farmers and conventional agricultural practices as they anticipated that big corporations and the food retail industry will benefit the most from cellular agriculture (B). Another informant brought up the potential issues of market concentration:

"The problem with start-ups is that at some point they will be bought by the big companies anyway." (G)

The informants anticipated potential conflicts between the key stakeholders. According to the interviewees, the big food producers, the food retail businesses and partly the consumers getting cheaper meat and more selection, start-ups developing cultured meat and small-scale farmers specialising in quality products would be on the winning side in the cellular agriculture development. On the losing side would be factory farms, but adverse impact could be spread later to small-scale farmers, start-ups that are bought by the big players and also the consumers who may end up being alienated from nature and conventional meat products, which some of the informants perceived as naturally produced foods.

4.6. Networks of participation: who should be involved?

The sixth TIP principle considers the inclusiveness of all stakeholders to the transformation process (Cele et al., 2020). It is a social question of just participation and consideration of the stakeholders influenced by a potential transformation. The perceptions regarding the networks of participation varied depending on the informants' priorities and their knowledge on cellular agriculture. The informants did not have a clear opinion regarding who will be influenced and who will be involved in bringing cultured products to the market.

One of the themes discussed was the question of how far farmers could be involved in the processes of cellular agriculture. For some it seemed clear that farmers will not be involved, whereas others foresaw that farmers who have merely focused on meat production would need to confront this new development by changing their production sector or learning how to produce cultured products themselves (also C):

"I can hardly imagine farmers starting to produce laboratory meat. They will not put a bioreactor on the farm. Those are going to be big industrial plants." (M)

As pointed out in the discussion of potential beneficiaries and sufferers of the cellular agriculture development, small farms were also on the losing side once cellular agriculture products have been established in the market. Some informants perceived that big multinational food producing companies will be the main participants in the network of cellular agriculture in the end (J). The informants tended to base their arguments on their experiences in the current food system in which a handful of big companies have managed to capture the major share of the food markets. One informant pondered the role of the major German retail companies:

"[…] there is a quasi-monopoly of Lidl, Aldi, Rewe and Edeka [retail chain companies] dominating the German food market. This means that you do not stand a chance as a supplier if the four chains agree. And that is of course especially difficult for the small food producers." (C)

The concern of multinational food companies taking over the development of cellular agriculture provoked discussion amongst the informants. One of them pointed out that experts from politics to science should work together and be involved in creating a safe food future and to develop controlling systems for a faceless industry that might take over the novel field:

"Politicians should be on the same page as researchers and check whether it really is safe. Of course, you can believe the producers themselves, but you also must monitor them. The communication is still going through the scientists. Independent research should definitely take place and not just by the companies themselves." (M)

There tended to be consensus among the informants regarding the unsustainability of current meat production and consumption. Especially the younger generations were perceived to demand a change:

"One cannot ignore the fact that the younger generation, a large percentage of whom eat vegetarian or vegan food, are the decision-makers of the future. The climate crisis will put enormous pressure on us. We know that we will have to reduce the amount of animal husbandry anyway." (F)

The informants tended not to believe that conventional farmers will be the future producers of cultured meat and the main actors in the processes of cellular agriculture. Rather, they anticipated that the big industrial multinational companies would be the realistic actors in the cellular agriculture sector. The informants assumed that the big retail companies already dominating the German food market would just add cultured meat to their product range. The informants thought it important for politicians and independent scientists to be involved in the development and monitoring of cellular agriculture and they outlined the policies that would be needed for multidisciplinary involvement. Lastly, informants highlighted that farmers or food producers have to meet consumer demand and adapt to the change by altering their current production methods.

5. Discussion

The purpose of this article was to explore how the representatives of German political and policy stakeholders perceive cellular agriculture and cultured meat. We were particularly interested in analysing how they anticipated a potential transformation from the current food and agricultural systems towards a cellular agricultural system. We aimed to contribute to discussions about cellular agriculture by using the TIP approach as an interpretation theory for the data analysis.

Cultured meat is an innovative product of cellular agriculture often mentioned as having the potential to transform the future food ways. Our analysis shows that the informants do not currently consider that cellular agriculture has substantial transformative potential for changing the conventional food systems and livestock farming, but rather perceive products such as cultured meat as a novel addition to the market and as an extension to the existing meat product category. We further identified potential transformation bottlenecks and drivers of cellular agriculture based on the political and policy stakeholders' perceptions. The next few subsections summarise the findings according to the TIP principles, present the data structure (Fig. 1) and discuss the limitations of the study.

5.1. Transformative potential of cellular agriculture

According to the informants, the future development of the food system could proceed in four directions when cellular agriculture products are introduced: 1) the future could be more diverse as cellular agriculture will help to broaden the food product range available by introducing novelties beside the conventional agricultural products. 2) It could be more artificial as the products of cellular agriculture are perceived currently as being less natural than those of the conventional meat and dairy. 3) It could be decided on political or regulatory levels without individual stakeholders having a significant influence on the matter. 4) The future could be demand driven and comply with the needs and wants of the consumers and markets. These future directions anticipated by the informants are not mutually exclusive but tend to overlap.

The anticipated societal and environmental consequences of cellular agriculture are various according to the informants. In addition to various environmental, animal welfare and public health benefits of cellular agriculture, the informants discussed societal and social consequences for farmers. Similar threats, such as loss of livelihood and income for farmers or barriers of being able to transition into the alternative meat sector but also novel opportunities of cellular agriculture such as growing inputs for the emerging industry, raising animals for genetic material or producing cultured meat have been identified (Newton and Blaustein-Rejto, 2021).

In addition, a change in agricultural landscapes and hence a loss of grassland biodiversity was identified by the informants as negative consequences potentially stemming from cellular agriculture. Some of the informants fit the Green Luddite ideology (Chiles, 2013) in this context. Environmental benefits and the advancement of animal welfare issues are parts of this ideological position. Human-animal relationships were expected to develop in two directions: alienation could continue but there could be a change towards respecting farmed animals. Moreover, cellular agriculture could have a positive impact on bridging the gap between the global rich and poor and an answer to global food shortages.

Stakeholders in the Böhm's et al. (2018) study anticipated that cultured meat would increase the meat consumption and that it would be an elitist product. While the informants in our study also perceived cultured meat to be an expensive product at first, they also emphasised it having the potential to make meat available to everyone. That cellular agriculture should not be seen in isolation but rather as an additional protein source (Böhm et al., 2018) was a notion also expressed by the informants of our study.

The expected system level changes were also addressed by the informants. Some of them anticipated that there would be no need for cellular agriculture products as the current food system should be changed with already existing meat alternatives and plant-based foods. The informants perceived the food system stakeholders as proactive and willing to participate in the transformation introduced by cellular agriculture. Changing the system by proposing solution-oriented tools from open access approach to innovations and public research available to all interested would require active work. The informants tended to perceive that the structures of the current food system are hindering potential transformation progress due to existing power relations and bureaucracy. Decision-makers tend to comply with the agricultural lobby and act in favour of farmers, which was perceived as unsustainable practice by some of the informants. Just as policymakers cannot be beholden to producers of fossil fuels, they also cannot be beholden to factory farms.

Communication regarding cellular agriculture was perceived as an important aspect by the informants. Transparent communication of the novel production methods and careful consideration of all the stakeholders influenced by the potential development of cellular agriculture tended to be key factors in ensuring a smooth transformation. Closing the information gaps and promoting the benefits of cultured products were emphasised. Moreover, the informants in our study suggested that fact-based educating and guiding measures aimed at the decision-makers as a functional way to promote transformation. This was perceived as a participatory action in which the decision-makers could communicate the processes in a qualified way to the public. A study suggested that stakeholders' perceptions tend to be multifaceted as some favoured cultured meat while others preferred switching to plant-based products (Böhm et al., 2018). Moreover, the results of that study showed that the stakeholders perceived cultured meat as being unnatural. Our results align with these results and extend the discussion by presenting how the perceived unnaturalness could be overcome with better understanding and communication by stakeholders.

A system level transformation tends to benefit certain stakeholders whilst others may encounter adverse consequences. Identifying these potential beneficiaries and sufferers in the development of cellular agriculture raised conflicting perceptions. The informants specified consumers and farmers being potentially on the losing side. Consumers were placed on the losing side mainly for two reasons: their alienation from the conventional food systems perceived as "natural" was anticipated to increase due to "artificial" cellular agriculture and it was implied that consumers might not understand what they buy even if the products of cellular agriculture are properly regulated and labelled. The informants addressed the role of farmers as they might be in a disadvantageous position when products of cellular agriculture reach a mass-market stage: farmers are potential sufferers in the cellular agriculture development as they were anticipated to be replaced or disregarded by multinational companies potentially producing cheap cultured meat.

In this respect, the informants' perceptions align with previous findings from the US where the threat of a few big companies was expected to overtake the development of cellular agriculture (Newton and Blaustein-Rejto, 2021). However, some of the informants in our study foresaw niche markets for high-quality conventional meat products and opportunities to engage in small-scale cultured meat production in advanced farms. Paradoxically, some of the informants placed consumers as beneficiaries as well as start-up and large food companies, retail businesses and smaller but specialised food producers, which would have an advantage in a transformative setting. The German stakeholders prioritising the technological development of cellular agriculture or embracing the Techtopian ideology (Chiles, 2013) reasoned that development of cultured meat could benefit humanity and the world food situation.

The informants had varying perceptions regarding the network of participation and who should participate in the development of cellular agriculture. The perceptions ranged from a country level regulators' proactive involvement to a passive adaptation to the future consumer demand. In between these active political steering efforts and passive acceptance of market driven development, the informants perceived that the German state should support independent research, all the key stakeholders should be encouraged in sector-crossing multidisciplinary development and multinational corporations should be obligated to share information and participate transparently to the joint process of the food system transformation. Several of these points were discussed in terms of developing the current food system, not only a potential transformation initiated by cellular agriculture. A recent study by Chiles et al. (2021) also highlights the benefits of democratising ownership of cellular agriculture to create a fairer transition.

The informants' perceptions and anticipated bottlenecks and drivers of transformative potential are summarised in the data structure presented in Fig. 1.

5.2. Bottlenecks and drivers: transformative potential of cellular agriculture

5.2.1. Bottlenecks of cellular agriculture progress

The bottlenecks represent themes that could slow down the development of cellular agriculture and therefore reduce its transformative

potential. The first bottleneck is *current practices*. The bureaucracy encountered by new technologies and other innovations tend to slow down progress. Moreover, the current power relations and advantages that big companies have already achieved can move the development in unexpected directions. These stakeholders might prefer status quo and support the current food system structures instead of promoting or investing in products of cellular agriculture.

The second bottleneck is *unfavourable prospects*, which were anticipated to hinder the progress of cellular agriculture. For instance, a food future perceived as more artificial than natural has a negative connotation and is not desirable whereas the future of cellular agriculture left to decision-makers might lead to complicated regulatory processes or banning of cultured meat. The informants mentioned a decided future specifically as a bottleneck, even though it could also be a driver when decisions are made to promote cellular agriculture. Lastly, an alternative pathway to more sustainable food system in which plant-based products would be preferred would simply diminish the progress of cellular products such as cultured meat.

The third bottleneck is *threats*, which refers to societal disadvantages of a transformation to cellular agriculture (e.g. Newton and Blaustein-Rejto, 2021; Helliwell and Burton, 2021). Novel development paths have a positive connotation for some but dismiss other stakeholder groups such as farmers. The potential threats might be used as arguments against cultured meat. Emergence of this novel food sector might also launch an anti-cellular agriculture mass movement as happened before with genetically modified food in the US and the EU (Mohorčich and Reese, 2019).

5.2.2. Drivers of cellular agriculture progress

The drivers of cellular agriculture could advance progress and therefore increase its transformative potential. The first driver is *diversity and transparency*. Products of cellular agriculture will potentially expand the protein options available for consumers in the future. More options to choose from have been traditionally perceived as a necessary condition for functional and competitive markets. Consumers' potential acceptance of cultured meat will also create markets and demand for cultured products. However, extrinsic and intrinsic product attributes such as price, availability, taste, appearance and texture will partly define whether cultured products are accepted or not. Market success of cultured meat could be also advanced by communicating all sides of cellular agriculture development and presenting production technologies transparently to the public.

The second driver is *supply and retail*. The involvement of established corporations in the production of cultured products could significantly accelerate bringing them to the market. The same argument is valid for the big retail companies in Germany as they currently distribute market and sell most of the food and consumer goods. The informants also tended to perceive the power of the established food production corporations and the retail companies pessimistically: they anticipated that big organisations might overtake the development and markets of cellular products while creating pressure on smaller companies. However, success in the highly competitive and global food markets is capable of producing vast quantities of quality products with a price point comparable to conventionally produced foods.

The third driver is *external benefits* such as environmental advantages, health benefits and advances in humanity and the world food situation. They represent a set of positive impacts cellular agriculture could produce on a global level. These drivers are geared towards the common good and create a motivation for the development of cellular agriculture.

Prior research has suggested that the optimistic promise of reducing climate change impacts will most likely not be achieved via cellular agriculture (Stephens et al., 2018). These researchers pointed out that producing cultured meat on a large scale could take decades if it were possible at all. Moreover, the motivations of cellular agriculture start-ups tend to stem from creating an environmentally beneficial and animal ethically improved product, but it is unclear if these benefits are embedded within the technology (Stephens et al., 2018). Our results show that the informants tend to believe that the current German food system would not actively support the development of cellular agriculture. However, they also addressed a range of drivers that could advance the development of cellular agriculture.

6. Conclusions

The development of cellular agriculture and products such as cultured meat is at an early stage. Analysing the transformative potential of the novel food technologies and products of cellular agriculture are timely as their successful introduction and reception depends on social, societal and cultural issues such as acceptance by key stakeholder groups. The transformation from the current food system to a cellular agricultural system is characterised in our study by bottlenecks such as hindrance from current practices, unfavourable prospects and severe threats. But as well as advancing drivers such as promoting product diversity and transparency of communication, our study identified opportunities in supply and retail, and wider external benefits such as environmental and public health improvements and advancement of humanity in general.

The drivers for transformation identified in this study describe positive factors that could advance the development of cultured meat in Germany from the political and policy stakeholders' perspective. These include a need for public funding sources and public support for cellular agriculture development. Although the informants anticipated drivers and promising prospects for cellular agriculture, they also emphasised several bottlenecks that could hinder the transformative potential of these emerging food technologies. Bottlenecks such as unwanted artificial food futures or disadvantages potentially created for certain stakeholder groups such as farmers represent challenges that need to be addressed while developing cellular agriculture.

The novel findings of this paper are that the informants perceive cultured products as an addition to the market rather than a transformative movement. Moreover, their knowledge of cellular agriculture was limited and none of the political parties or organisation the informants represented had an official stance towards cellular agriculture. In addition, the informants of this study anticipated that the markets would have a substantial role in deciding whether the products of cellular agriculture will be successful in the future.

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Author contributions

JM was the responsible for the research design, collection of the data, analysing the data, writing the first draft and writing the final version. TR acquired funding, took part in research design and analysing the data, commenting the first draft and final version of the paper. HT contributed to funding acquisition, study design, supervision of the work and commenting on the drafts.

Declaration of competing interest

The first author is a co-founder of CellAg Germany, a non-profit organisation aiming to accelerate the development of cellular agriculture in Germany.

Appendix 1

List of interviewees.

Identification letter (A-M)	Organisation	Position	Interview date/length
A	Political party (CDU)	Member of Parliament	March 09, 2020/60min
B	Political party (AFD)	Member of Parliament	March 04, 2020/60min
C	Political party (FDP)	Member of Parliament	March 05, 2020/60min
D	Political party (Linke)	Member of Parliament	March 11, 2020/60min
E	Political party (SPD)	Member of Parliament	March 12, 2020/60min
F	Political party (Gruene)	Member of Parliament	March 18, 2020/30min/Telephone interview
G	Political party (Linke)	Representative of the committee of consumer protection	February 27, 2020/60min
H	Ministry of Agriculture and Nutrition (BMEL) Bundesministerium für Ernährung und Landwirtschaft	Group leader	06.03..2020/60min
I	Scientific Institute (IZT) Institut für Zukunftsstudien und Technologiebewertungen	Senior Researcher	March 11, 2020/60min
J	Environmental NGO Forum Umwelt und Entwicklung	CEO	March 03, 2020/60min
K	Environmental and Animal Welfare NGO - Pro Veg	Sub Pro Veg Branch (in validation phase); Project of Pro Veg	January 28, 2020/60min/ Telephone interview
L	Environmental NGO - Germanwatch	Project leader	March 13, 2020/60min
M	Private Person	Author and Filmmaker	March 07, 2020/30min/Telephone Interview

Appendix 2

Interview Questions.

1. General starting questions.

1. Can you briefly describe your education, work experience and an area of representatives?
2. Have you heard about cellular agriculture and cultured meat before?
3. What is your first reaction and personal opinion about cultured meat?

2. General questions related to cellular agriculture.

Does your organisation have a general - implicit or explicit – position towards cellular agriculture or cultured meat? (Or innovative food technologies in general?)

What concerns and challenges come to your mind when you think about cellular agriculture?

Will it pose a threat to the food system, food production or traditional farming?

What are the biggest barriers of bringing it to the market from your point of view?

What are in your opinion food safety concerns?

Do you see a risk of food fraud with cellular food?

What cultural impact could this new development have in your opinion?

3. Political questions (national level)

Can you describe your political agenda in a few words? What are most important values and beliefs from your parties' perspective?

Does your organisation have a political agenda? If yes, can you describe it and its most important values from members' perspective?

Does the concept of cellular agriculture or cultured meat fit into your or your party's/organisations political agenda?

Would you promote this new development? Does it comply with the needs of your voters or party's/organisation's members?

4. Policy questions (national and EU level)

What would it take to provide free government sponsored training and support for small-scale producers who wish to transfer to cultured meat production?

Should cellular agriculture producers be entitled to EU and/or national agricultural subsidies? If yes, what kind and how could it be arranged?

How do you think would a first step towards a national policy of cellular agriculture look like? Who do you think would or could initiate it?

5. Regulatory questions.

How do you anticipate cellular agriculture will be regulated in the EU?

In your opinion, how should cellular agriculture products appear in the supermarket, for example? (e.g., labels and naming. If alternative products replacing meat, how should it be communicated?)

6. Summarising questions.

Who do you think will be the winners and losers in this new development?

Lastly, based on our discussion, how do you see the future (the year 2040 e.g.)?

Are there any other comments you wish to add that we have not discussed yet?

Appendix 3

Background Information provided to the stakeholders

Future food production will encounter many open questions and challenges that need to be addressed at an early stage with long-term solutions in mind. Some of the most apparent challenges are the discussions about excessive meat consumption. Solutions for saving the environment and feeding almost 10 billion people by 2050 are needed. Some of the most innovative ideas for future protein production include insects, algae, various plant-based proteins but also cellular agriculture. Cellular agriculture refers to a novel food production sector in the post farmed-animal bioeconomy defined as a new field utilising cell culturing technology, stem cell biology and in some cases synthetic biology and genetic engineering for producing animal products without using animals. One product of cellular agriculture is cultured meat which means that animal cells are placed under a growth medium and grown in a bioreactor. It is theoretically possible to produce most animal products such as meat, dairy and eggs in a laboratory with this technology without harming animals. Other potential advantages include reduced greenhouse gas emissions, less land and freshwater usage.

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