Master Thesis

The Development of a Responsible Cultured Meat Innovation System in The Netherlands

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November 30th, 2020

Executive summary

Background

As of today, many people are aware of the negative impacts of eating farmed meat. The current farming system is a burden on the environment and animal welfare, as well as a potential threat to human health. Moreover, to secure food for our growing society, a change in the current food system is inevitable. Since people are still hesitant to cut meat out of their diets, this asks for a more sustainable production of meat. We can think of improving our current farming system. However, new technologies can offer more efficient and sustainable alternatives to the (improved) existing farming system. Potential alternatives are (hybrid) plant-based and insect-based alternatives or cultured meat (CM). In the basis, CM is exactly the same product as farmed meat, but more sustainable and harm-free.

Problem statement

Many academic research has already been published on CM over the past few years. These papers mainly describe either the technical aspects, consumer acceptance, ethics, and/or environmental impact. The focus has rarely been on describing the entire socio-technical context of CM, and the formation and subsequent functioning of a future CM industry. This, while deep changes of the socio-technical system are required to succeed in developing CM. Therefore, this research aims at mapping out the Dutch socio-technical system of cultured meat, in order to evaluate the development of the socio-technical system.

Research approach

This research aims at answering the question: '*How has the Dutch socio-technical system of cultured meat been developing and under which circumstances could it grow?*'. In finding an answer to this question, a framework combining the functions of innovation system (FIS) approach and the multi-level perspective (MLP), is utilized. To complement the lack of focus on actor values and strategies of an integrated FIS-MLP framework, analysis of actor strategies and actor values are separately integrated in this model. Information is retrieved from a combination of desk research and expert interviews.

Results

In the first part of the research, the Dutch cultured meat innovation system has been analysed in terms of its structural and functional components. The Dutch CM scene is still in its infancy. The technology is still strongly evolving – mostly at the two Dutch CM start-ups Mosa Meat & Meatable – , the networks are still small, little amount of suppliers are in sphere, and no product is on the market yet. Looking into the functioning of the system, no central guidance is present in the Dutch CM system, while this is important to align the visions and actions of key stakeholders. Moreover, lobby activities are limited, while these can be crucial in increasing the legitimacy of the technology.

In the second part of this research, the strategies of the actors in and around the innovation system have been explored. First, the recent developments on landscape and regime levels have been determined, followed by the identification of actor strategies and actor values. Over time, an increase in landscape and niche pressures on the embedded regime actors for sustainability, animal welfare and health transitions can be observed. This forces the strongly embedded actors to reconsider their activities to stay relevant in business and to avoid being completely overtaken by more sustainable niche transitions as CM. The CM sector is no longer government funded, but fully dependent on private investors. This caused the research to shift from universities to the two start-ups, who keep their research highly confidential. This also causes the CM research and values within this research of actors to diverge. All discussed actors recognize the importance or need of increasing sustainability and

animal welfare, but their view on how to achieve this significantly differs. Ranging from improving current farming system to meat alternatives as CM.

Conclusion

The environmental benefits of CM remain to be proven, but the experts are clear: something has to change in our current way of farming to reduce the burden on the environment. The opinions of experts on how this sustainability should be introduced into the Dutch meat sector widely diverge from improving the current farming system to switching to radical innovations as CM. For now, the embedded farmed meat system, as well as the high competition with other upcoming meat alternative niches, puts up some major challenges ahead for CM. Altogether, the development of the Dutch CM scene and subsequent industry, requires more time and more money to do research.

Recommendations

By collecting and coupling the outcomes of all the research parts, the elements blocking or facilitating the development of the Dutch cultured meat innovation system have been identified. Based on these analysed system problems, recommendations have been composed for policy makers and the industry. Policy makers are recommended to develop a long-term vision on the meat sector, stimulate the sustainability of the meat sector by subsidies, grants or projects, stimulate multi-disciplinary projects, and lastly, stimulate education on meat alternatives. Industry is recommended to collaborate with the embedded meat sector, form alliances, increase their lobby activities, use landscape changes to their advantage and educate society.

Contents

List of Abbreviations

CM	Cultured Meat
EFSA	European Food and Safety Authority
EU	European Union
EZ	Ministry of Economic Affairs
FIS	Functions of Innovation System
IS	Innovation System
LNV	Ministry of Agriculture, Nature and Food Quality
MLP	Multi-Level Perspective
NGO	Non-Governmental Organization
NVWA	Dutch Food and Safety Authority
R&D	Research and Development
RRI	Responsible Research and Innovation
TIS	Technological Innovation System
TSIS	Technology Specific Innovation System
TU/e	University of Technology Eindhoven
UM	University of Maastricht
UU	University of Utrecht
UvA	University of Amsterdam
VWS	Ministry of Health, Welfare and Sport
WUR	Wageningen University and Research institute

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1. Introduction

As early as 1.5 million years ago, pre-human ancestors were found adapted to eat meat (Domínguez-Rodrigo et al., 2012). Since then, meat has always been a central part of the human diet. Around 1817 dietary choices were first connected to higher social and political aims, raising ethical consumer awareness and starting the first vegetarian movement (Shprintzen, 2011).

As of today, many negative impacts of eating meat have extensively been described in literature. Meat consumption is accountable for approximately 13% of the total European greenhouse gas emissions, represents the largest anthropogenic land use and is a key player in water depletion (Tukker, Eder, & Suh, 2006) (FAO, 2006). Moreover, the negative impact of meat on human health has widely been described, as well as the scarcity of land left for livestock usage (Thornton, 2010; World Health Organization & World Health Organization/Tufts University Consultation on Nutritional Guidelines for the Elderly (1998 : Boston, 2002). One solution to this problem could be, to cut meat out of people's diet. However, in 2013, De Boer et al. only found a minority (5-18) of their participants willing to completely cut meat out of their diet (De Boer, Schösler, & Boersema, 2013). This can be traced back into either personal, cultural and/or social values (Macdiarmid, Douglas, & Campbell, 2016). Therefore, our modern society asks for a safe, affordable, and more environmental friendly alternative, which still meets the needs of the consumer and the demands of the citizens for a high quality and animal friendly product (Hocquette, 2016).

We can think of improving the existing farming methods, reducing food wastage or eating more diverse meat sources. However, new technologies can offer more the advantage of an more efficient and sustainable alternatives to the (improved) existing farming system (Hocquette, 2016). One sustainable alternative, could be to replace the meat with a plant-based diet, with plant-based meat alternatives. The environmental advantages of these products have been proven, but people are still hesitant to cut meat out of their diets (Graca, Oliveira, & Calheiros, 2015). In 2013, Vanhonacker et al., found Flemish consumers more willing to eat meat hybrids, in which part of the meat is replaced by plant-based ingredients, than an entirely plant-based alternative (Vanhonacker, Van Loo, Gellynck, & Verbeke, 2013). Moreover, edible insects could offer a more sustainable alternative. However, especially in the Western world, major negative perceptions surround eating insects (Van Huis et al., 2013). Lastly, another alternative is cultured meat (CM). This technique is based on the proliferation of animal's satellite cells (adult stem cells), which can still grow into the desired cells to most closely mimic the taste and texture of farmed meat. (Post, 2014). CM offers several environmental advantages compared to farmed meat: it has 99% lower land use, 78-96% lower greenhouse gas emissions, 7-45% lower energy use and 82-96% lower water usage, depending on the animal compared to farmed meat (Hanna L. Tuomisto, 2011). Additionally, the production of CM is proven chemically safe, genetic modifications are not required and it reduces the chance of animal-to-human diseases (Zuhaib F Bhat, 2011). Despite those advantages, CM is still in its infancy, and several technological and regulatory challenges are to overcome (Post, 2014).

1.1. Problem statement

Many academic articles have been published on different aspects of CM, including the technique, consumer acceptance, ethics and its sustainability. However, the CM industry itself, coupling all those different aspects, has to my knowledge not been analyzed in current literature yet. This, while radical changes as the transition to CM, require deep changes of its socio-technical system. When we bring together all those separate parts (e.g. technical, ethical, institutional, political, economical) in one analysis, can we point out the factor(s) that are hindering or facilitating the development of the CM industry? Can the transition towards CM be influenced or even steered by the system? Therefore, mapping the CM industry itself, would be a valuable addition to the currently available CM research.

On top of bridging this research gap, a clear social interest can be pointed out to bridge. At least in the nearby future, research outcomes emphasize that society won't be willing to completely cut meat out of their diets. The option of CM would bridge the gap between completely removing meat from the human diet for environmental concerns and then only being able to eat plant-based/vegetable products. For this, this research could also bridge an academic gap. By involving the potential consumers for CM, the consumers could become more aware of the innovation process and the possibilities it has to offer for them.

In order to couple all the different aspects of a potential CM industry, an innovation systems approach will be utilized. Moreover, to analyze the sociotechnical system, its hindering factors and bridge an academic gap, values of the actors in the system are key. Coupling this to responsible innovation and actor strategies, could lead to new insights for further development. Therefore, the systems approach is supplemented with an analysis of the strategies and values of the actors in the system, to determine the opportunities and bottlenecks of the CM innovation system.

1.2. Research questions

In this research, the socio-technical system of cultured meat will be explored. More specifically how this system can hinder or facilitate the development of cultured meat in The Netherlands. This leads to the following main research question:

How has the Dutch socio-technical system of cultured meat been developing and under which circumstances could it grow?

In order to answer the main research question, additional sub-questions have been formulated to cover areas of the research that need some more in-depth research. These questions will eventually guide towards answering the main research question.

SQ1: What does the Dutch cultured meat innovation system look like?
SQ2: What are the opportunities and bottlenecks for the development of the Dutch cultured meat innovation system?
SQ3: How have strategies and values of the different actors evolved over time and how has this influenced the development of cultured meat in The Netherlands?
SQ4: How can the opportunities and bottlenecks be managed and by who, to facilitate the development of the Dutch cultured meat innovation system?

1.3. Research approach and scope

To bridge the aforementioned theoretical and educational knowledge gap, a systemic approach would be well-suited. A system approach implies that innovation is a joint activity, involving a large number of actors with different interests and perceptions, and does not only occur through the innovating entrepreneurs (Twomey & Gaziulsoy, 2014). Thereby, a systemic approach not only takes into account the innovating firm and its shareholders, but also other stakeholders as policy makers, authority and consumers, which is valuable for a technology which strongly depends on their environment and innovation system, as cultured meat. With such a systemic approach, the potential influence of the different stakeholders on the development and diffusion of the new technology can be determined (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008). Moreover, a systemic approach has proven its usefulness as a framework for studying the development of new technologies in the past (Tziva, Negro, Kalfagianni, & Hekkert, 2019).

In this study, the scope will be narrowed down to The Netherlands. The Netherlands makes for an interesting place of research, due to the fact that meat substitutes are already part of the diet of many Dutch consumers, as well as the openness of the Dutch consumers to innovation and its leading status in agricultural innovations (Shin, 2014; Weinrich, 2019). This work narrows down into work of Rabl, who assessed the CM innovation systems in the US and Europe (Rabl, 2020). On top of that, much of the cultured meat research is published in The Netherlands. Scopus database results for “cultured meat” show The Netherlands as the third most publishing country, closely following the leaders The United States and The Unite Kingdom. Moreover, The Wageningen University and Research Centre has the highest amount of cultured meat publications of the universities.

1.4. Relevance to master programme Management of Technology (MoT)

In this research, the development of a technical innovation is central. Understanding of the cultured meat technology as a corporate resource and how to organize this process of is key in its further development. This requires a systemic approach, which takes into account the socio-technical context of the innovation. By exploring the socio-technological system of cultured meat, a strong focus is on dealing with stakeholders and society, making for a complex task that includes a technical component and has a strong focus on society. Instead of only adapting a ‘market pull’ or ‘technology push’ point of view, in a systemic approach the feedback from its environment can be interwoven in the innovation process. To take the socio-technical context into account, is highly important for a technology as cultured meat, for which its success strongly depends on the willingness of society to embrace the innovation outcomes. Therefore, responsible research and innovation is also an important aspect for its potential success. Moreover, a successful innovation process is also essential from an economic point of view. Successful innovation is viewed as one of the major drivers for economic growth. A direct link between economic growth and the amount of innovation through patents, publications, technology export, and R&D activities can be found for The Netherlands (Maradana et al., 2017). By taking into account major topics as discussed in the MoT-programme, namely innovation from a technology to a corporate resource, as well as coupling this to responsible innovation and economical opportunities and development, this research is well connected to the MoT-programme.

1.5. Thesis structure

In the first part of Chapter 2, more background information will be provided on the different meat alternatives, followed by a description of the relevant frameworks in the second part. In Chapter 3, the research methods are discussed. This entails the research design and approach, as well as the validity of the research, data collection and analysis. Chapter 4 and 5 comprise the innovation structure and functioning respectively. Chapter 6 contains explores the actor strategies of the actors within and around the innovation system. Chapter 7 contains the last research part, coupling the previous research parts to identify the opportunities and bottlenecks for the CM innovation system. Chapter 8 contains the discussions. Lastly, conclusions and recommendations will be drawn in Chapter 9.

2. Background

2.1. Conventional farmed meat

Meat is considered as an excellent source of macronutrients (fatty acids and amino acids) and micronutrients (minerals and vitamins). Therefore, meat is still highly valued around the world, and the percentage of people choosing not to eat meat is relatively small (2-10% in developed countries) (Bohrer, 2017). Meanwhile, along with the growing human population, the global meat consumption keeps rising (Figure 1) (Godfray et al., 2018).

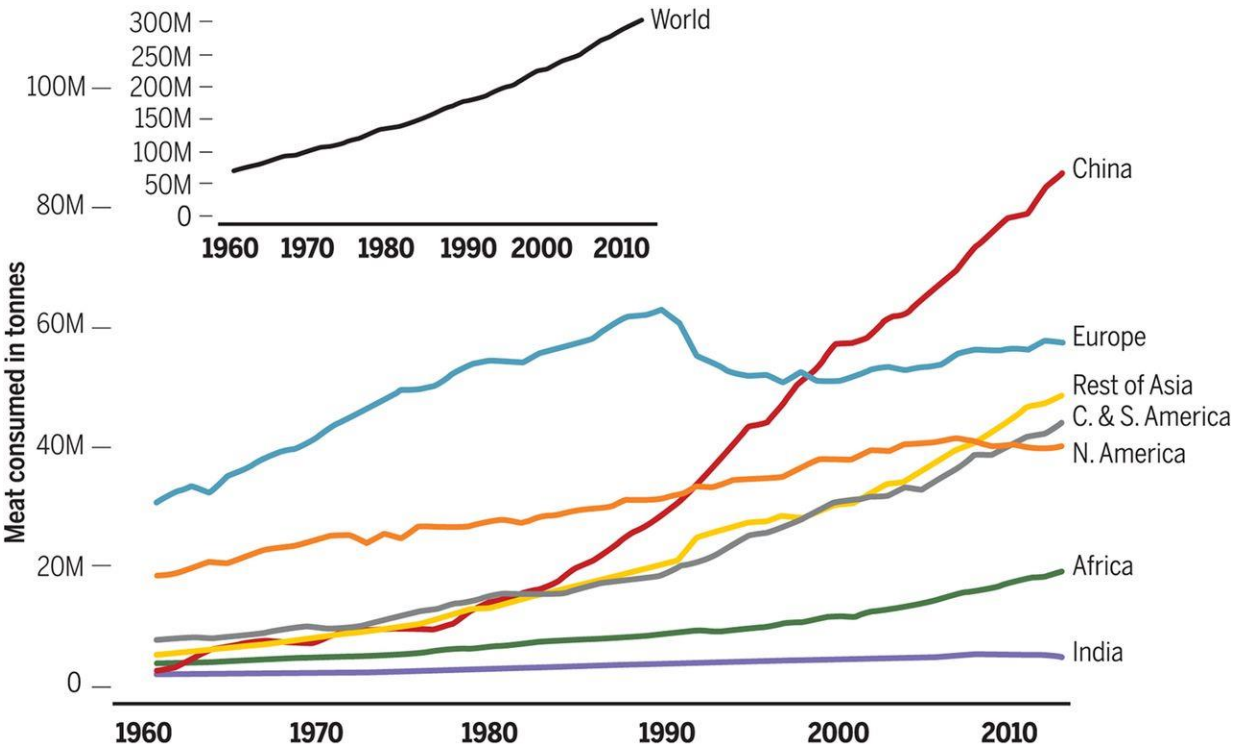

Figure 1 Meat consumption in tons over time for different parts of the Despite its nutritional value, many negative impacts of eating – and farming – meat have extensively been described in literature. These environmental impacts include emission of greenhouse gas, land use and water depletion (FAO, 2006; Tukker et al., 2006). Following the increase in global meat consumption, the negative impacts on the environment also increase. Moreover, consuming farmed meat is associated with health issues as diabetes, cardio-vascular diseases and different types of cancer (World Health Organization & World Health Organization/Tufts University Consultation on Nutritional Guidelines for the Elderly (1998 : Boston, 2002).

In 2019, Clark et al. compared the environemental and health impact of several food groups. Both the environmental impact, based on 5 environmental indicators: GHGs, land use, eutrophication, acidification and water use, and health impact were found significantly more negative for processed and unprocessed red meat (Figure 2).

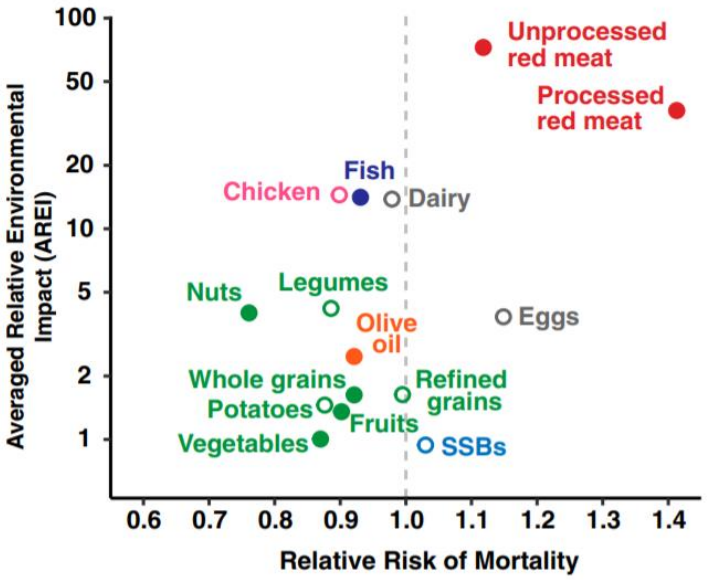

Figure 2 Averaged Relative Environmental Impact (AREI), *based on 5 environmental indicators: GHGs, land use, eutrophication, acidification and water use, and Relative Risk of Mortality of different food groups. Closed circles are associated with a significant change in risk of mortality, while open circles are not.*

Besides the challenges to keep up with the growing meat demand, the environmental and health impact, the use of antibiotics forms another negative impact of farmed meat. The use of antibiotics in animal farming is connected to increasing antibiotic resistance in humans, causing a decline in the effectiveness of treating bacterial infections. Although many countries (OECD countries and China) have set a not legally-binding target to reduce antibiotic use to 50 milligrams per kilogram of meat production, multiple countries are still exceeding this target (Figure 3)(Van Boeckel et al., 2017).

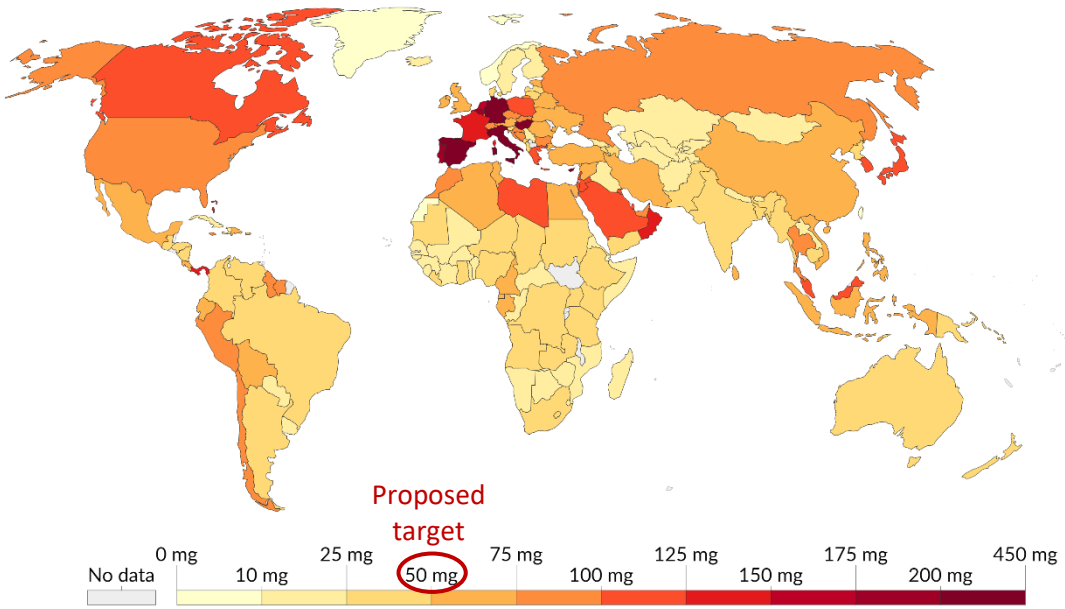

Figure 3 Antibiotic use in livestock in 2010 (Van Boeckel et al., 2017)

2.2. Meat alternatives

Due to the rising concerns about farmed meat, different meat alternatives have already or are making their way to the market. These meat alternatives are suggested to be more sustainable than farmed meat, while still offering a nutritional value (Van der Weele, Feindt, Van der Groot, Van Mierlo, & Van Boekel, 2019). The main meat alternatives to be distinguished here, are: cultured meat, plant-based meat, hybrid meat and insect-based alternatives.

2.2.1. Cultured meat

Milestones of cultured meat

In 1931, Winston Churchill already shaped the idea of producing meat in the laboratory in his essay "Fifty Years Hence" (Eschner, 2017). More than sixty years later, researchers discovered the potential of producing cultured meat, and Willem van Eelen received the first patent for industrial scale production of '*in vitro'* meat (Van Eelen, 1998). Not much later, in 2000, Jon Vein obtained the patent for the production of tissue engineered meat from muscle and fat cells for human consumption (Vein, 2000). In 2005, for the first time, an article about cultured meat, received considerable amount of media attention (Z. F. Bhat, Morton, Mason, Bekhit, & Bhat, 2019; Edelman, McFarland, Mironov, & Matheny, 2005). To further encourage research to cultured meat, The People for the Ethical Treatment of Animals (PETA) organization organized a contest to produce the first 'in vitro' chicken between 2008 and 2014. The first participating organization that would produce the chicken, would receive 1 million dollar (PETA, n.d.). In 2009, Mark Post was the first person to synthesize cultured meat (Rogers, 2009). Four years later, in 2013, the first lab-grown burger by Mark Post was presented and tasted in public. The burger consisted of only muscle tissue, thereby lacking the taste of regular 'fat' meat (BBC News, 2013). This first burger, had a price of $325,000. Only two years later, Mark Post announced that this price had already dropped below $12 (Schwartz, 2015). After two government funded projects in the early 2000s, government funding was cut, and the amount of CM research at the universities significantly decreased. This technological research later shifted towards the two Dutch start-up companies: Mosa Meat and Meatable. The concept of synthesizing meat, has already been written down in EU and US regulations. In January 2018, the EU novel food regulation was published, describing that cultured meat can be marketed, as long as regulators conclude that the food is safe, nutritionally equivalent to preceding products and not misleading to consumers. New potential products within Europe, as culture meat, have to apply for this novel food regulation (European Union, 2015). Recently, in March 2019, The Food and Drug Administration (FDA) and The United States Department of Agriculture (USDA) joined their forces in the regulation of cultured meat in The US. The document sets the same main requirements as the European Union, namely that the novel food should be ensured 'safe, wholesome and unadulterated' (FDA & USDA, 2019). Despite the regulations forming, the technical feasibility and market acceptance still need to be ensured, before cultured meat can reach the public.

Technology and feasibility

In the process of synthesizing cultured meat, notable bottlenecks remain. Usually in bioreactor work, cells are solely used as production hosts and their products are of interest, as in for instance vaccine production. The challenge in cultured meat research, is that researchers are not aiming at the cell's secreted products, but at the cells itself. Therefore, the first major technical step to take, was to develop tissue engineering growth technologies and suitable bioreactors (Stephens, King, & Lyall, 2018). Cell-based therapy preceded cultured meat in this challenge. Similar to cultured meat production, cell-based therapy technology also aims at the cell itself as final product. Therefore, many techniques can be altered from cell-based therapy technology to fit cultured meat production, as cell line development, scaffolding materials and optimizing cell culture media. Much progress has been

made on how to mimic the specific structure and taste of meat. In 2011 and 2012, research papers of Bhat et al. and Post respectively received quite some attention. In these papers the challenges of producing cultured meat at that time were discussed, namely: (1) selecting proper stem cells, (2) optimizing culture media for growth, and (3) growing long muscle fibers (Zuhaib F Bhat, 2011; Post, 2012). Major steps have been made in developing cell lines, defining a culture media and the ability to grow long muscle fibers, resulting in a cultured meat burgers that consists of all kinds of tissues as fat-cells to better mimic the taste of farmed meat (Chriki & Hocquette, 2020). However, developing affordable animal-free culture medium, edible or biodegradable scaffolds, and large-scale bioreactors for the production of intact tissue are still the major challenges today (Li et al., 2020; Specht, Welch, Clayton, & Lagally, 2018). These challenges can be traced back in latest research, where Rubio et al., Ikeda et al. and Verbruggen et al. investigate new microcarriers and scaffolds for the attachment of growing tissue fibers (Ikeda & Takeuchi, 2019; Rubio, Fish, Trimmer, & Kaplan, 2019; Verbruggen, Luining, van Essen, & Post, 2018). Subsequently, Ding et al. and Li et al. focus their research on the large scale cell expansion, and Okamoto et al. and Simsa et al. on the development of cell culture media (Ding et al., 2018; Li et al., 2020; Okamoto, Haraguchi, Sawamura, Asahi, & Shimizu, 2019; Simsa et al., 2019). Together with the technical feasibility, the economic feasibility should be considered. Research has to be performed on the cost effectiveness of the technology to evaluate its full potential (H. F. Bhat, Kumar, & Fayaz, 2015). While small-scale, more local production offers its advantages as more close contact with cell-donor animals, from an economical perspective this remains a major challenge (van der Weele & Tramper, 2014).

Environmental and health impact

First research indicates that cultured meat has lower land use, greenhouse gas emissions, energy and water usage, compared to farmed meat (Hanna L. Tuomisto, 2011). However, the environmental gain, largely depends on the amount of purification and processing steps required in the final process, since those processes require considerable amounts of energy and chemicals. Due to the fact that the large-scale process for cultured meat has not been fully established yet, the specific environmental gain of cultured meat compared to farmed meat, remains to be determined (Mattick, Landis, Allenby, & Genovese, 2015; Van der Weele et al., 2019). Another aspect complicating the prediction in environmental gain, are the fact that the animals are not only used for their meat, but also for co-products as leather, cosmetics, milk, fertilizers, and other chemicals. This would either mean that (part of) the current livestock is still required for those products, or that alternative technologies are required for production of those co-products (H. L. Tuomisto, 2019). Latest research concerning the environmental impact of cultured meat, focuses on developing a sustainable protein production. Proteins are an important macronutrient, as well as an essential structural component for the meat. However, as mentioned before, their extraction and purification require a considerable amount of energy. For this reason, current research focuses around optimizing the process, and looking for other potential protein sources, as insects (Fernandes, de Souza Teixeira, Palma Revillion, & Leal de Souza, 2019; Hamm, 2018; Loveday, 2019).

Market acceptance and ethical considerations

Apart from the technical feasibility and to be proven environmental gain, a possible market for cultured meat has to be ensured. Both consumer acceptance and ethical aspects of cultured meat are key in development of the cultured meat market (Fernandes et al., 2019). The consumer acceptance is driven by many different factors, some of which can be influenced. The first factor which drives the decision to choose for cultured meat and which can be influenced, is the knowledge about cultured meat of potential consumers. When their *familiarity* with cultured meat increases, they are also more likely to have an open attitude towards cultured meat (C. Bryant & Barnett, 2018). Besides familiarity, also the manner in which cultured meat is *framed and named* towards consumers changes their attitudes.

When explaining cultured meat in a more non-technical way, consumers are more likely to adapt cultured meat (C. Bryant & Dillard, 2019; C. J. Bryant & Barnett, 2019; Siegrist, Sutterlin, & Hartmann, 2018). In this framing, (social) media also has a significant stake (O'Riordan, Fotopoulou, & Stephens, 2017). Moreover, *geographical location* influences the attitude of potential consumers. People from urban areas tend to be more positive towards cultured meat, than from rural areas (Shaw & Iomaire, 2019). In addition, people from less economically developed countries are found less accepting than people from better developed countries (Gomez-Luciano, de Aguiar, Vriesekoop, & Urbano, 2019). The *price and popularity* also influence consumer decisions. The lower the cultured meat price and the higher the popularity, the more positive consumers' attitudes (Slade, 2018). Nevertheless, some factors found to influence the decision to eat cultured meat cannot be influenced, as *gender*, *age* and *education* (Gomez-Luciano, Vriesekoop, & Urbano, 2019). In face of *religion*, since cultured meat production does not involve slaughtering of animals, several religious groups have showed their (cautious) acceptance towards cultured meat, including potential Islamic and Jewish gorups (Friedrich, 2017; Hamdan, Post, Ramli, & Mustafa, 2018; JTA, 2018). Looking at the actual consumer acceptance, consumers were found hesitant to cultured meat, due to the provoked unnaturalness, personal, and societal risks (Verbeke et al., 2015).

Besides the consumer acceptance, the ethical considerations concerning cultured meat are still debated and important to consider for the formation of a potential target market. In 2008, Hopkins and Dacey listed some major ethical points of concern. The following points were brought to attention; (1) the potential danger of cultured meat, (2) cannibalism, (3) (un)naturalness, (4) technical solution to social problems, (5) selfishness option instead of self-sacrificing, (6) moral change will be delayed, (7) animal integrity, (8) animal source (Dilworth & McGregor, 2015; Hopkins & Dacey, 2008). Still, cultured meat is promoted as solution to feed the world. However, how ethical is this claim, if we already have plant-based alternatives, which are entirely animal-free (Z. F. Bhat et al., 2019)? How the future meat market will develop, remains a big question. Plant-based alternatives were not able to rule out farmed meat (yet). For cultured meat to do so, a major regulatory and market challenge is ahead. The conventional meat industry could also take their advantage with the new technologies, by assimilating biotechnologies to compete against the upcoming artificial meat market (Bonny, Gardner, Pethick, & Hocquette, 2015). As such, the cultured meat practice could already start a rich history before even entering the market, but by inspiring new perspectives on the conventional practices (van der Weele & Driessen, 2013b).

2.2.2. Plant-based meat alternatives

Milestones of plant-based meat alternatives

As early as 1990's, the meat substitute industry was already running, and vegetarians and vegans driven by different factors, consumed meat substitutes. The Dutch market then was overtaken by international firms Quorn and Tivall, while the Dutch Schouten and Vivera were just establishing. Only a small range of plant-based substitutes were available. In the later 1990's, attention to meat substitutes increased, due to rising public concerns over health and safety aspects of meat. This increase in interest, led to more research, resulting in two new firms: Meatless and Valess. From 2006 on, the animal welfare and environmental awareness increased, boosting the growth of the meat substitute sector. A major milestone in the diffusion of the plant-based meat substitute products, was the establishment of innovative firms, in particular Ojah and Meatless, referred to as the second generation of meat substitutes (Tziva et al., 2019). As of today, plant-based meat alternatives have a widespread market. Big rivals Impossible Foods and Beyond Meat, have both reached the Dutch

market via several channels, including supermarkets, Burger King and Ikea ("Nederlandse Ikea's zetten ‘nepburger’ Beyond Meat op het menu," 2020).

Technology and feasibility

The primary ingredients in the plant-based substitutes are generally soybeans, but also tofu, tempeh, seitan, quorn or fibers from lupines can be precursors for plant-based substitutes (Kumar, 2015). To mimic the meat-like fibrous structures, multiple technologies can be utilized, including fiber spinning, shear, thermo-extrusion, and cross-linking. Despite the fact that traditional and emerging technologies to transform plant proteins into fibrous structures are quite satisfactory for making these fibers, the water-binding (juiciness) and mouthfeel (chewiness) properties have not been engineered as successful (Sha & Xiong, 2020).

Regardless of the fact that plant-based meat alternatives are becoming cheaper these days, there is still an economic challenge present. Due to the extensive processing methods and high amount of (expensive) functional ingredients and additives, the price remains higher than conventional meat products. High-capacity production processes and innovating cheaper additives could help in lowering these prices (Sha & Xiong, 2020).

Environmental and health impact

At the end of 2018, Beyond Meat, one of the major plant-based meat suppliers, performed an extensive life cycle analysis (LCA) on their product. This study showed that their burger requires 99% less water, 93% less land, generates 90% fewer Greenhouse Gas Emissions (GHGE), and requires 46% less energy compared to a conventional beef burger (Beyond Meat, 2018). These findings are supported in literature. Plant-based meat requires less land, decreases the GHG emissions, nitrogen and lower the impact on terrestrial and aquatic biodiversity (Curtain & Grafenauer, 2019).

Very little academic research can be found to the health impact of plant-based meat alternatives. The found research on this topic emphasizes, that a diet with plant-based meat products could make for a healthier human diet compared to farmed meat (Hu, Otis, & McCarthy, 2019; Neacsu, McBey, & Johnstone, 2017). This, since conventional meat has been associated with certain chronic diseases and higher cholesterol (Collaborators, 2019). However, for the newest plant-based meat alternatives, the impact on human health has to be proven, due to the high amount of processing and additives (Hu et al., 2019).

Market acceptance and ethical considerations

Consumer acceptance of the plant-based meat substitutes, are found more likely among younger and more educated consumers. On top of that, the consumers their believe about the environmental impact of the farmed meat and the amount in which the consumer values the environment, played a significant role in choosing for meat alternatives. According to research of Slade in 2018, if prices and taste of the alternatives and conventional meat were equal, 65% of consumers would go for the beef burger, 21% for the plant-based burger, 11% for the cultured meat burger, and 4% will not choose any of choose products (Slade, 2018). With these findings, Slade underlines that these alternatives are not eliminating farmed meat (Slade, 2018). This is supported by the fact that the demand for farmed meat remains high. Projections of the OECD and FAO show a rising global meat production from 328 million metric tons (pork, beef, mutton and poultry) in 2019, to 364 million tons in 2028 (OECD & FAO, 2019).

2.2.3. Hybrid meat alternatives

In hybrid meat alternatives, farmed meat and plant-based are both combined to one product. This can be in different percentages, for instance half farmed meat, half plant-based. Even though this alternative is not as sustainable as the previous mentioned 100% plant-based meat alternative, this is still in interest because of the higher consumer acceptance. Recently, Tarrega et al. supported that consumers in Spain, who are most attached to meat, were significantly more likely to eat a hybrid alternative, compared to a fully plant-based substitute. Therefore, hybrid meat alternatives are considered a viable option as first step towards conservative meat consumption (Tarrega, Rizo, Murciano, Laguna, & Fiszman, 2020).

2.2.4. Insect-based meat alternatives

Milestones of insect-based meat alternatives

Eating insects is definitely not a new concept. Insects are eaten by certain tribes in Africa and Australia, as well as many people enjoying a fried beetle in Thailand. Since 2003, the Food Agriculture Organization (FAO), is working on spreading awareness, generating and sharing knowledge, and networking on project on edible insects worldwide. In this light, the FAO Forestry Department partnered up with the Wageningen University and Research Centre, to promote research and innovation on insects. Despite the increasing amount of research on cultured meat, still very few insect-based companies are situated in The Netherlands (Van Huis et al., 2013).

Technology and feasibility

The insects as replacement for meat, can be slightly different than the other three categories. While the other three alternatives actively mimic our current meat, insects can also be eaten as whole insects (roasted, fried, boiled). Moreover, the insects can be processed into powder or paste. This powder and paste could be added to low-protein products. Lastly, the proteins of these insects could be extracted to also supplement other foods. However, this is a highly difficult process for the proteins to be extracted and maintain their desired properties (amino acid profile, thermal stability, solubility). More research to extracting proteins from the insects would be required (Van Huis et al., 2013).

Environmental and health impact

Insects are found more efficient in converting feed. Moreover, Oonincx and de Boer (2012) showed that the mealworm production required less land, water and lowered the GHG emissions compared to conventional meat sources, making it a more sustainable choice (Oonincx & de Boer, 2012). Moreover, animal welfare is increased, while using less land, since many insects show crowding and are significantly smaller than the current farmed animals. Lastly, the risk of zoonotic infections is much lower, since insects are taxonomically more distant to human, than the farmed animals (Van Huis et al., 2013).

Concerning the health impact, several advantages have been found. In contrast to larger amounts of saturated fat in farmed meat, which is more difficult to break down for the human body, edible insects contain considerable amounts of fat, but unsaturated fatty acids, which are easier to process in the human body (Womeni et al., 2009). The nutrient value and vitamins widely differ over the kind of insect species. Moreover, this nutrient value is highly dependent on the diet of the insect. The same accounts for getting the required minerals and amino acids out of insects. Not all of the insects are suitable, since it highly deviates over the different species (Van Huis et al., 2013).

Market acceptance and ethical considerations

Especially in the Western world, insects seem to trigger feelings of disgust when proposed to potential consumers (Poortvliet, Van der Pas, Mulder, & Fogliano, 2019; Rozin & Vollmecke, 1986). However, in the Tropics this is much more common, which might also be because of some trends that are in favor for the Tropics and insects, namely: insects tend to be larger there, they can be found year-round, many species can be found and are easy to locate (Van Huis et al., 2013). For now, many Westerns will still associate insects with the flies and mosquitos within their houses. However, already in 1990, Elorduy recognized the trend of changing Western attitudes towards insect. Instead of only assign eating insects to poorer regions, and called scientists to start working on researching the possibilities (Ramos-Elorduy, 1990). Even though, the possibilities are being explored, a clear change in consumer attitude is required before insects can take over the Western market.

2.2.5. Comparison of the meat alternatives

Comparing the different meat alternatives, plant-based meat offers some major advantages in this stage. It has been proven more environmentally friendly, safer and ready to be mass-produced (Table 1) (Bonny et al., 2015). Despite the clear advantages of plant-based meat, people are still hesitant to cut meat out of their diets (Graca et al., 2015). The insect-based alternatives could offer a more sustainable, highly safe and rich product. However, in the Western world, there is still a 'disgust'-factor to overcome. In this view, cultured meat could be a more sustainable option for people who are unwilling to cut farmed meat out of their diets. Cultured meat is in basis similar to farmed meat, but more sustainable and potential lower health impact. However, cultured meat is still in its infancy, and several technological and regulatory challenges are to overcome before it can reach the public (Post, 2014).

Table 1 Comparison of traditional meat, cultured meat, plant-based meat and insect-based meat (Bonny et al., 2015)

		Traditional meat	Cultured meat	Manufactured meat (plant and mycoproteins)	Insect proteins
Sustainability	Resources used	High	Significantly reduced	Significantly reduced	Moderate reduction
	Waste	High	Potentially reduced	Reduced	Reduced
	Greenhouse gas emissions	High	Potentially reduced	Reduced	Reduced
Health		Unchanged	Potential improved fatty acid profile and reduced iron content Untested product	High in protein	High in protein and minerals
Safety		Unchanged	Untested product	Reduction of food borne diseases Reduced cholesterol content	Safe with small scale production, untested with large scale production
Market acceptability	Capacity for mass production	Yes, but reaching limitations	Marked technological barriers at present	Yes	Yes
	Need for further research	Moderate	High	Low	Moderate
	Cost	Increasing	Very expensive	Cheap	Moderate
	Government regulation	Subsidies, but increasing regulation	Untested	Subsidies, standard regulation	Standard regulation
Addresses welfare concerns		No	Yes	Yes	Yes
Acceptability to consumers		Demand increasing	Neophobia and technophobia	Palatability problems	Neophobia

2.3. Outline of relevant frameworks

2.3.1. Introduction to transition frameworks

As can be deducted from the cultured meat literature, an extensive description of the socio-technical system of cultured meat, is still lacking. This while, society's current environmental problems, cannot be tackled by incremental improvements, but require radical and structural changes. Those shifts are called 'sustainability transitions' (Markard, Raven, & Truffer, 2012). In transition research, the aim is to explain and conceptualize how these sustainability transitions impact society and the focus is primarily at the meso-level of socio-technical systems (Geels, 2004).

The aim of this study, is to analyze a single technology – cultured meat – in terms of its embedded sociotechnical system and its potential for further development. For this, the innovation system theory offers a useful framework into analyzing the systemic structure and functioning. In addition, the Multi-Level Perspective could offer more insight in macro-level influences on strategies and values.

2.3.2. Innovation System (IS) theory

The innovation system theory implies that innovation is a joint activity, involving a large number of actors with different interests and perceptions, and does not only occur through entrepreneurs (Twomey & Gaziulsoy, 2014). The innovation system approach has been applied to different levels: national (Freeman, 1995), regional (Cooke, Uranga, & Etxebarria, 1997), sectoral (Malerba, 2002) and technological levels (Bergek et al., 2008). Many definitions of an 'innovation system' can be traced back into literature. However, some common characteristics can be found. These characteristics are described by Lundvall: (1) The central focus is on a technology, but the organizational and institutional values are also important, (2) Innovation systems differ per country, (3) IS use a holistic point of view, (4) A historical perspective is used, (5) Innovation is described as an iterative process, (6) The importance of learning is emphasize, (6) No clear rules about boundary setting of the IS, (7) A structural view is combined with an actor perspective (Lundvall, 1992). It should be noted that over time, the central focus shifted from not only on a technology to also on knowledge as a central part of IS analysis.

For the analysis of the socio-technical system of cultured meat, the unit of analysis will not be based on geographical location (National Systems of Innovation), nor on an entire industrial sector (Sectoral Innovation System), but a technology is the starting point. Therefore, the most interesting focus in relation to this research, is on technological innovation systems. Hekkert et al. define the technological innovation system as "the set of actors and rules that influence the speed and direction of technological change in a specific technological area" (M. Hekkert, Negro, Heimeriks, & Harmsen, 2011).

As the world is getting smaller, and ideas spread over various countries or even continents more easily due to modern society, also technologies originate from multiple geographical locations. The same accounts for sectoral systems. Research takes place all over the world, in different institutions, organizations and knowledge bodies. Therefore, even by basing the unit of analysis for the innovation system on a particular technology, as in this research, the technological innovation system will still cut through multiple geographical and sectoral systems (Figure 4) (M. P. Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007).

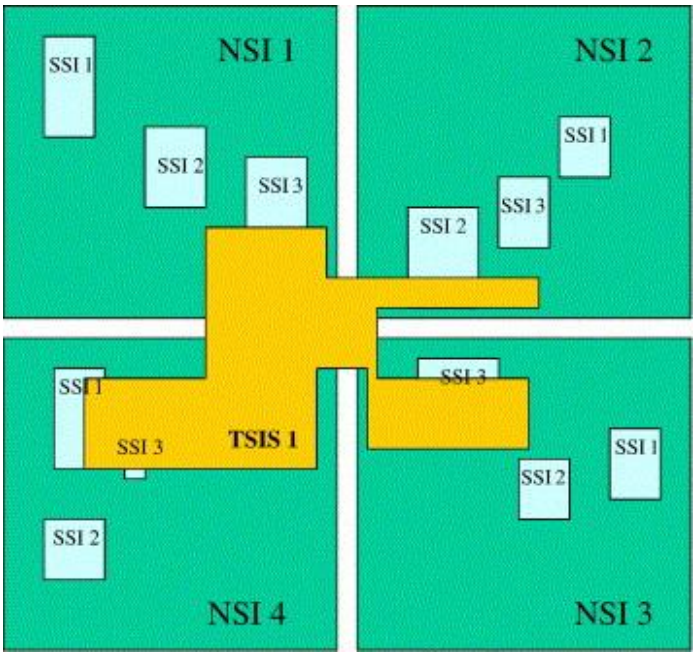

Figure 4 Relation between different systems of innovation - Relation between National System of Innovation (NSI), Sectorial System of Innovation (SSI), and Technology Specific Innovation System (TSIS) (M. P. Hekkert et al., 2007).

Nevertheless, the amount of networks, actors and institutions involved in TSIS are generally smaller than in NSIs or SSIs, leaving more space for the identification of the interaction dynamics in the system (M. P. Hekkert et al., 2007). However, only identifying the structural components as described in the technological innovation systems by Hughes and Carlsson, leaves us with a rather static model. An additional part of analysis, including the interactions of the system, which are of great importance in technological change, can be mapped by functions of the innovation system. With these functions, boundaries of the system can be set, system dynamics can be studied, performance of the innovation system can be assessed (Johnson, 2001).

Acknowledging the importance of interactions in the development of a new technology as described in this research, the focus will be on a Functions of Innovation System (FIS). In specific, the innovation system described by Hekkert et al. serves as a useful framework for performing an analysis of a technological system for policy purpose (M. Hekkert et al., 2011; M. P. Hekkert et al., 2007). Hekkert et al. have defined a technological innovation system as "the set of actors and rules that influence the speed and direction of technological change in a specific technological area". (M. Hekkert et al., 2011). The first step, towards analysis of the TIS according to the manual written by Hekkert et al., is to identify the structural components. Those components include actors, institutions, networks and technological factors (Table 2). In this system, technological factors are viewed as part of the innovation system structure, due to its influence on the activities of the actors in the system. This knowledge is essential in the following step of mapping the functions (M. Hekkert et al., 2011).

Table 2 Structural dimensions of an innovation system. Adapted from Hekkert et al. (M. Hekkert et al., 2011)

Structural dimension	Subcategory
Actors	- Knowledge institutes: The universities, colleges, research institutes were research is performed, thereby generating or confirming knowledge. - Educational organizations: The organizations where educational activities take place, passing on knowledge - Industry: The industry entails all the actors involved in the production chain. - Market actors: The market actors include all the players (sellers and producers) that are active and thereby influence the potential market. - Government bodies and regulatory organizations: The involved ministries and organizations with formal regulating or influencing power on the development of an innovation - Public interest groups and key individuals: Entails persons or groups that can actively stirs the opinions of a significant group of people, mostly via the social media channels
Institutions	- Formal institutions: codified rules, enforced by authority - Informal institutions: more tacit rules and organically shaped interactions
Networks	
Technological factors	

According to the FIS framework described by Hekkert et al. and Bergek et al., for successful development of new technologies, seven functions needs to be positively fulfilled. Those functions are: entrepreneurial experimentation, knowledge development, knowledge exchange, guidance of the search, formation of markets, mobilization of resources and counteracting resistance (Table 3) (Bergek et al., 2008; M. Hekkert et al., 2011).

Table 3 System functions of an innovation system (M. Hekkert et al., 2011)

System function	Description
F1 Entrepreneurial experimentation	Entrepreneurs are the essential element in any innovation system. Their role is to turn potential due to changes in the system, into new business opportunities. This function can be observed by the number of new entrants, diversification of incumbent actors, and number of experiments with the new technology
F2 Knowledge development	Learning is central to any innovation process. This can be mapped through R&D projects, patents and investment in R&D as indicators.
F3 Knowledge exchange	Knowledge diffusion through networks is important to make sure that policy decisions and research agenda are consistent with the latest insights. This function can be observed by the number of workshops/conferences about a specific technology topic, and by analyzing the intensity and network size across time.

F4 Guidance of the search	Guidance of search represents the activities within the IS that can positively affect the clarity and visibility of specific needs of technology users. Resources are limited, and a specific foci for investments should be chosen when multiple technological options are present. This can be analyzed by specific targets set by governments or industries concerning the use of the specific technology, and by observing the number of articles in journals that raise expectations about the developments in the new technology.
F5 Formation of markets	New technologies usually cannot compete with older more established technologies. To outperform those technologies, and stimulate innovation, it is essential to stimulate the formation of (niche) markets. This function can be observed by the number of niche markets established, specific tax regimes, and set new environmental standards.
F6 Mobilization of resources	For all activities within the innovation system, financial, material and human resources are required. E.g. resources are required for knowledge generation, as funds for (long-term) R&D. Specific factors are difficult to point out to map this function. Interviews to whether core actors receive sufficient resources is the best way to map this.
F7 Counteracting resistance to change	The new technology has to become part of the existing regime, while it can meet resistance from existing actors. Political lobbies can counteract this, and support the technology. This function can be observed by the amount of lobby actions of specific groups of interest.

Between those seven aforementioned functions, many different interactions are possible. However, patterns can be observed in how these interactions start and proceed. Those patterns are referred to as 'motors of change' or 'motors of innovation'. Suurs (2009) distinguishes four different motors of innovation: Science and Technology Push (STP) motor, Entrepreneurial motor, System building motor, and Market motor (Suurs, 2009). The STP motor centers around knowledge development (F2) and diffusion (F3), followed by guidance (F4) towards most promising technologies, and subsequent resource distribution (F6). The Entrepreneurial motor follows in a later stage of TIS development, and is all about (corporate) entrepreneurial activities (F1) leading to more knowledge development (F2) and creation, as well as guidance (F4) towards viable options. Moreover, lobby activities are introduced potentially leading to new resources (F6). The System building motor also focuses on entrepreneurial activities (F1), but shifts from knowledge development to (mass) market creation. The Market motor is the final motor in the TIS development. All functions are present, except for lobby activities (F7), since the TIS is no longer dependent on government market formation and resources (Suurs, 2009).

Criticism on the systems of innovation approach

The system of innovation approach has proven to be useful in many different cases (Bergek & Jacobsson, 2003; Jacobsson & Bergek, 2004). However, despite the proven usefulness this approach, some criticism on the framework can still be pointed out in literature. In 2015, Markard et al. published a paper to respond to the six major points of criticism on the technological innovation systems approach (Markard, Hekkert, & Jacobsson, 2015).

The first criticism to TIS, is that the approach is too *inward focused*, lacking attention for the system's environment. This inward focus can cause users of the framework to become ignorant towards competing or complementary technologies (Markard & Truffer, 2008; Smith & Raven, 2012). The second point of criticism concerns the *boundary setting* for analyzing the context. Coenen argues that if those boundaries are set ad hoc, important actors, interactions of relations might be missed (Coenen, 2015). Third, criticism was placed on the influence of *changing context*, when utilizing TIS approach in a certain country or in a certain institutional context. Critics note that results are not necessarily applicable to other countries or institutional contexts (Binz, Truffer, & Coenen, 2014; Blum, Bening, & Schmidt, 2015). Fourth, the TIS framework was designed for the analysis of *emerging technologies*. However, as the emerging technologies were maturing, the framework became a key framework in transition studies. Multiple studies question its competence as framework for studying socio-technical transitions (Kern, 2014; Smith & Raven, 2012). The fifth point of criticism, is that *politics* should be better incorporated into the framework, due to its influential and pervasive nature, affecting various functions of the model (Kern, 2014). The last of the six points of criticism responded to by Markard et al., is the critical note that *policy recommendations* resulting from this framework, are rather general and support only a certain technology (at the potential cost of others). While criticists argue that it should be justified why a certain technology is supported above another, and that they call for more concrete, workable recommendations (Bening, Blum, & Schmidt, 2015; Markard et al., 2015).

Markard, Hekkert & Jacobsson critically analyze the points of criticism on TIS, and subsequently respond to the constructive feedback in their 2015 paper. Regarding the first point of criticism, the too *inward focused* character of the approach, Bergek et al. further developed the TIS context structure and dynamics (Bergek et al., 2015). For some other points of criticism – boundary setting, changing context, emerging technologies, and policy recommendations – steps are taken, but they acknowledge the need for further research.

Summarizing, some research gaps in the TIS framework remain. The generalizability of the TIS framework across different institutional contexts is still in question. Even so, more research is required towards analyzing mature technologies with the TIS framework. Lastly, the interplay of strategies of actors are underexposed in this framework. Altogether, those remaining gaps are important points to be aware of when utilizing the TIS framework in this research.

2.3.3. The multi-level perspective (MLP)

The multi-level perspective theory holds that transitions are generated through interactions between three different analytical levels: niches (micro-level), regimes (meso-level), and a socio-technical landscape (macro-level) (Figure 5)(Geels, 2010).

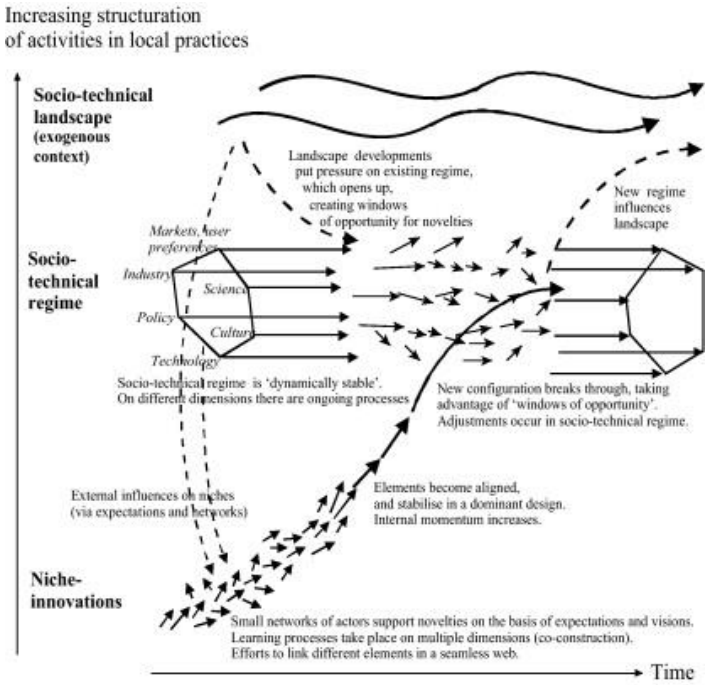

Figure 5 Transitions according to the multi-level perspective (Geels, 2011)

Niches offer a protected space for radical innovations, that deviate from the existing dominant regimes. Those protected spaces could be R&D laboratories, small niches with special demands, or subsidized demonstration projects (Geels, 2011). Where niches are open for radical new innovations and are crucial for transitions, the existing regime accounts for stability of the system. Innovations occur in an incremental manner and the regimes are characterized by lock-in. In these regimes, actors adhere to the set rules on one hand, while the rules configure actors on the other hand. Examples of these regime rules are shared believes, lifestyles, user practices, and legally binding contracts (Geels, 2011). The third level, the socio-technical landscape, is the wider context that influences niche and regime dynamics (Rip & Kemp, 1998).

Developments in the socio-technical landscape can put pressure on the regimes, allowing niche-innovations to break through. These developments can lead to tensions in the regime, therefore offering a window of opportunity. Interactions between the regime and niche following this opportunity, are shaped by multiple dimensions (cultural, regulations, technologies, etc.) and are enacted by actors trying to steer the transition. The tension between the stability and changes in this system are central to MLP, and are caused by the interplay of the three different levels (Koehler, Geels, Kern, Onsongo, & Wieczorek, 2017).

Criticism on the multi-level perspective

Similar to the systems of innovation framework, the MLP received some constructive criticisms. In his 2011 paper, Geels responds to some major points of criticism and formulates suggestions or extensions for future use (Geels, 2011). The seven major points of criticism are: (1) Lack of agency, (2) Operationalization of regimes, (3) Bias towards bottom-up change models, (4) Epistemology and

explanatory style, (5) Methodology, (6) Social-technical landscape as residual category, and (7) Flat ontologies vs. hierarchical levels(Geels, 2011).

Based on these criticisms, some extensions were suggested by Geels, while some limitations remain. Geels suggests that transition research could benefit from using other methods, as comparative or nested case studies, network analysis, and agent-based modelling to overcome the methodology criticism, and offers some suggestions to better formulate and involve the influences from the socio-technical landscape (Geels, 2011). Moreover, Geels and Schot published a paper, in which they are varying the timing and nature of multi-level interactions, to overcome the bottom-up bias (Geels & Schot, 2007). One limitation that remains, is the underdevelopment of some types of agencies, as rational choice, power struggles, and cultural-discursive activities, in the MLP framework (Geels, 2010).

2.3.4. Actor strategies

Interestingly, we can derive from the criticism on both TIS and MLP, that both frameworks put little emphasis on actor strategies. Budde et al. dived into this pitfall, and coupled actor strategies, expectations, and activities in relation to TIS and MLP (Budde, Alkemade, & Weber, 2012). The focus is on the anticipatory character of technical and non-technical expectations of actors, in which expectations are defined as "real time representations of future situations". They conclude that different types of expectations are important for different kind of actors, and used the MLP framework to analyze expectations, distinguishing the three different levels (niche, regime, landscape). Here, expectations are based on happenings in the regime and landscape level. These actor expectations drive actor strategies, thereby leading to certain activities of the actors. On top of the actor expectations, the values of the actors also guide in the activities of the actors. In this study, strategies are defined as "The determination of long-term goals of an organization that guide decision making, management activities and the necessary allocation of resources" as by Budde et al. (2012). These expectations, strategies, and activities are in major interest, since they can lead to quick changes in the meso-level. While transition dynamics usually require time to mature, expectations can more rapidly lead towards changes (Budde et al., 2012) (Figure 6).

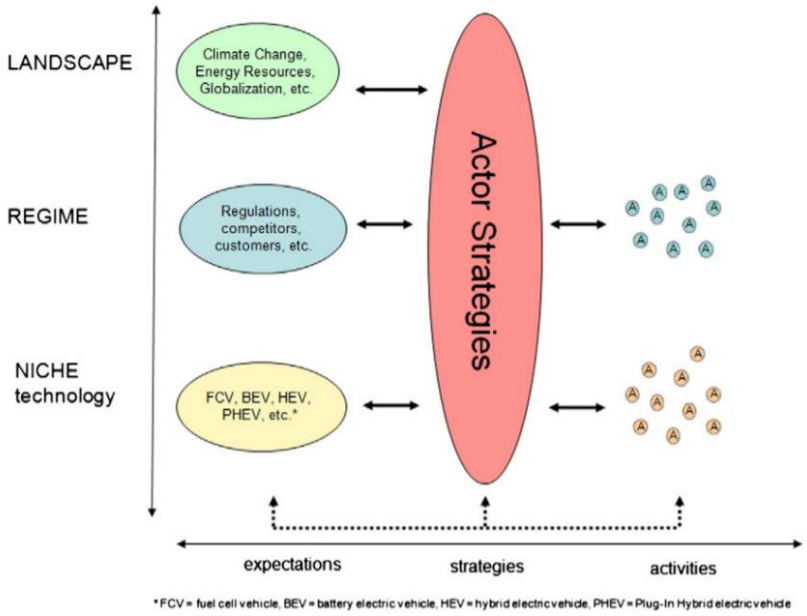

Figure 6 Schematic representation of actor expectations, strategies and activities on the MLP levels (Budde et al., 2012)

2.3.5. Responsible research and Innovation (RRI)

On top of the fact that both IS and MLP put little emphasis on actor strategies, also little attention is paid to responsible innovation in these frameworks. This, while the success of this technology highly depends on how eager society is to embrace the outcomes of it. Moreover, Therefore, during the innovation process, it is important that not only the innovator's point of view is taken into account, but all the stakeholders are integrated into the innovation process.

A framework to achieve this deeper integration, is described by Werker (2020), by coupling responsible research and innovation (RRI) to the system approach. Here, Werker points out two major reasons for adopting a system approach for RRI: (1) all-encompassing fields (as biotechnology), require deeper integration of the different stakeholders (society, government, industry, academia), and (2) to come to jointly acceptable solutions, all stakeholders, their dynamic networks and supporting institutions have to be taken into account. For this, Werker (2020) introduced responsibility into the innovation system approach structure, by adding value considerations to each stage of the system approach (Figure 7) (Werker, 2020). Due to the fact that the framework of Werker elaborates on the innovation system framework, clear resemblances in the analyzing steps can be noted, making them well compatible. In this study, values are described as " 'Things worth striving for', societal needs as well as economic opportunities. Relevant values during the innovation process." as defined by (Taebi, Correljé, Cuppen, Dignum, & Pesch, 2014).

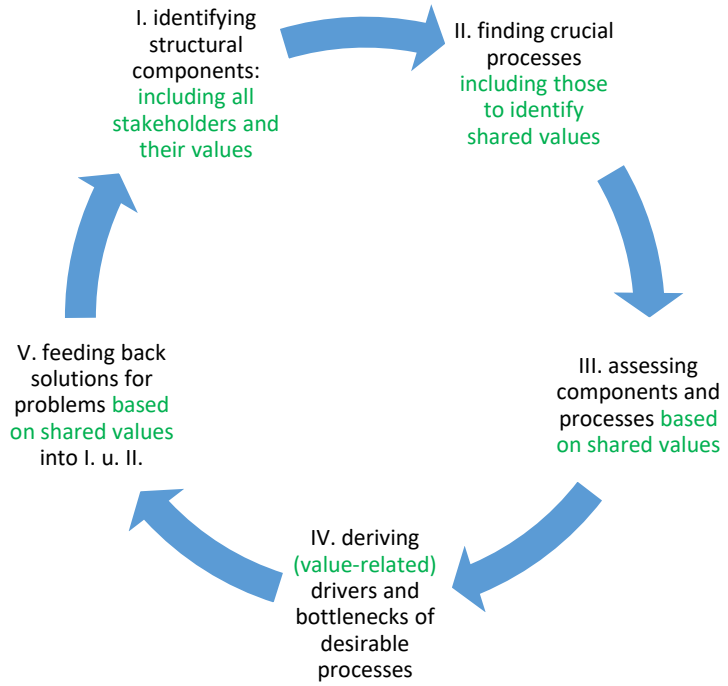

Figure 7 Integrating RRI (green) into the system approach (Werker, 2020).

2.4. Conclusions on framework

The TIS framework, and more specifically, the functions approach (FIS), is well-suited to study the development of new technologies, as cultured meat (Tziva et al., 2019). The FIS approach not only takes into account the innovating firm and its shareholders, but also other stakeholders as policy makers, authority and consumers (Farla, Markard, Raven, & Coenen, 2012). This is valuable, especially for this case, since government support and knowledge exchange with national or local actors are important when the technology is still developing (Vasseur, Kamp, & Negro, 2013). The need for further analysis of the cultured meat sector in terms of its stakeholder positions, working together to address current social, regulatory and technical difficulties has been emphasized in literature (Stephens, Di Silvio, et al., 2018). The fact that sustainable innovations, as cultured meat, depends strongly on their environment and dynamics of the innovation system, makes FIS a suitable approach (Alkemade, Kleinschmidt, & Hekkert, 2007).

However, the FIS approach misses out on how the technology actually fits into the landscape and/or regime, while the MLP framework strongly focuses on these interactions. Combining both frameworks combines their strengths, but still misses out on actor strategies and responsible innovation. By including the extensions by Budde et al. (2012) and Werker (2020) to the integrated framework, a well-suited approach is designed, bringing together some important aspects in the development of the Dutch cultured meat industry.

3. Research methods

3.1. Research design

Based on the theoretical frameworks analyzed in chapter 2, a framework integrating the FIS and MLP approach, while taking into account actor strategies and values, was found as a well-suited approach for this study. In this section, the operationalization of such a framework will be further developed and discussed.

Starting from the functions of innovation perspective as described by Hekkert et al. (2011). We can recognize the following steps: (1) Boundary setting for the IS, (2) Analysis of the IS structure, (3) Analysis of the functioning of the IS, (4) Analysis of the system problems, and lastly (5) Policy recommendations based on the system analysis (M. Hekkert et al., 2011). This process, integrated with RRI as described by Werker (2020), is shown in more detail in Figure 8.

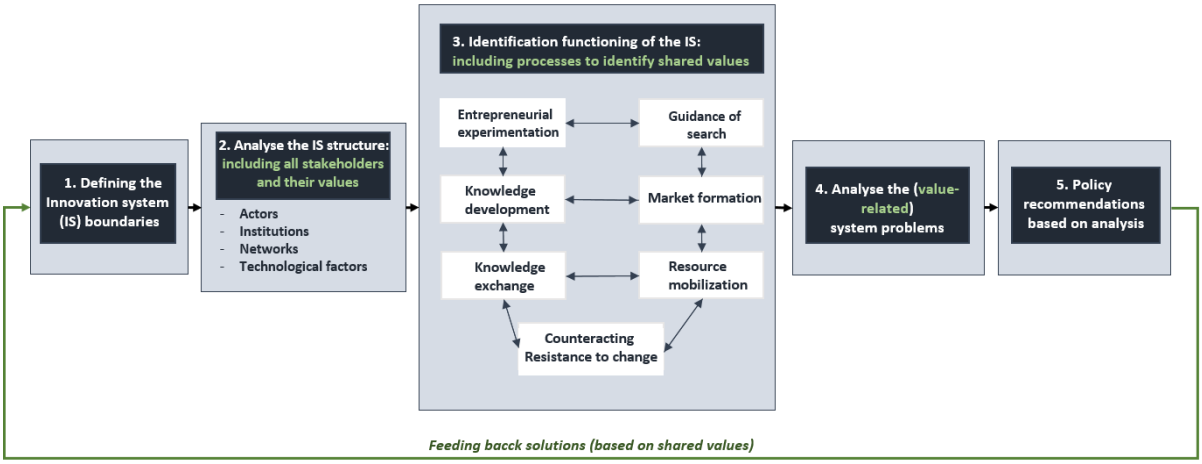

Figure 8 Combining FIS and RRI - Schematic representation of functions of innovations approach according to Hekkert et al., combined with the RRI approach (shown in green) as described by Werker (M. Hekkert et al., 2011)(Werker, 2020).

In addition to these steps in the innovation system, this study also takes into account some of the external environment through actor strategies. The strategies of the actors strongly depends on their expectations regarding the landscape and regime developments. The landscape-level can be defined as "the set of residual factors that have an impact on innovation and production processes without being influenced by the outcome of innovation processes on a short to mid term basis", as described by Markard et al. (Markard & Truffer, 2008). Examples of landscape factors are environmental issues, shock factors (crisis and natural disasters), national income level, and political situation (Geels, 2002). The technical regime is defined by Rip and Kemp as "the grammar or rule set comprised in the complex of scientific knowledges, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology" (Rip & Kemp, 1998). However, literature is not conclusive in a shared understanding of the regime characteristics (Markard & Truffer, 2008). Hekkert describes the socio-technical regime at the sectoral, or sub-sectoral, level of a particular technology (M. P. Hekkert et al., 2007). The additions of these levels to the FIS framework, allow for analysis of the recent developments in the field of cultured meat in The Netherlands on both the level of the sector, and the wider landscape and how this influences the actor strategies. Subsequently, actor strategies drive to certain actions of those actors, which can influence the activities in the niche, IS, and/or regime. As already mentioned before, in this case the innovation system is still in its infancy, which also means that there are not many significant niches to be distinguished yet. Therefore, in this case, the innovation system is the niche. Complementary innovation systems are formed by other meat substitutes, all interacting with the

foods regime, in which the current meat system is embedded. A representation of such an integrated framework and interactions in this framework, can be found in Figure 9.

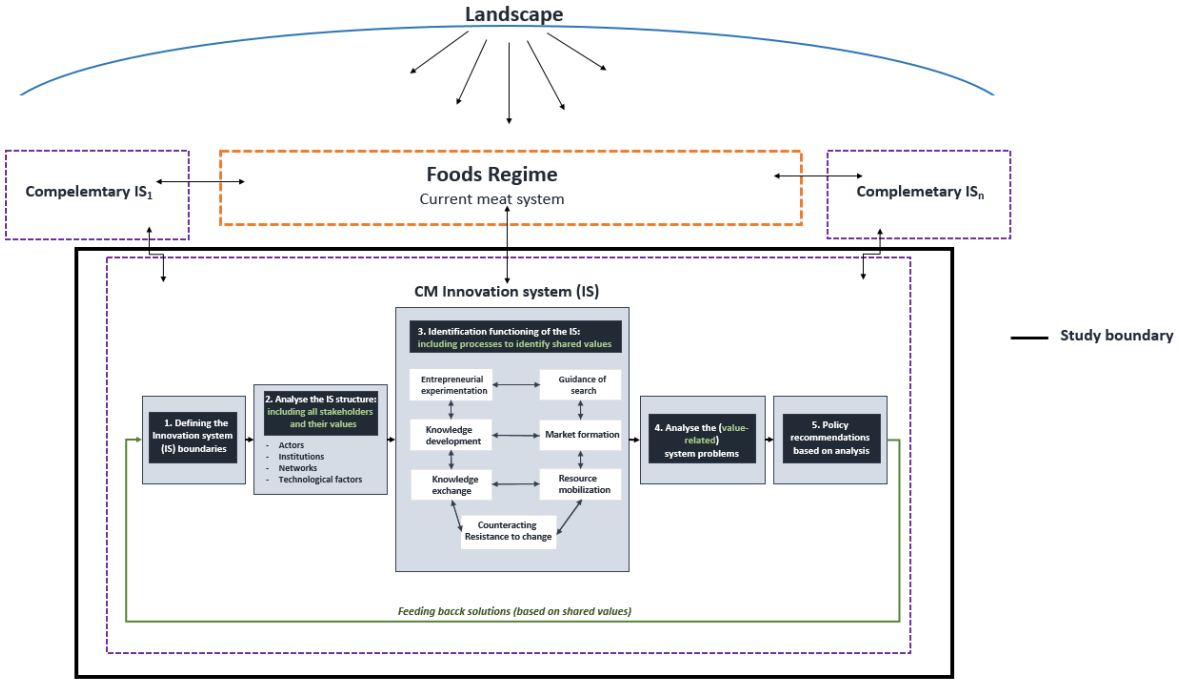

Figure 9 Interactions and levels of the framework used in this study

3.1.1. Study boundaries

For this study, the boundaries are set to the Dutch cultured meat innovation system. In addition, the external influences from the landscape, from (and to) the foods regime and other IS on this innovation system are taken into account. This is schematically represented Figure 9

3.2. research approach

This research is based on qualitative research, since it concerns an 'immature problem' that is yet not well understood, and little research has been performed on. Whereas quantitative research are appropriate for more mature theories, nascent theories are well served by qualitative research. Qualitative research is likely to yield descriptive answers, which will help to understand and explain the research problem (Edmondson & Mcmanus, 2007). Mapping the socio-technical system of cultured meat and its development in The Netherlands, has not been extensively described in literature yet, accounting as an immature technology. Strauss and Corbin describe qualitative research as: "any kind of research that produces findings not arrived by means of statistical procedures or other means of quantification", thus a more in-depth understanding of the topic based on experiences, rather than numbers. Different methods can be applied based on a qualitative approach. Those methods include: interviews, focus groups, content analysis of both text and visual means and surveys (Strauss & Corbin, 1990).

Zooming into applying a qualitative research approach to this study using Figure 8, (1) the first step is to define the system boundaries. The boundaries are set to the entire cultured meat innovation system, and the external influences from the landscape and from (and to) the regime and other ISs on this CM innovation system. This is schematically represented in Figure 9. (2) In the second step, desk research is performed to determine the initial structure of the Dutch cultured meat innovation system. Content analysis of research and websites will be performed to identify the actors, institutions,

networks and technological factors of the innovation system. In this desk research, first actors can be identified for the interviews. If needed, the desk research can be complemented with data from the interviews. This research will guide towards answering the first sub-question *(What does the Dutch cultured meat innovation system look like?)*. (3) The third step as indicated in Figure 8, aims at describing the functioning of the innovation system. Literature analysis will be performed to collect information about the seven functions, and the data from the interviews will be used to assess the functioning of the innovation system, and thereby answering sub-question 2 *(What are the opportunities and bottlenecks for the development of the Dutch cultured meat innovation system?)*.

After defining the Dutch innovation system, the second part of the research aims at describing the external factors influencing the system. These external factors include the influences from the socio-technical regime and the landscape affecting the innovation systems functioning. Technical, social, political and economic developments should be taken into account, on which actors base their strategies, as well as their values. Those strategies and values are highly related to the recent developments influencing the system. Changing landscape factors, regulation, competitor landscape or customer expectations, are all examples that can possibly affect the innovation system development. Websites of the actors involved in the innovation system will help to answer this question. The company/institutes direction and motto explains their values and might give some hints to their linked strategies. Here, website analysis, scanning company reports and, if necessary, additional contact through email or phone will be utilized. This information will be supplemented with data from the interviews to elaborate on actor strategies and values, thereby answering sub-question 3 (*How have strategies and values of the different actors evolved over time and how has this influenced the development of cultured meat in The Netherlands?).*

In the last part of the research towards answering the main research question, the findings of the first four sub-questions will be gathered and coupled to obtain an overview of the current problems in and surrounding the Dutch cultured meat innovation system (step 4, Figure 8). These answers will help to determine which actions could be taken and by who, to facilitate the development of the innovation system (step 5, Figure 8). This guides towards answering sub-question 4 (*How can the opportunities and bottlenecks be managed and by who, to facilitate the development of the Dutch cultured meat innovation system?).*

Finally, these four sub-questions will support in answering the main research question in this study:

How has the Dutch socio-technical system of cultured meat been developing and under which circumstances could it grow?

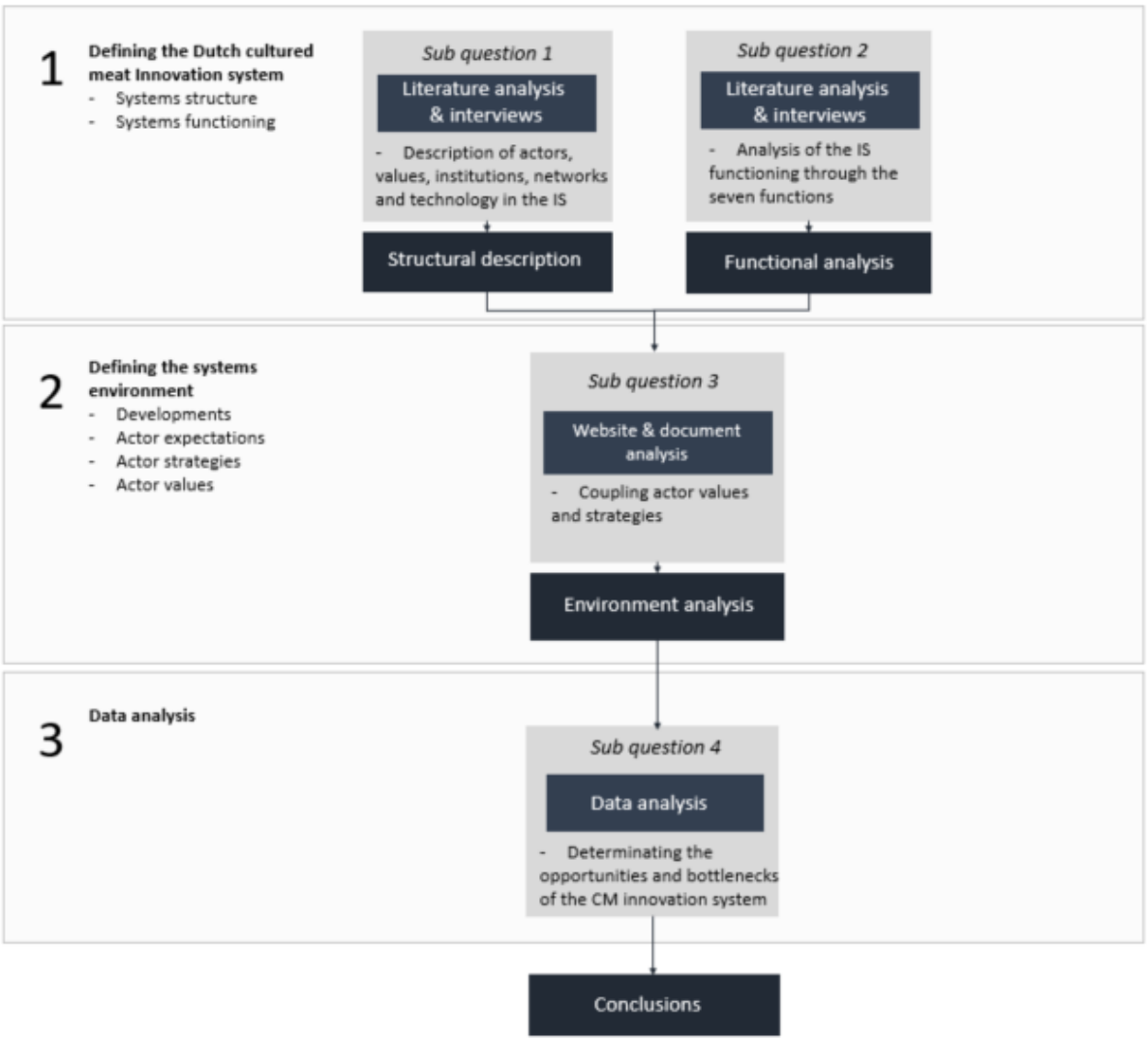

Figure 10 Overview of the methods and approach utilized in this study

3.3. Validity of the research approach

Qualitative data is focused on words rather than numbers. Therefore, one should be aware of the validity and reliability while adopting a qualitative approach, as well as keeping the study objective. Reliability is regarding the repeatability of the obtained results, while validity is about the integrity of the conclusions generated (Bryman, 2008). Achieving reliability in qualitative research, is a difficult task. Answers on interview or survey questions can for instance slightly differ. To overcome this obstacle, Silverman (2006) proposes to keep the research transparent in terms of research process, choice of theory, and observations. By for instance, recording or quoting interviews/surveys, readers can access some concrete observations (Silverman, 2006).

For the validity of the research, Bryman (2008) points out four measures to take care of: (1) Measurement validity: the extent to which the chosen tool measured the desired construct, (2) Internal validity: how confident we can be that the independent variable is (partly) responsible for the observed variation in the dependent variable, (3) External validity: how generalizable the findings are among our society, (4) Ecological validity: how generalizable the findings are over people's every day, natural settings.

3.4. Data collection

Data for the research was retrieved through a combination of desk research and interviews. First, desk research was performed to collect initial data. The data retrieved through the desk research, was supplemented with information retrieved via the interviews. Lastly, this data was complemented through additional desk research, to confirm or validate information retrieved via the interviews. During the desk research different methods were employed, depending on the information aimed. These methods include bibliometric analysis, patent analysis, or scanning newspapers, websites and/or literature.

The interviews were held between May and August 2020. Potential interviewees from different actor groups were approached. These actors were found through initial desk research and 'snowballing effect', by asking other interviewees during the interviews. An overview of the 12 interviewees of this study, can be found in Table 4. Due to the Corona virus, all interviews were via Zoom, Skype or Phone, except for the interview with Amanda Govers. The interview was a semi-structured interview of about 30 minutes average. The interview started with some more general questions, which narrowed down, based on the answers and area of expertise of the interviewee, towards the end. To ensure transparency of the research, the interviews were recorded through either phone, Skype or Zoom. The interview questions can be found in Appendix A.

Table 4 Overview of the interviewed experts in this study

#	Name of interviewee	Description of interviewee	Way of interviewing	Actor Group
E1	Ira van Eelen	CM 'activist', involved with start-up JUST and daughter of Willem van Eelen (first CM patent owner)	On the phone	Key individual
E2	Armanda Govers	Owner Evengeenvlees.nl and lobbyist	In person	Key individual
E3	Mac van Dinther	Culinary reviewer of the Volkskrant	On the phone	Key individual
E4	Koert van Mensvoort	Next Nature Network, The In vitro cookbook, Bistro in vitro	On the phone	Key individual
E5	Mosa Meat	Dutch cultured meat start-up	Via email	CM start-up
E6	*Anonymous*	Performed research on cultured meat innovation systems in the past	Online	Key individual
E7	Prof. Dr. Cor van der Weele	Involved in CM research in the area of Social sciences at WUR	Online	University
E8	Dr. Bernard Roelen	Was involved in biological cultured meat research at UU	Online	University
E9	Tjeerd de Groot	Minister at Ministry of Agriculture, Nature and Food safety	Online	Government
E10	Dutch Society for Veganism (NVV)	Promote a plant-based diet in The Netherlands	Online	Public interest group
E11	Wakker Dier	Strive for higher animal welfare in The Netherlands	Online	Public interest group
E12	The Good Food Institute	Work with scientists, investors, and entrepreneurs on food innovations as CM	Online	Public interest group

3.5. Data analysis

The collected data from the interviews was first transcribed, using the recordings. This transcription process was executed manually. In the transcription process, all words were transcribed. However, expressions as hesitations or laughter were not included in the transcript. Moreover, the interviews were transcribed in the language in which they were conducted, to make sure that no meaning was lost over translation. The transcripts were analyzed by a thematic analysis using NVivo 10. This software allows for a useful overview of reoccurring topics for thematic analysis.

3.6. Research indicators

Hekkert et al. (2011) established diagnostic questions and research indicators to identify the main structural and functional elements. These questions and indicators have been adapted to this study, resulting in the questions and indicators in Table 5 and

Table 6. For the structural part of the analysis, following the questions and elements towards the questions, will guide towards identifying the important actors, technological factors, networks and institutions. For the functional analysis, following the questions in combination with expert/key stakeholder interviews, will help to identify the weakest, or hindering, function.

Table 5 Overview of the structural components , their central questions and elements for the structural analysis of an innovation system as described by Hekkert et al. (2007), including RRI for the actor-element as described by Werker (2020)

Structural component	Central question(s)	Elements to answer central question
Technology	What does the technological system look like? What are the most prominent research directions?	- Publications - Patent classifications/citations (e.g. via WIPO, EPO, or PTO)
Actors	Who are the relevant actors? Are all the stakeholders from all sectors (i.e. government, academia, industry, and civic society) and their values included?	- Knowledge institutes - Educational organizations - Industry - Market actors - Government bodies and regulatory organizations - Public interest groups and key individuals
Networks	What does the network look like? And who are the central players in the system?	- Formal networks: networks for strategic reasons and a common goal (collaborating research project, technical committees) - Informal networks: no clear boundaries or common goal (seller-buyer, university-industry)
Institutions	What are the rules/boundaries of the innovation system?	- Formal institutions (codified laws, regulations) - Informal institutions (standards/norms, culture, visions/expectations of the actors)

Table 6 Overview of the functions , diagnostic questions and indicators for the functional analysis of an innovation system derived from Hekkert et al. (2007)

Functions	Indicators
F1 – Entrepreneurial Experimentation and Production	- Presence of new entrants (start-ups/spin-offs) - Diversification of incumbent actors - Recent and future activities (research projects, demonstrations/pilots) - Complementary technologies
F2 - Knowledge Development	- Number of patents and publications - Presence of R&D projects - Investment in R&D - Research convergence
F3 - Knowledge exchange	- Presence of workshops/conferences - Network size - Network intensity (collaborations on R&D, co-authorship)
F4 - Guidance of the Search	- (Long-term) targets set by government or industry - Expectation on further development - (Alignment of) visions/expectations of key stakeholders
F5 - Market Formation	- Market size - Efforts to create market
F6 - Resource Mobilization	- Availability of financial recourses - Change in amount of investments - Availability of human recourses - Change in amount of human capital - Availability of physical recourses
F7 - Counteract resistance to change/legitimacy Creation	- Amount of lobby activities by advocacy coalitions (for/against technology) - Result of lobby activities

4. Description of the structure of the innovation system

Towards understanding the development of the Dutch CM innovation system, first its structure is described by mapping its key elements. Here, four structural elements are analyzed: Actors, Networks, Insitutions and Technology. This will guide towards an answer to the first research sub-question:

SQ1: What does the Dutch cultured meat innovation system look like?

Using the RRI system approach as described by Werker (2020), the values of the actors will be integrated into the structural analysis.

4.1. Actors

The first structural factor discussed here, are the actors. In this study, the actors are defined as "the parties that are actively influencing the research and innovation, as well as the stakeholders affected by either the process or the outcome", following the definition from Werker (2020). This embraces all the actors in and involved with the cultured meat innovation system. The fact that all actively influencing, as well as the affected stakeholders are all taken into account, is especially important in the later step of identifying and considering the values of the actors.

According to Hekkert et al. (2011), the actors can be divided into five different groups: knowledge institutes, educational organizations, industry, market actors and government bodies and regulatory organizations. Following the 'actor' definition in this study, one groups will be added, namely: "Public interest groups and key individuals". Since this study is concerning a highly new product, still to be developed and accepted, this group has a higher influencing power compared to for already embedded products.

4.1.1. Knowledge institutes

Interviewed: Prof. Dr. Cor van der Weele (WUR), Dr. Bernard Roelen (UU).

CM research in The Netherlands, started at the universities. First with a government-funded project between Eindhoven, Amsterdam and Utrecht, followed by a second government-funded project between Utrecht and Wageningen. After these projects had finished, government funding was cut, and research shifted to the CM start-up companies: Mosa Meat and Meatable [E7, E8]. Due to the Maastricht University's close connection to Mosa Meat through Mark Post, and Mark Post's efforts to raise new research money, research at UM continued [E4, E8]. By analyzing CM publications from authors with Dutch affiliation, the knowledge institutes can be further identified (Appendix B). Today, only the universities in Wageningen and Maastricht are still actively involved in CM research. The current and past knowledge institutes involved are summarized in Table 7.

Table 7 Knowledge institutes involved in Dutch CM research

Actor	Still actively involved?	Involvement
Wageningen University and Research Institute (WUR)	Yes	Active in the area of social and environmental research
Maastricht University (UM)	Yes	Biological research
University of Amsterdam (UvA)	No	Biological research
Utrecht University (UU)	No	Biological research
Eindhoven University of Technology (TU/e)	No	Biological research

Values of the knowledge institutes

In generating knowledge, the institutes all benefit from quick and accurate development of a knowledge basis to decide on future research directions or to evaluate the potential of a certain research trajectory.

In basis, the universities are all about producing knowledge [E7, E8]. Findings are published in academic papers, and sharing and building a knowledge base, are the most important aspects of an academic institution. Patents are also part of it, but the most important aspect remains opening up your academic research through publications [E8]. In building this research base, CM is not a goal in itself [E7]. CM is one of the alternatives to reduce the harmful effects of current farmed meat [E7, E8].

4.1.2. Educational organizations

Interviewed: Prof. Dr. Cor van der Weele (WUR).

In contrast to the knowledge institutes, educational organizations are more focused on passing on knowledge to other persons or institutions for learning purposes. Still, these two categories can (partly) overlap.

Educational organizations are difficult to identify in the Dutch CM scene, as mentioned during one of the expert interviews: "There is no place to study 'cultured meat' in The Netherlands. For now, knowledge creation mostly happens at Meatable and Mosa Meat. However, those companies can only tell what they are allowed to tell by their investors, but that won't educate the next generation.". In that view, only the universities in Wageningen and Maastricht are left as educational organizations. Those institutions are freely publishing their research through academic research papers, which could potentially educate and stimulate the next generation.

Table 8 Dutch educational organizations involved in the Dutch CM sector

Actor	Involvement
Wageningen University of Research (WUR)	In the area of social and environmental sciences
Maastricht University (UM)	On the biological aspects of cultured meat

Values of the educational organizations

As more generally described for the knowledge institutes, the universities are about producing (open) knowledge through amongst others publications. Besides their role as generator and repository of knowledge, universities bear the task of educating their graduates, offering them the opportunity on viable employment. However, the direction of this education and the vision and values of universities can differ. This can also be observed for the visions and values on innovating our current meat and farming system. Technological and biological research at the WUR focuses on plant-based alternatives, and not on CM, since plant-based alternatives are more sustainable [E7]. On the other hand, the UM is highly interlinked with Mosa Meat, focusing their technological and biological research also on CM.

4.1.3. Industry

Interviewed: Mosa Meat. Contacted for interviews, but declined or not responding: Meatable, M ventures, Future positive, Bell Food Group, Lowercarbon Capital, Biotech Delft Campus, Nutreco.

The industry entails all the actors involved in the potential future production chain of CM. An overview of those actors and their potential role in CM, can be found in Table 9.

Table 9 Overview of the actors involved in the Dutch CM industry

Actor	Involvement
Mosa Meat	Producing the cultured meat
Brightlands Maastricht	Accommodating Mosa Meat
Meatable	Producing the cultured meat
Biotech Delft Campus	Accommodating Meatable
Nutreco	Contract for delivering raw materials to Mosa Meat
Investors	Funding cultured meat development

The Dutch CM industry is still in its infancy, and therefore currently makes up for a small scene. The two CM start-up companies are present, Mosa Meat and Meatable. Formal ties between those start-ups and other companies, industries or actors are still very limited. During the expert interviews with GFI, the limited amount of formal ties was emphasized, and linked to the infancy of the industry: "From a standpoint of market incentives, it's difficult to get these suppliers into the cultured meat market, since the market is not yet there. Essentially, as we see the market attract increase, then the incentives will align for larger suppliers." [E12]. At the moment, the only formal tie formed in the Dutch CM scene, is between Mosa Meat and Nutreco. In early 2020, Nutreco announced their strategic partnership with Mosa Meat, in which Nutreco will be able provide Mosa Meat with a more cost-competitive supply of raw materials than the current dependence on pharmaceutical raw materials (Nutreco, 2020) [E1]. Besides the strategic partnership between Mosa Meat and Nutreco, Brightlands Maastricht and Biotech Delft Campus are involved by facilitating working space for Mosa Meat and Meatable respectively. Moreover, the fact that the Dutch government or European Union is currently not funding the Dutch cultured meat research, makes for many venture capital companies and business angels to invest in the Dutch CM scene. Mosa Meat has attracted the following investors over the past few years: Sergey Brin, Chris Sacca, M Ventures, Bell Food Group, Lowercarbon Capital, and Meatable: BlueYard Capital, Future Positive, Backed VC, Atlantic Food Labs, Charles Songhurst, Jörg Mohaupt, Taavet Hinrikus, Union Square, European Union ("Crunchbase," n.d.).

Values of the industry

The current actors of a potential CM industry, benefit from a quick and successful transition to CM, in particularly for their return on investments.

The two start-ups both state their own goals and thereby values during the development process. Mosa Meat states in the interview: "Our mission is to commercialize cultured meat and make it a hugely popular product so that we can all continue to eat the real meat we enjoy, but without the very harmful effects of livestock meat production." [E5]. From the website of Meatable, a similar goal can be derived: "We're pioneering a way of producing real meat without harm. Change without compromise, the best of all worlds. Efficient. Sustainable. Harm-free. And most importantly of all, delicious." (Meatable, n.d.). So, the values of the start-ups can be deducted as: harm-free, efficient and sustainable.

As indicated, nowadays the Dutch CM scene is privately funded by venture capital companies or business angels. The returns of their investments, is completely dependent on the future growth of the company they invested in. These major investors, therefore have their say within the company and a significant amount influencing power. Their major value is to receive an as high as possible return on their investment money. In order to achieve this, the company they invested in has to reach the market and become one of the market leaders. In this view the investors values align the start-up values, to set up an as efficient process as possible to achieve those high returns.

However, the fact that the scene is based on private investors, also significantly slows down the development process. In the early days, when government funding was cut, the start-ups and universities had to attract investors themselves to be able continue their research. Moreover, knowledge exchange between and from the companies is scarce, due to the high competition factor, increased by the private investor structure. Each company wants to be the first to commercialize and take the market, and avoid being scooped by others.

4.1.4. Market actors

Contacted for interviews, but declined or not responding: LTO Nederland, COV, FDF, Vion Food Group, VanDrie Group, Nestlé – Garden gourmet, Vivera, De Vegetarische Slager, Albinsecta.

The market actors include all the players (sellers and producers) that are active in and thereby influence the potential market for CM. This consist of the producers who are selling their products on this potential market, and the channels through which those products are sold. The producers can be divided into three main categories: the conventional meat industry, meat alternatives producers (the producers of plant-based fish and meat alternatives, and the producers of hybrid products). Many of these market actors can be, or are already, involved in CM development. Currently, the potential role of farmers in the CM process, is investigated by Ira van Eelen and Cor van der Weele [E1][E7]. Moreover, the major embedded meat companies could facilitate CM supply or distribution chain in the future. The channels through which those products are sold, can be divided into two main groups: supermarkets and restaurants.

Table 10 Overview of the actors involved in the potential Dutch CM market

Actor	Involvement
Farmers	Delivering the animal and agricultural related products
Farmed meat producers	Selling their products on potential cultured meat market
Meat alternatives producers	Selling their products on potential cultured meat market
Supermarkets	Potential channel to market cultured meat
Restaurants	Potential channel to market cultured meat

A more detailed overview on the meat alternative products, supermarkets and restaurants, can be found in Appendix C.

Values of the market actors

All market actors benefit from a high interest and expense of society in the meat market. While farmers and farmed meat producers benefit most from investments in farmed meat, meat alternative producers benefit from investments in their range on the other hand. The retail channels (supermarkets and restaurants) are less bound to a specific area of interest in this matter. The values of each specific group is discussed in more detail below.

Farmers – For the farmers, the current agricultural sector system are their revenues. This is a fairly self-contained system, in which the grain that has been grown, in its turn eaten by the animals (about 60% of the entire EU grain supplies) [E2]. CM could be a threat, destabilizing the current farming system, and thereby their source of income. However, most of the farmers recognize the importance of making the current agricultural sector more sustainable to maintain business. To achieve this, farmers have suggested new machinery (robots, tractors) or sensors to make the current faming system greener (CRM partners, 2020). This clearly shows the different perspectives on sustainable food. According to

the research of 'Planbureau voor de Leefomgeving (PBL)', this all depends on the different (academic) knowledge sources consulted, as well as the values and point of views they use to approach the current food system (Muilwijk, Westhoek, & De Krom, 2018).

Farmed meat producers – Conventional meat companies are not necessarily against meat alternatives. Their main focus is delivery of good quality and well-considered product to the consumer [E1, E2]. In The Netherlands, two major meat companies can be identified: Vion Food Group (€5.1 billion revenues in 2019) and VanDrie Group (€2 billion revenues in 2019) (VanDrie Group, 2020; Vion Food Group, 2019). Both of these companies value to increase the sustainability of the meat sector. However, their approach to achieving this is different. Vion has announced in 2019 to invest in meat alternatives; "Vion has a large knowledge base on the production of meat. This can knowledge basis can be useful and utilized in the production of meat alternatives.". Thereby, Vion focuses on three meat alternatives: Plant-based, hybrid, and CM. However, for CM no concrete further steps have been taken yet, but Vion underlines its potential (Kloosterman, 2020). VanDrie Group has taken another route to sustainability by improving the current farmed meat production process. One cooperation for this, is with the 'Digital Food Processing Initiative' (DFPI) formed by WUR, TNO and TU/e. Possible innovations for a Smart Food System according to VanDrie Group, are: Big Data, Internet of Things, robotics and improved sensors (Lentjes, 2018).

Meat alternative producers – The three major industrial actors in the Dutch meat alternative sector, are Vivera, The Vegetarian Butcher, and Garden Gourmet (Tolonen, 2018). Their values as described in their mission statements and business reports, are strongly similar. These can be summarized as; sustainability, animal welfare, transparency, innovation, local, food security, taste and nutritional value ("De vegetarische slager," n.d.; Nestlé, 2019; Vivera, 2015). Interestingly, all of these values can also be projected to the CM start-ups.

Supermarkets - The increasing popularity of meat alternatives is also reflected in the supermarket sales and the availability of meat alternatives. Between 2017 and 2019, the sale of meat substitutes in Dutch supermarkets increased by 51 percent. The two largest supermarket chains are Albert Heijn and Jumbo. At Albert Heijn, the amount of meat substitutes increased by 33% since 2016 to 100 different products in 2019. In that year, Jumbo had almost 200 meat alternatives available (NOS, 2019). Altogether, their values can be summarized as: inexpensive, healthy, tasty, ethical-considerate and easy.

Restaurants - Restaurants are often mentioned as starting point for CM products. Selling it as a niche product at high-end restaurants. Values of restaurants deviate from restaurant to restaurant. While high-end restaurants go for more luxury and high priced products aiming at a specific target group, other restaurants aim at the masses with lower priced and more accessible dishes. Changing consumer preferences, also show in restaurants. The amount of vegetarian and/or vegan dishes are increasing, as consumer awareness about the environment increases. Especially take-away restaurants alter their packages to suit societies sustainability wishes. All restaurants benefit from sustainability, animal welfare, valued employees, and high nutrition. Also for the restaurants holds: obeying consumer wishes, helps to attract consumers and increase their profit.

4.1.5. Government bodies and regulatory organizations

Interviewed: Tjeerd de Groot. Contacted for interviews, but declined or not responding: NVWA, EFSA.

The government bodies and regulatory organizations include all the ministries and organizations with formal regulating or influencing power on the development of CM. An overview of the governmental organizations influencing the Dutch CM scene, can be found in Table 11.

Table 11 Overview of the government bodies and regulatory organizations involved with CM in The Netherlands

Actor	Involvement
Ministry of Economic Affairs (EZ)	Funding
Ministry of Health, Welfare and Sport (VWS)	Supervision on food safety in The Netherlands
Ministry of Agriculture, Nature and Food Quality (LNV)	Organization of the agricultural system
Dutch Food Safety Authority (NVWA)	Food safety, inspect if food companies obey the laws
European Food Safety Authority (EFSA)	Legalize cultured meat as novel food

In The Netherlands, three ministries are involved in the development of cultured meat. The first ministry, is The Ministry of Economic Affairs. This Ministry is responsible for distributing funds to promising initiatives, as possibly CM. The second involved ministry, is The Ministry of Health, Welfare and Sport, that carries the supervision over food safety in The Netherlands. This task includes among others the labelling of the future cultured meat product. The third, and last, involved ministry, is The Ministry of Agriculture, Nature and Food Quality. This ministry is in charge of the organization of the agricultural system, as well as its sustainability, our valuable nature and nutrition. In this role, they can be recognized as highly important in promoting cultured meat research if they see a future in cultured meat in our food chain.

Besides the Dutch Ministries, also the Dutch Food Safety Authority (NVWA) is involved, which is an agency of the Ministry of LNV. The NVWA has the task to supervise if all companies involved in the food chain, obey to the current laws and standards, as well as to assure food safety.

The last involved body, is the European Food Safety Authority (EFSA). In current state of the CM development, this organization plays a key role. Since CM is not recognized as an innovation or improvement of an already existing product, the product is marked as a 'novel food'. This means that the potential CM product has to obey to the novel food laws set by the EFSA, before the product can reach the European consumer.

Values of governmental organizations

In the end, despite the different areas of specialization of the Ministries and agencies, all the involved governmental organizations aim at a safe and sustainable developments. The Ministry of EZ stimulating this financially and the Ministries of VWS and LNV, and the safety authorities, assessing its potential and safety. Assessing novel foods as CM, can take a significant amount due to the strict procedures to obey. Looking at The Netherlands, a significant bottleneck time-wise can be found in the EFSA regulations.

4.1.6. Public interest groups and key individuals

Interviewed: Ira van Eelen, Amanda Govers, Koert van Mensvoort, Mac van Dinther, GFI, Wakker Dier, NVV. Contacted for interviews, but declined or not responding: Nederlandse Vegetariersbond, ProVeg Nederland, Lisa Stel, WNF, Greenpeace, Chloé Rutzerveld.

In addition to the actor groups mentioned by Hekkert et al. (2011), another actor group has been added in light of this study: "Public interest groups and key individuals". An actor group that entails persons or groups that can actively stir the opinions of a significant group of people. This mostly occurs via the social media, but can also take place via other channels or events. Especially since this research is concerning a new, still developing technology, producing a product that yet has to be brought to the market, many people are still unaware of the technology and potential product. This ignorance, makes the big crowd more sensitive to the coverage by the group, also referred to as "influencers". A summary of Dutch influencing organizations with respect to cultured meat can be found in Table 12.

Table 12 Overview of the Dutch influencing organizations concerning CM

Influencing organizations	Examples
Cultured meat promotors	Ira van Eelen, Koert van Mensvoort
Animal Welfare organizations	PETA, Wakker Dier
Vegan/Vegetarian organizations	ProVeg, Nederlandse Vegetariersbond, Dutch Society for Veganism (NVV)
Environmental awareness organizations	Greenpeace
Religious societies	Jewish, Christian, Islamic community
Journalists	Food reviewers, culinair journalists

Each of those influencers has their own way of passing on their ideas about CM. While the animal welfare, vegan/vegetarian, religious and environmental awareness organizations mostly represent a specific group to which they transfer their more or less formed ideas on CM, the CM promotors and journalists aim for a wider public. Some interesting examples of Koert van Mensvoort can be point out here, with a cultured meat cookbook in the stores, a fictional restaurant 'Bistro In Vitro' and an exhibition 'Meat the Future' on CM [E4].

Values of public interest groups and key individuals

The public interest groups and key individuals aim either at their specific target group or at society to share their ideas and thoughts. Their goals are to eventually influence or provide information to their target group. Their specific values shared, differ significantly among the influencers. Some are focusing on health (Red Cross, KWF cancer foundation, Hartstichting), human safety (Unicef/War Child), or the environment (Greenpeace, Wereld Natuur Fonds, Natuurmonumenten). Even within these categories of organizations, different values exist. While for instance Wakker Dier does not specifically aim for a future with animal-free diets, but rather decrease the meat consumption and increase the conditions for the animals, the Dutch Association for Veganism (NVV) aims for an entirely plant-based future [E10, E11]. To spread their ideas, events, initiatives or talks are organized to reach the public.

4.1.7. Actor overview

All the aforementioned actors can to some extent be related to the CM innovation system. While the focus here is on the IS, some of the 'outsiders' and the general public cannot be left out in this, due to their influence on the CM innovation system. An overview of the actor groups, the innovation system, and their positioning within the whole, is shown in Figure 11.

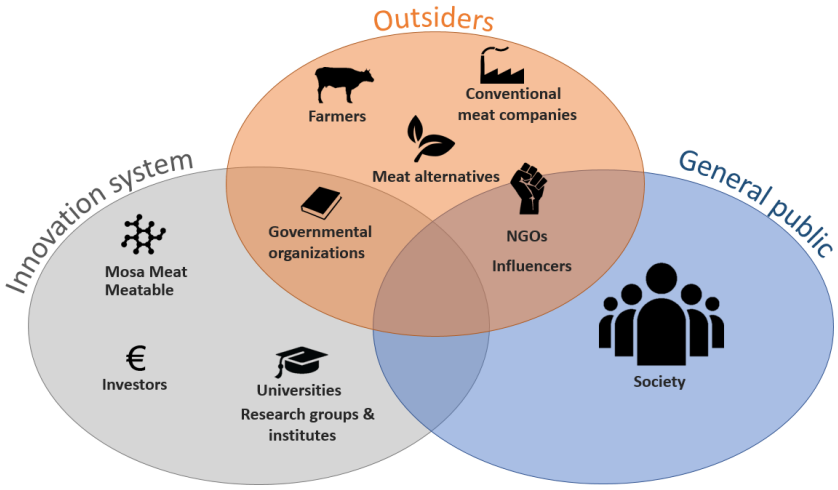

Figure 11 Schematic overview of the stakeholders in and around the Dutch CM scene

As discussed, all actor groups hold their own personal values. Within, and between the different actor groups, conflicting and shared values can be recognized. Increasing the sustainability of the current meat sector can be recognized as a common theme. However, ideas on how to achieve this, significantly differ. While CM start-ups, meat alternative producers, investors in these sectors and meat producer Vion are looking at innovating new technologies, the farmers and VanDrie are focusing on improving our current farming system (Figure 12, (3)). Within the group that aims to innovate towards sustainability, also different preferences and values can be observed, leading to either CM or other (existing) meat alternatives (Figure 12, (4)). Plant-based alternatives offer the advantage of not being anything related to animals, and thereby attracting a significant group of vegans, as opposed to CM. Moreover, plant-based alternatives are currently more sustainable than CM. Diving into the option of CM, all the parties within the IS benefit from quick knowledge development to assess or prove its potential. However, the current private investor structure, causes the start-ups to keep their research highly confidential. In combination with little university research, the process is significantly slowed down (Figure 12, (2)). Moreover, lengthy procedures and novel food regulations from governmental organizations, as EFSA and NVWA, also hinder quick commercialization of CM for the start-ups (Figure 12, (1)).

The most stringent conflicting values for the development of a CM innovation system, have been illustrated in Figure 12.

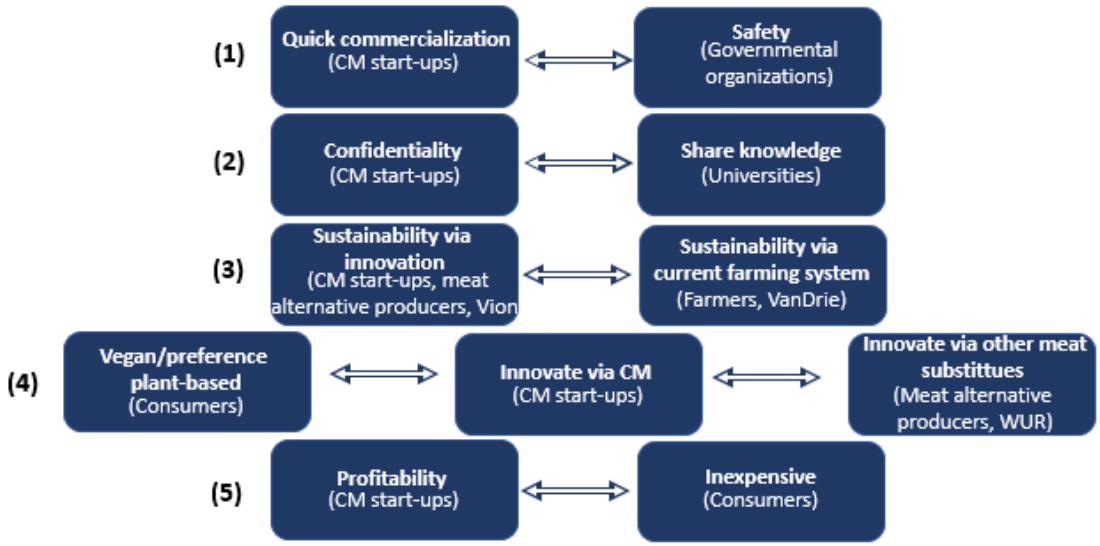

Figure 12 Conflicting values in and around the Dutch CM system

4.2. Networks

The second structural component of the innovation system structure to be discussed, is the networks. In this study 'networks' are defined as: "Interactive learning (e.g. consumer-industry or university-industry networks) and the formation of political networks" (Bergek et al., 2008; Jacobsson & Lauber, 2006). Here, a distinction between formal networks (for strategic reasons and a common goal) and informal networks (no clear boundaries or common goal) is made.

4.2.1. The cultured meat start-ups and their networks

Based on the actor analysis, we can recognize the two CM companies as central players of the cultured meat innovation system. However, for the start-ups to exist and execute their core activities, their investors are key. Without the private investments, the start-ups would not have been able to survive or exist in the first place. This dependence on ties with private investors, forces the network of the start-up companies to be very limited to their own 'bubbles'. Due to the many start-ups in the world, as well as the private funding structure, competition is massive. This leads to confidentiality of their research activities and trying nog to be caught up by others. Besides the investor ties, the formal ties between the companies and their facilitator of workspace can be recognized. Brightspace Maastricht for Mosa Meat and Biotech Delft Campus for Meatable [E4]. Ties between the universities and the companies are very minimal. The foremost network tie to be distinguished here, is between Mosa Meat and Maastricht University. No further formal or informal connections have been observed or found between the potential future consumers and the start-ups [E1, E2, E4, E5, E8]. Moreover, the two Dutch start-ups are not in close contact to each other: "The two Dutch start-ups are not friends, they have very different views." [E1]. Regarding supplies of materials, the only connection here, can be found between Mosa Meat and Nutreco. Moreover, Mosa Meat recently announced its cooperation with Celltainer, that is going to focus on designing bioreactors for cultured meat production.

Overall, the Good Food Institute is in (informal) contact with cultured meat related innovation activities worldwide. For The Netherlands, this includes Mosa Meat and Meatable, as well as Cultured Blood, a producer of artificial blood circulation systems, and Celltainer. However, no further connections between Celltainer, cultured blood, universities and the two start-ups themselves have been identified. Besides the Good Food Institute, the other established network tie outside of the start-up 'bubbles', is with the government. Via the government, the cultured meat start-ups are in contact with the ministries, trying to stimulate cultured meat research. Furthermore, Mosa Meat is in contact with EFSA to start the procedure to be acknowledge as novel food. It is not known if Meatable has already started this procedure as well.

Table 13 Overview of the network ties with the Dutch cultured meat start-ups

Start up	Network ties
Mosa Meat	Investors
	Brightspace
	Nutreco
	Celltainer
	Maastricht University
	Good Food Institute
	Government
Meatable	Investors
	Biotech Delft Campus
	Good Food Institute
	Government

4.2.2. Network nodes touching the start-ups network

On top of the mentioned network ties within the start-up networks, a few other major and important networks, still closely touching the networks of the start-ups, can be recognized (Table 14).

Table 14 Overview of the Dutch network ties touching the cultured meat start-up networks

Actor	Network tie
Universities	Eindhoven – Amsterdam – Utrecht (2004-2009)
	Utrecht – Wageningen (2010-2014)
Government / Ministries	Cultured meat experts
	NGOs

The first network tie in the area of cultured meat between universities was between 2004 and 2009, and involved the University of Technology in Eindhoven, University of Amsterdam and Utrecht University. This research focused on finding suitable pig stem cells, for the production of cultured meat (Eek, 2015). Later on, in 2010, a collaboration between the University of Utrecht and Wageningen University of Research was announced. In this multi-disciplinary research, social sciences and biological research were combined. These collaborations have built the initial knowledge base about CM.

Moreover, during the interviews another informal tie appeared between the government (ministries) and NGOs and cultured meat experts. The members of the Parliament have contact with experts in the CM field once in a while, to be kept in the loop and informed about new developments in the field. Since it can be pretty challenging for a Minister to have knowledge about every topic. This is an informal tie via a WhatsApp-group [E9]. On top of that, the interviewed NGOs mention that they give informal advice to parties [E10, E11].

4.2.3. Network formation outside the start-up 'bubbles'

Besides the networks more directly influencing the cultured meat company activities, some other networks can be found in the meat (alternative) scene. Two major networks are the True Animal Protein Price (TAPP) Coalition and the Green Protein Alliance (GPA). The partnering companies, institutes and organizations in these networks are shown in Table 15.

Table 15 Overview of the network formation outside the start-up 'bubbles' , still possibly influencing these start-up bubbles

Network	Network tie
True Animal Protein Price (TAPP) Coalition	Dierenbescherming, Oxfam Novib, Natuur&Milieu, Caring Vets, Wakker Dier, Milieudifensie, Willem&Drees, Greenpeace, Nationale week zonder vlees, De hippe Vegetarier, Amsterdam Open Air, Vegapolis, Hutten, Questionmark, Milkshake, Vegetariersbond, Varkens in Nood, Kipster, Groencampain, Green budget, Even geen vlees, ProVeg, Dier&Recht, Mauritsgroen, Climate cleanup, Arts en Leefstijl, Dierencoalitie, Eosta, Nature&More, Urgenda
Green Protein Alliance (GPA)	Albert Heijn, Alpro, Bonduelle, Boon, Botanic Bites, Bumi, Dutch soy, The Dutch Weedburger, Garden Gourmet, Goodbite, Griffith, Gro, Hak, Intersnack, Marley Spoon, Myco, Nextfoods, Olijck, Puple Bee Hive, Quorn, Rabobank, Rotterzwam, SoFine, Unilever, Vivera, Willicroft

The TAPP coalition is founded in 2018, aiming for 'true' prices for food, including costs for the environment, health and animal welfare. In this target, meat and dairy products are prioritized, due to their major impact (TAPPC, n.d.). Moreover, the GPA targets at making a plant-based food choice top of mind by the Dutch consumers (GPA, n.d.).

4.2.4. Overview the networks in the Dutch CM scene

All the nodes and ties involved in the Dutch CM scene, still make up for a small network today. In Figure 13 all the nodes and ties within the CM innovation system are represented.

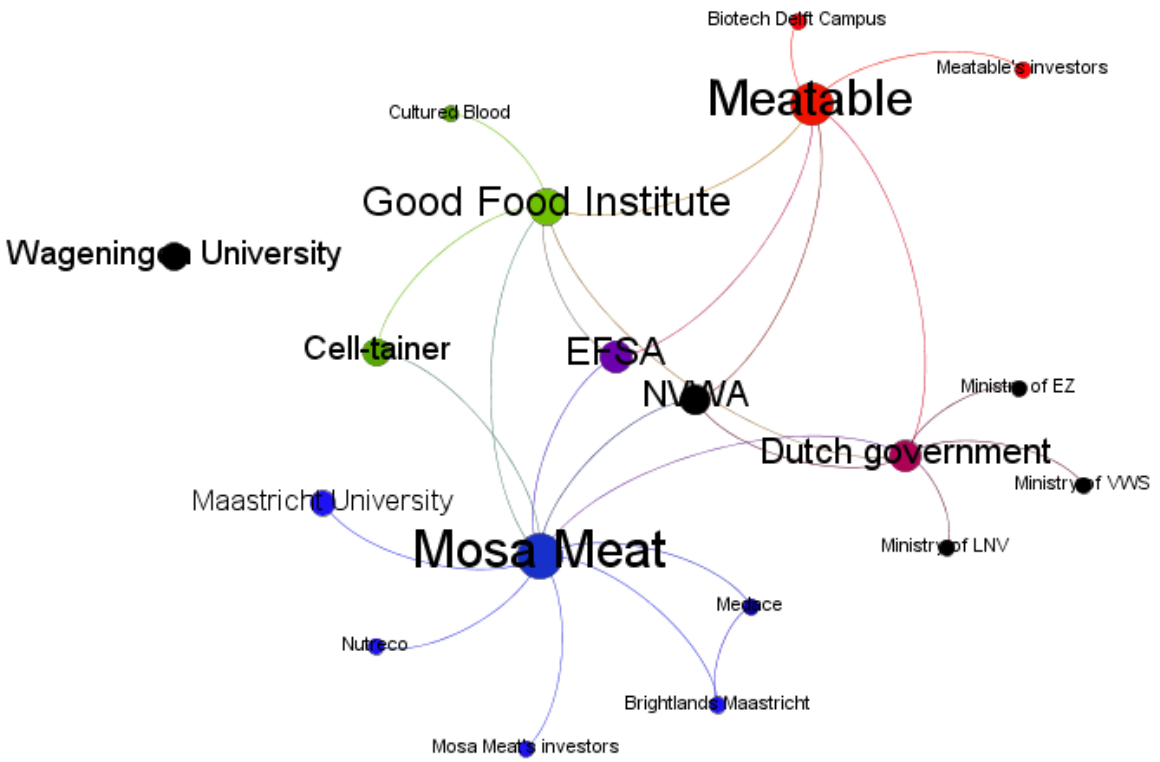

Figure 13 Overview of the nodes and connections in the Dutch CM scene (created with the network analysis software 'Gephi'[1])

4.3. Institutions

4.3.1. Formal institutions

The third structural component of the innovation system described here, are the institutions. Institutions are defined as "'the rules of the game in a society, or, more formally as the humanly devised constraints that shape human interaction. A distinction can be made between formal institutions and informal institutions, with formal institutions being the rules that are codified and enforced by some authority, and informal institutions being more tacit and organically shaped by the collective interaction of actors." as described by Hekkert et al. (M. Hekkert et al., 2011).

The formal institutions for CM are arranged on a European level via the EFSA. Since CM is not an improvement or other version of an already existing product, CM is included in the EFSA novel food regulations. The EFSA describes Novel Food as: "Food that had not been consumed to a significant degree by humans in the EU before 15 May 1997, when the first Regulation on novel food came into

[1] https://gephi.org/

force." (European Commission, n.d.). A major amount of novel foods have preceded CM in completing the steps of the Novel Food Regulations. These products range from production of cereal bars involving yeasts to UV-treated mushrooms. Since the new European Novel Food regulations 2015/2283 became fully applicable as of January 1st 2018, applications no longer need to be submitted on a national level. This centralized authorization procedure, makes for a harmonization of its safety assessment criteria among the member states, as well as a quicker authorization process. Whereas the old (decentralized) novel food procedure, took between 16-60 months, with an average of 35 months, the current procedure could ideally only take 400 days. This includes a maximum of 9 months for the EFSA to deliver its opinion, and another 9 months for the Committee to present the measures to authorize the Novel Food concerned (Centre for Strategy & Evaluation Services (CSES) & ADAS UK Ltd, 2013).

Eventually, the NVWA, and ministries will have their say about the product and safety (labelling), but the main approval is currently in hands of the EFSA. As described by the NVWA itself: "Once the company has demonstrated the safety of their product to the European Commission (EFSA, ed.), the cultured meat may be marketed and served in restaurants." (NVWA, 2018).

At the moment, Mosa Meat is focused on obtaining regulatory approval for the sale of cultured meat, however this process can certainly take some time. About the requirements, Mosa Meat states during the interview: "One interesting point is that in the EU, the law requires that any "novel" food must offer the same nutritional values as an equivalent already on the market. Because our meat is taken in biopsies from cows, this is not an issue for us (as opposed to if someone was creating the meat from scratch). It is also worth noting that our meat is not genetically modified, so this will not be an additional part of the regulation process." [E1].

4.3.2. Informal institutions

The informal institutions are much more difficult to hold on to, since there are many different views on cultured meat in society. While some consumers keep valuing farmed meat, despite the proven environmental disadvantages of the current system, other consumers have already removed farmed meat from their diets, with all their individual motives. These motives can for instance relate to their demographics, religion or educational background. Regardless of personal choices, some higher discussions can also be linked to these informal institutions. Increasing attention for themes as the climate changes, sustainability, animal cruelty, but also increasing awareness of the negative impact of eating meat.

As many of the experts also note, independent of their food preferences and spreading ideas, most of the consumer will eventually go for the cheapest option [E1, E2, E3, E8]. The price is an important, whether or not the most important, value and indicator in consumer decisions. CM could become a luxury product, at least near market introduction, and therefore not widely available for the entire consumer group. Moreover, in every product choice, taste and ease are also key for consumers.

Interestingly, for this matter, no ties have been formed between industry and potential consumers. As one of the influencers note during the interview: "What also happens with Apple, they are not growing public support, they just launch their products on the market." [E2]. On the other hand, several motions have been written by, amongst others, member of the parliament Tjeerd de Groot, to allow for more experimentation with cultured meat and consumers. This was submitted with support from the Dutch cultured meat scene, indicating that they might be looking at ways to involve consumers.

4.4. Technology

The fourth and last structural component of the innovation system to be discussed, is the technology. In this study, the technology component is defined as “Technological structures consist of artifacts and the technological infrastructures in which they are integrated” according to Hekkert et al. (M. Hekkert et al., 2011).

From the interviews, more detailed information could be obtained on the technology. It showed that, overall, the technology is rather ‘simple’ and on the basis the same for every company, institute or university. However, some organizations focus on innovating a specific part of this basis process. First the basis of this production process will be explained in more detail, after which the past and current research will be described, followed by a discussion of the bottlenecks of the technology.

4.4.1. Overview of the cultured meat production process

Mosa Meat and Meatable both use the same basic process for the production of CM. In this process, five main steps can be distinguished. First, a small biopsy of cells are taken of an animal under anesthesia. In the second step, the cells of interest are isolated from the biopsy. The cells of interest, are stem cells, due to their unique characteristic to grow into new cells. Originally, stem cells possess this characteristic to repair tissue when injured in the animal. In the third step, these cells are placed in a nutrient-rich medium containing growth factors to induce proliferation of the cells. This proliferation step takes place in a bioreactor. In the fourth step, these proliferated cells are forced to differentiate into muscle cells and/or fat cells. In the last step, these cells have to be collected and layered to form the desired piece of meat (Meatable, n.d.; Mosa Meat, n.d.). These same five steps can be recognized in Figure 14, taken from a research co-authored by Mark Post (Bodiou, Moutsatsou, & Post, 2020).

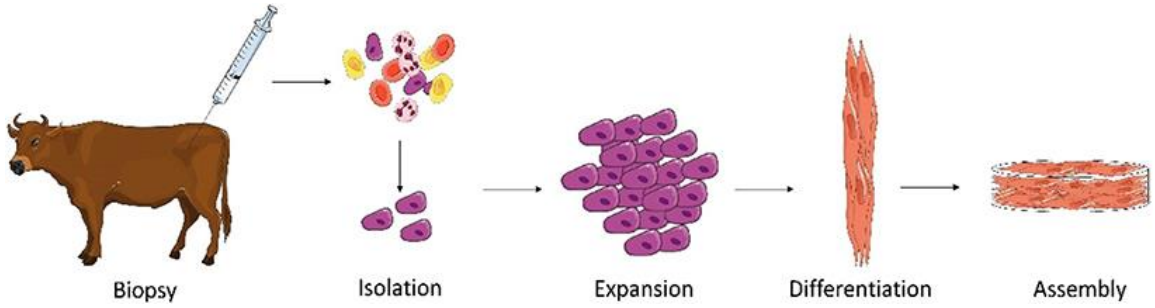

Figure 14 Overview of the cultured meat production process (Bodiou et al., 2020).

The main differences that can be recognized in the processes of the two Dutch start-up companies, are the cells of interest from the biopsy, and the cells obtained through the process. Mosa Meat aims at muscle stem cells in the biopsy. Eventually, the growth factor feed to the stem cells is cut off, thereby creating muscle cell “myotubes” of no longer than 0.3mm. Subsequently, these myotubes are placed in a gel, helping them to form muscle fibers. Lastly, those muscle fibers are collected and layered together to form a piece of meat (Mosa Meat, n.d.). Instead of muscle stem cells, Meatable aims for induced pluripotent stem cells (iPS cells). Whereas the muscle stem cells only differentiate into muscle in the differentiation step, Meatable describes a process obtaining a mixture of both fat and muscle cells. Meatable claims to make faster and cheaper CM with their proprietary stem cell technology.

4.4.2. Past and ongoing technology-related research in The Netherlands

To trace the past and current technological trajectories, the direction of technological research in Dutch organizations is an important indicator, which is mapped through publications. Technology and/or biological research for CM in The Netherlands, has been performed at different universities as well as within the two start-up companies. A broad range of research has been performed, focusing on different aspects along the CM production chain. While the universities have mostly focused on specific parts along the CM production chain, the CM companies cover the entire chain. A more detailed description of the research, can be found in Appendix D.

4.4.3. Technological bottlenecks

From the interviews, websites and literature some major bottlenecks for the development of the cultured meat technology can be pointed out. These bottlenecks are: cell line development, cell culture medium, scaffolding, and the scaling up of the process.

Cell line

The production process starts by taking a biopsy from the desired animal. However, in a more ideal situation, this biopsy and thus the animal, are completely removed from the chain. To achieve this, the development of long living or even indefinite cell lines is needed. This requires cells to be modified to survive high shear stress or resistant to certain toxic metabolites that might build up during the process (Polizzi & Kontoravdi, 2015).

Cell culture medium

Another bottleneck following in the process, is the growth medium for the expansion of the cells. This problem is two-fold, referring to the animal products (fetal bovine serum) in the medium, as well as the expensive growth factors.

Focusing on the first problem, removing the animal products from the medium, multiple institutions indicated to have removed this problem, including Mosa Meat and Meatable. During the interview, Mosa Meat stated to have solved this problem: “We have a “Medium Optimization” team who have worked hard the past year and successfully removed the Fetal Bovine Serum from our medium.” [E5]. A similar statement can be found on Meatable’s website, on the FAQ-page. “Do you use Fetal Bovine Serum (FBS) to make your meat? - No, for a simple reason: we’re committed to making meat without causing any harm at all to animals. So we’ve developed a production process that doesn’t require FBS.” (Meatable, n.d.). However, recent literature – co-authored by Post – still states that more research is required to optimize serum-free medium for animal cells. A serum-free medium in which the cell proliferation is comparable to the current medium with fetal bovine serum (Kolkmann, Post, Rutjens, van Essen, & Moutsatsou, 2020).

The second part of the growth medium problem, are the costly growth factors. Despite the fact that the growth factors are required in the medium to promote rapid growth of the cells, these growth factors are expensive (Zhang et al., 2020). Demonstrations suggest that optimization of the growth factor production can reduce the cell medium costs by at least 97% (Kuo et al., 2020). Another method can be, to develop small molecules that mimic the bioactivity of the expensive growth factors. However, the safety of residuals which might be present in the final product remains to be proven (Swartz, 2019). For this bottleneck, Mosa Meat recently announced to collaborate with Nutreco. Nutreco could supply raw materials for the medium that are ‘good enough’ for the cultured meat process, but do not reach the pharmaceutical standards, which will significantly reduce the cost for the growth medium (Byrne, 2020).

Scaffolding

Scaffolds serve as a construct surface for the cells to attach and differentiate into the desired structure, to mimic the 3D cyto-architecture of the intended meat product. For this, a cost-effective and edible or biodegradable material is required. Further exploration of possible scaffolding materials is needed. Plant- or fungal-derived polymers may be engineered as an scaffold (Swartz, 2019; Widhe, Shalaly, & Hedhammar, 2016).

Upscaling

To make the cultured meat production process feasible, scaling up of the process is required. For Mosa Meat, with its current capacity it takes about 10 weeks to create one hamburger [E5]. This causes a scientific and engineering challenge for creating a scalable production system. However, there are only a few companies around the world, working specific on the development of bioreactors for cultured meat, incorporating a scaffolding element, as well as meeting all specifications necessary for producing cultured meat. This is especially a major bottleneck, since the bioreactor is going to present as the highest fixed cost in the process [E12]. Mosa Meat is currently working on designing this bioreactor, in collaboration with Celltainer, and implementing it in their first pilot factory. For now, the process remains expensive, and will only really come down in price when significantly scales up.

4.5. Overview of the Dutch CM innovation system structure

The structural components of the Dutch CM innovation system are summarized in Figure 15.

The formal institutions and policies are determined via EFSA, NVWA and Dutch government. Those are in formal charge of accepting CM to the market. Norms and ethics of the consumers will eventually lead in determining if CM will be successful on the market. The biological and technological research activities take place at the CM start-ups, in collaboration with UM. Research in the area of social and environmental sciences take place at WUR. These research activities are supported by investors, the incubators providing workspace, and Good Food Institute (GFI) who is able to provide strategic support to the companies. Currently, the known supply streams are limited to the collaborations of Mosa Meat with Nutreco and Celltainer.

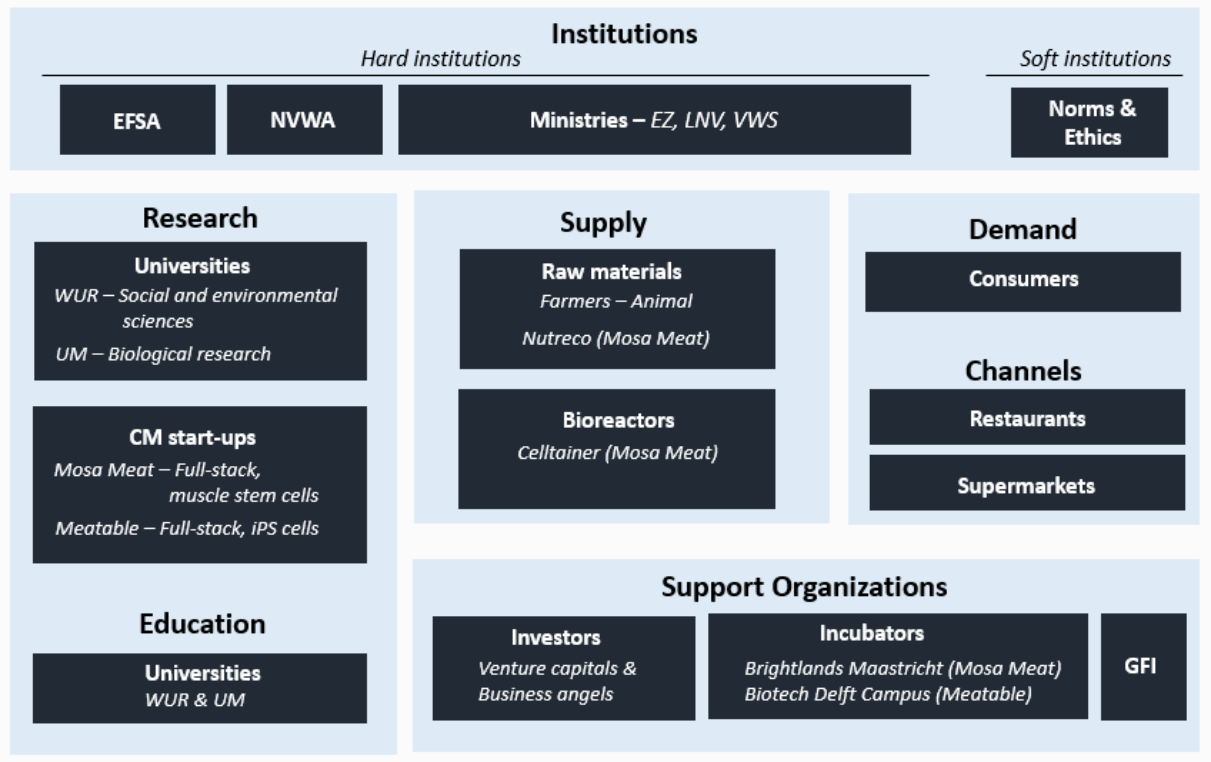

Figure 15 Overview of the Dutch CM innovation system structure. Adapted from Hekkert et al. (2011).

As can be concluded from the IS structure analysis, the Dutch cultured meat system still makes up for a small scene. It is still in its early development phase, and the fact that no feasible product is available yet, and that CM is not allowed to be marketed or tasted, attracts little new suppliers to the system.

5. Description of the function dynamics of the innovation system

The functioning of the Dutch cultured meat innovations system, and thereby its barriers and opportunities, are analyzed through the seven different system functions as described by Hekkert et al. (M. Hekkert et al., 2011). Each of the seven functions is separately discussed, analyzed and evaluated. The functions are evaluated through a classification system, rating high – moderate – low, to guide towards answering sub-question 2:

SQ2: What are the opportunities and bottlenecks for the development of the Dutch cultured meat innovation system?

5.1. Function 1. Entrepreneurial activities

The entrepreneurial activities are mapped through four indicators: the number of new entrants, diversification of incumbent actors, recent and future activities, and complementary technologies.

Presence of new entrants

Over the past few years, the total amount of CM start-ups has been growing enormously all over the world. Near the end of 2019, a total of about 20-30 CM companies were around, which has increased to 55 companies active in CM nowadays [E1]. Still, the amount of start-ups in The Netherlands is relatively stable. In 2016, the first Dutch CM start-up, Mosa Meat, was formed (Meat, n.d.). Two years later, in 2018, the second Dutch CM start-up company, Meatable, was established (TG, 2019). After that time, no more new companies have entered the Dutch cultured meat market. However, during the interviews, the foundation of a potential new Dutch CM start-up was brought up by Ira van Eelen [E1]. Multiple of the experts couple the small growth of the Dutch CM start-up scene compared to the rest of the world, especially The Unites States, to the negative start-up climate in The Netherlands [E1, E3, E4, E6, E8]. Whereas The Netherlands used to be the leader in the field, presenting the world's first cultured meat hamburger in 2013, The Netherlands is now about to fall behind. The Dutch investment climate (E1, E3, E4, E6 and E8) and 'Dutch modesty' [E4, E6] are mentioned as the two main reasons for the negative Dutch start-up scene. The financial boundary conditions are more difficult compared to the rest of Europe [E1, E12]. Moreover, the investment climate in the US is significantly different compared to The Netherlands, allowing for quicker and more aggressive accumulation of companies there [E4]. Looking at Silicon Valley, there is a highly developed ecosystem allowing for funding and support. For cultured meat companies to start in The Netherlands, is requiring considerably more effort. The external economies of scale in the Netherlands are simply negative for starting [E6]. On top of the influence of the investment climate, the 'Dutch modesty' causes The Netherlands to fall behind other countries. In the Netherlands, we cautiously support innovative ideas coming from university. However, the transition to launch these ideas into the world ('getting the man on the moon'), we just seem too modest for that (E4). The Netherlands is very passive and hesitant, only taking routes which are known to work. Most important and innovative technologies come from the US. It makes you a technology taker instead of developer [E6].

Due the small growth of the Dutch CM start-up scene, while worldwide the start-ups are popping out of the ground, the number of new entrants is rated as 'low'.

Diversification of incumbent actors

The two incumbent Dutch CM companies, Mosa Meat and Meatable, diversify themselves based on their production techniques, especially on the basis, which stem cells they use. However, they aim at the same end-product of beef cultured meat. Whereas some CM start-ups in the world only focus on the proliferation as cells, the two Dutch start-ups aim at the proliferation as well as fusion of the cells to tissue. Mosa Meat is currently focusing on building large-scale production units and innovating how

they can upscale their production equipment [E5]. Mosa Meat expects to launch their first products on the market in the next 3-4 years (Mosa Meat, n.d.). Meatable seems to be in a more early phase of development, and therefore has less interest in immediately accelerating legislation [E2]. In this early stage of product research and development, not much can be said about their target markets and possible diversification in this area.

Summarizing, both start-up companies aim at the same products, but utilize different means to realize this end-product. This indicator is therefore rated 'moderate'.

Recent and future activities

Apart from the research activities within the two Dutch CM start-ups, research took and still takes place within Dutch universities. Two research projects have been funded by the government. The first major cultured meat research project at Dutch universities, was a cooperation involving the University of Technology in Eindhoven, University of Amsterdam and Utrecht University between 2004 and 2009. This research focused on finding suitable pig stem cells, for the production of cultured meat (Eek, 2015) [E7, E8]. A second major CM research project started in 2010, connecting the areas of expertise of the University of Utrecht and Wageningen University and Research institute. In this multi-disciplinary research, social sciences and biological research were connected [E7, E8]. After those projects, no more funding was retrieved from the government for further research proposals an no other investors were found, causing a decline in CM research activities at universities. Later on, Mark Post received investor money to continue the CM research. However, as the a researcher from the UU states: "I already started working on other projects and did not feel like jumping back into the CM research" [E8]. Currently CM research activities still take place at WUR and UM. CM research at UM is highly connected to Mosa Meat activities through Mark Post. The ongoing CM research at WUR is in the area of social sciences. Moreover, currently Dr. Cor van der Weele, Ira van Eelen and Ruud Sanders (co-founder Kipster) are evaluating the potential network for cultured meat in The Netherlands by talking to a wide range of stakeholders.

In short, a high amount of CM research takes at the start-ups, while the research at universities has declined since the start of CM research, ranking this indicator as 'moderate'.

Complementary technologies

As the cultured meat technology matures, specific problems have shown with for example the culture medium and bioreactor design. Other companies have been founded or are focusing on these specific problems. In The Netherlands, we can point out Cultured Blood and Celltainer Biotech BV. Cultured blood is aiming to produce an artificial blood circulation system, to reduce costs of the medium used for cultured meat production, and to remove the blood serum. No formal network ties have been formed between cultured meat and CM companies yet. Moreover, Celltainer is aiming to produce a large scale bioreactor for the growth of cultured meat. For this, they are cooperating with Mosa Meat. Those two companies, are currently the only Dutch companies for delivering complementary technologies for cultured meat. From a standpoint of market incentives, it is currently difficult to get more of these suppliers into the cultured meat market, since the market is not yet there [E12].

Despite the fact that more companies are embracing the opportunities in the CM value chain, vertical integration is the primary business model of the CM companies (The Good Food Institute, 2019). Therefore this indicator is labeled as 'moderate'.

Evaluation of entrepreneurial activities

The previously discussed rankings and their scores are summarized in Table 16 Evaluation of Function 1. Entrepreneurial activities Table 16, and averaged to a total functioning.

Table 16 Evaluation of Function 1. Entrepreneurial activities

Indicator	Score
Presence of new entrants	Low
Diversification of incumbent actors	Moderate
Recent and future activities	Moderate
Complementary technologies	Moderate
Total functioning	**Moderate**

5.2. Function 2. Knowledge development

Knowledge development is mapped through five indicators: presence of patents, number of publications, presence of R&D projects, investment in R&D and research convergence.

Presence of patents

Only two patents can be distinguished that are filed by authors with Dutch affiliation. The first one, is the patent 'US2006029922A1 Industrial production of meat' of Willem van Eelen, which triggered the first cultured meat research around 2000. The second patent is patent 'US20190338232A1 Apparatus and process for production of tissue from cells' by Jonathan Breemhaar and Mark Post from Mosa Meat.

The fact that only two Dutch CM patents are present, ranks this indicator 'low'.

Number of publications

To map further CM knowledge creation, Scopus was utilized to analyze cultured meat publications. The following query string was used to obtain the cultured meat publications available on Scopus: TITLE-ABS-KEY ("cultured meat" OR "cultivated meat" OR "In vitro meat") . This resulted in 215 publications, of which 211 publications were released between 2000 and present (Figure 16). Interestingly, WUR is the organization that hold the most publications (12 publications) and Mark Post is the person who (co-)authored the most publications (9) worldwide.

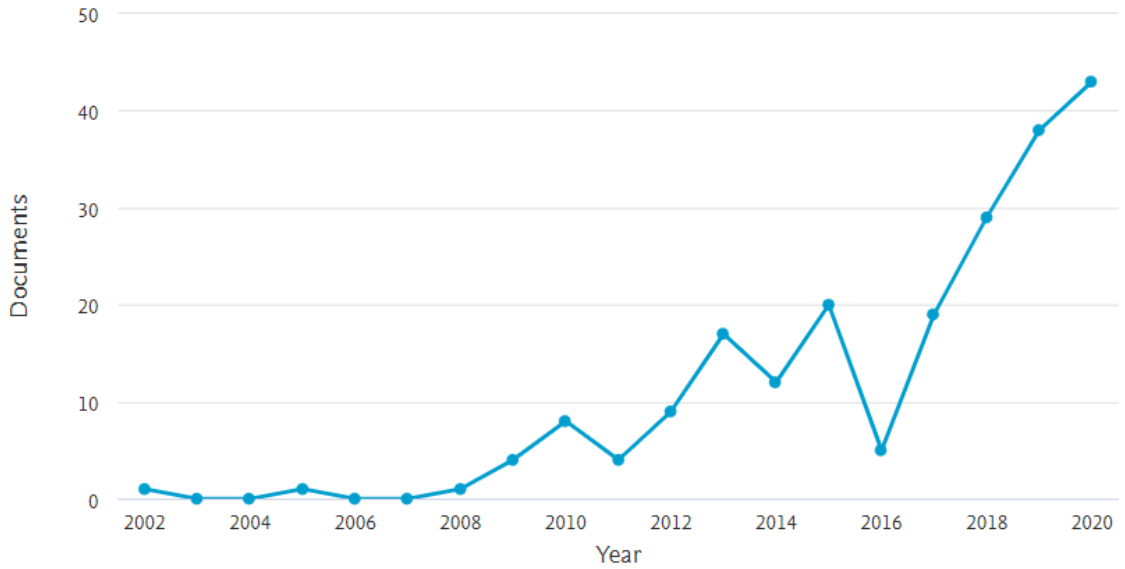

Figure 16 Scopus analysis total CM publications over the years. Scopus results for query string 'TITLE-ABS-KEY ("cultured meat" OR "cultivated meat" OR "In vitro meat") AND PUBYEAR > 2000 AND PUBYEAR < 2021' sorted by year.

27 of these obtained publications are from authors with Dutch affiliations (Figure 17). Similar to what can be observed for the worldwide trend, an increase in number of publications from around 2016 onwards can be observed.

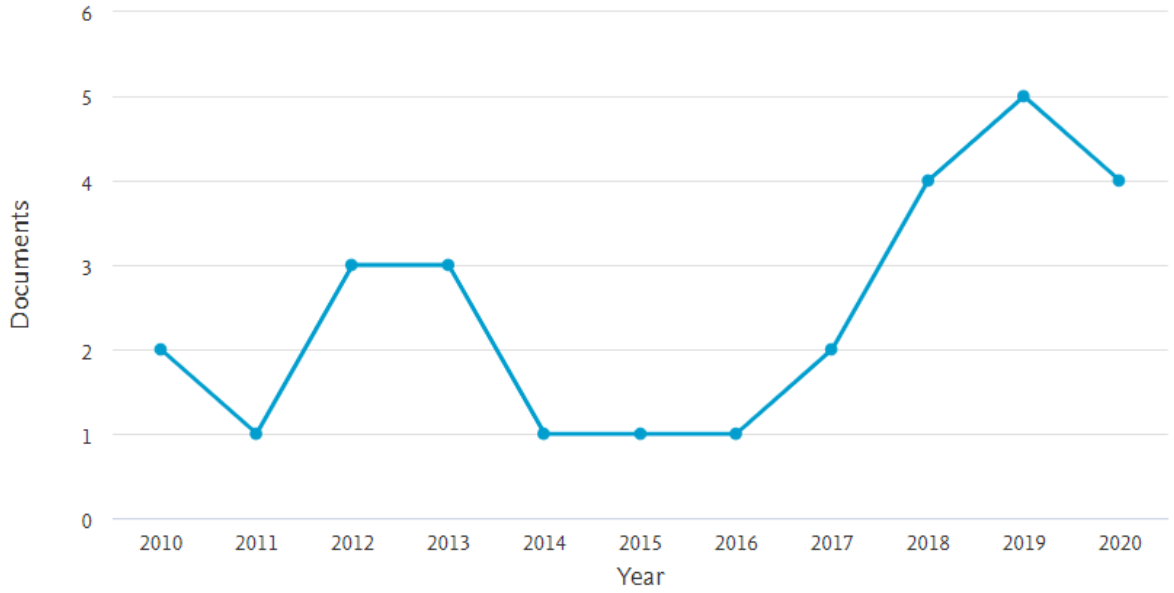

Figure 17 Scopus analysis total Dutch CM publications over the years. Scopus results for query string ' TITLE-ABS-KEY ("cultured meat" OR "cultivated meat" OR "In vitro meat") AND PUBYEAR > 2000 AND PUBYEAR < 2021 AND (LIMIT-TO (AFFILCOUNTRY , "Netherlands")) ' sorted by year

When analyzing the authors from the 17 most recent publications (query: 'TITLE-ABS-KEY ("cultured meat" OR "cultivated meat" OR "In vitro meat") AND PUBYEAR > 2005 AND PUBYEAR < 2021 AND (LIMIT-TO (AFFILCOUNTRY , "Netherlands"))'), most of the publications are coming from the UM and WUR (Figure 18).

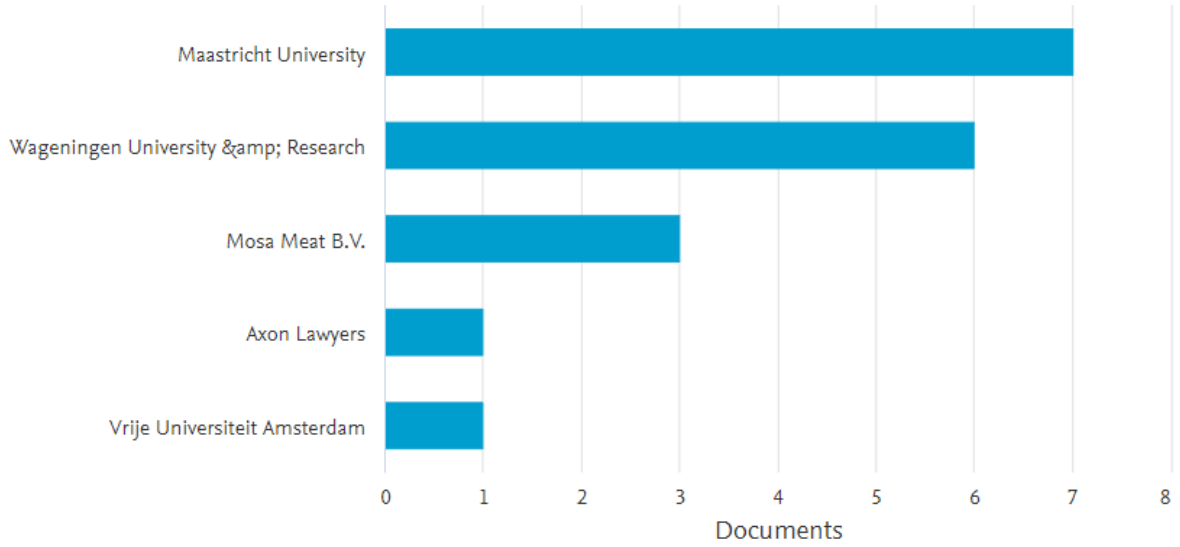

Figure 18 Scopus analysis total Dutch CM publications per institution. Scopus results for query string 'TITLE-ABS-KEY ("cultured meat" OR "cultivated meat" OR "In vitro meat") AND PUBYEAR > 2005 AND PUBYEAR < 2021 AND (LIMIT-TO (AFFILCOUNTRY , "Netherlands"))' sorted by institution

In summary, 8 percent of the total amount of publication originates from an author with Dutch affiliation, and Mark post and WUR are the most publishing person and organization worldwide. This leaves the number of publications with a 'high' ranking.

Presence of R&D projects

Much of the research is currently happening within the companies. During the interviews, all of the interviewed experts specified the two start-up companies, as the most relevant actors in the area of knowledge development. The confidentiality of this research within the two start-ups, making it difficult to map research activities through patents or publications.

Therefore, specific R&D projects are difficult to point out and this function will not be scored.

Investment in R&D

The start-up companies are currently all about knowledge creation and innovation. No products are on the market yet, and innovations are needed to overcome scientific and technical challenges [E5]. Therefore, the money they receive through investments, will go into research and development. At the moment, no financial support is offered by the government. All the investments for research stem from (corporate) venture capitals, seed funds, or business angels (Table 17 and Table 18).

Table 17 Investment details Meatable, retrieved via Crunchbase.nl[2]

Announced Date	Transaction Name	Money raised (€) Total = €11.5M	Lead investors
Dec 6, 2019	Seed Round	6M	BlueYard Capital, Union Squares, Taavet Hinrikus,
Dec 6, 2019	Grant	2.5M	Eurostars
Oct 1, 2018	Seed Round	3M	BlueYard Capital, Backed VC, Atlantic Food Labs, Charles Songhurst, Jörg Mohaupt

Table 18 Investment details Mosa Meat, retrieved via Crunchbase.nl[3]

Announced Date	Transaction Name	Money raised (€) Total = €?	Lead investors
Jan 10, 2020	Series A	?	Nutreco, Lowercase Capital
Jul 17, 2018	Series A	7.5M	Bell Food Group, M Ventures
2011	*Note: investment in Mark Post, not Mosa Meat yet*	700.000	Sergey Brin

Besides the investments in the start-up companies, Dutch universities have performed government-funded research in the past. In 2000, research within the In Vitro Meat-consortium between three universities (UvA, TU/e and UU) and market actor Stegeman, was funded by the Ministry of EZ. This research was initiated by Willem van Eelen and focused on three different aspects of cultured meat: the growth medium, the growing of cells and the social acceptance. This research demonstrated the feasibility of growing meat from stem cells. However, this research also led to many frustrations for Willem van Eelen, as he determined that only 10% of the government investments were used for the actual research. According to van Eelen, the remaining money was used for the research groups

[2] https://www.crunchbase.com/organization/meatable/company_financials, accessed on 18-08-2020
[3] https://www.crunchbase.com/organization/mosa-meat/company_financials, accessed on 18-08-2020

themselves (Ysebaert, 2018). Towards 2009, the government financing was cut, since the government expected the business to further invest in CM. Nonetheless, the businesses were hesitant to invest and The Netherlands was about to lose its leading position in CM [E8](van Dinther, 2011).

A few years later, in 2011, Mark Post was able to attract an anonymous investor to revive the Dutch CM research. In 2013, this anonymous investor was revealed as Google co-Founder Sergey Brin. This investment was used for the creation of the world's first CM hamburger (van Dinther, 2011). In that same year, 800.000 euros of government funding was awarded to UU and WUR for a four-year research project to stem cells and the social and moral aspects of CM [E7 and E8] (Table 19).

Table 19 Investment details to Dutch universities

Announced Date	Invested in	Money raised (€)	Lead investors	Source
2013	UU and WUR	800.000	Dutch government (Ministry of EZ)	(JB, 2013; Van der Weele & Driessen, 2013a)
2000	In Vitro Meat-consortium (UvA, TU/e, UU) and Stegeman	2M	Dutch government (Ministry of EZ)	(Ysebaert, 2018)

Thus, now that CM is more near-market ready, the amounts of (private) investments also increase. In this stage all this money goes into R&D, ranking an 'high' score for this indicator.

Research convergence

Due to the current investor structure, confidentiality of the research within the companies remains a major bottleneck. All the different start-ups seem to be 'reinventing the wheel'. For instance, looking at the problem of removing fetal serum from the culture medium. All companies are searching for ways to overcome this problem, but all by their selves. While the research convergence[4] used to be impressive, by bridging social, economic, technical and environmental hurdles in multi-disciplinary university projects, nowadays the research convergence is much lower. Nonetheless, more networks are forming to facilitate the cultured meat development, as the partnerships between Mosa Meat with Nutreco and Celltainer ("CELL-tainer single-use rocking bioreactor applied for cultured meat," 2020).

However, the fact that all different start-ups are re-inventing the wheel and the cooperation with parties in other areas (social or environmental) is low, the indicator is ranked 'low'.

[4] "An approach to knowledge production and action that involves diverse teams working together in novel ways—transcending disciplinary and organizational boundaries—to address vexing social, economic, environmental, and technical challenges in an effort to reduce disaster losses and promote collective well-being." (Peek, Tobin, Adams, Wu, & Mathews, 2020)

Evaluation of Knowledge development

The previously discussed rankings and their scores are summarized in Table 20, and averaged to a total functioning.

Table 20 Evaluation of Function 2. Knowledge development

Indicator	Score
Presence of patents	Low
Number of publications	High
Presence of R&D projects	N/A
Investment in R&D	High
Research convergence	Low
Total functioning	**Moderate**

5.3. Function 3. Knowledge diffusion

Knowledge diffusion is mapped through four indicators: presence of workshops/conferences, network size and network intensity.

Presence of workshops/conferences

In 2010, the first major congress about cultured meat was organized in The Netherlands, in Nemo. Led by Jort Kelder, Karen van Holst Pellekaan and Mark Post, several politicians, policy makers, scientists, entrepreneurs, investors and other interested public gathered to discuss and debate the topic cultured meat [E1] (Nationaal Centrum voor Wetenschap & Technologie, 2010). In 2017, Ira van Eelen attended a congress in Maastricht, where for the first time more than one or two attendees were already familiar with the cultured meat technology [E1]. Currently, Mark Post organizes these conferences on an annual basis. The conferences are open for everyone interested in CM. This stimulates all kind of people attend, making it a useful event for knowledge exchange and network formation [E8]. Besides these symposia, Koert van Mensvoort is active in creating awareness around CM. To achieve this, he for instance wrote a cultured meat cookbook, set up a fictive (online) cultured meat restaurant, and organized an exhibition [E4].

Conferences and other events to spread knowledge about CM are present, but rare. Therefore, this indicator is scored 'moderate'.

Network size

Despite the efforts of Mark Post to bring together all kind of interesting parties for CM, still a major (growing) gap exists between the start-ups and other knowledge institutes. Interestingly, this point was raised by all the questioned experts, including Mosa Meat themselves. The cooperation between Mosa Meat and UM is the exception rather than the norm. As Mosa Meat described during the interview: "given that cultured meat is a new technology and not yet on the market, scientific developments are commercially sensitive" [E5]. The foremost reason for this lack of sharing, which was brought up by the experts, is the current incentive structure for the start-ups [E1, E2, E4, E7, E8, E12]. All start-ups want to become a leader, and most of all, avoid being scooped by others [E3, E4]. This incentive structure makes that the start-ups do not want to share their information, resulting in a lot of start-ups which are working on the same fundamental problem [E12].

Knowledge sharing between the start-ups and other knowledge institutes is not the only important node in the network regarding knowledge diffusion. Sharing information with potential consumers is also an important step towards maturation of the technology. By involving the potential consumers for cultured meat, the consumers could become more aware of the innovation process and the

possibilities it has to offer for them. According to Mosa Meat, they do get a lot of feedback from the public, who are very interested and passionate about cultured meat and the potential it has to address current challenges. However, the product is not on the market, and there are no 'users' yet [E5]. Still, Mosa Meat is planning on educating and informing consumers to make sure that consumers know exactly what cultured meat is [E5]. Other experts do not recognize consumers being (actively) involved for knowledge diffusion. They rather expect the CM producers as Mosa Meat, to 'force' cultured meat to the consumers, by just launching the product on the market [E1, E2, E4, E7]. This is not unusual, looking at for instance Apple Inc., they are also not creating support from potential users, but they just launch their new product on the market [E2].

Looking at the fact that there are two CM start-ups in The Netherlands which are currently responsible for the majority part of the (technical) CM research, but mostly not sharing their knowledge with other institutes, makes for a small network size. Due to the little knowledge creation and no viable product yet, not many new or partnering companies are attracted to the CM scene yet [E12]. Only a few formal partnerships have been established, including Mosa Meat with Nutreco and Celltainer. Therefore, network size is ranked 'low'.

Network intensity

Diving into the network intensity, defined as frequency and thoroughness of contact, of those collaborations, this is highly deviating from tie to tie. While the start-up companies are most likely heavily in contact with their investors, and Mosa Meat with their partnerships and UM, their network ties with potential consumers and other knowledge institutes are weaker.

Thus, the high intensity of contact between the start-ups, investors and their partnerships, against low intensity ties with potential consumers and knowledge institutes, results in a 'moderate' ranking.

Evaluation of Knowledge diffusion

The previously discussed rankings and their scores are summarized in Table 21Table 16 Evaluation of Function 1. Entrepreneurial activities Table 16, and averaged to a total functioning.

Table 21 Evaluation of Function 3. Knowledge diffusion

Indicator	Score
Presence of workshops/conferences	Moderate
Network size	Low
Network intensity	Moderate
Total functioning	**Moderate**

5.4. Function 4. Guidance of the search

Guidance of the search is mapped through three indicators: (long-term) targets set by government or industry, expectation on further development and (alignment of) visions/expectations of key stakeholders

(Long-term) targets set by government or industry

Most of the questioned experts emphasized the little guidance of the search by the government for the cultured meat development in The Netherlands during the interview [E1, E2, E4, E5, E6, E7, E8, E9]. This, while a majority part of these experts would like to see more government guidance [E1, E2, E4, E6, E7]. Currently, no one is taking the lead, but this is all scattered around, everyone is taking their own focus. The government, or Ministry, could really take the lead here [E2]. An example could be taken from the 'Boerderij 2000'-project, which started around 1980, in which the Ministry of LNV took

the lead in facilitating the first developments in the area of automating the process of milking cows [E2]("Automatisering landbouw moet de kosten drukken," 1988). However, during the interview with a Parliament member, active for Ministry of LNV, no recognition was given for a role of the government in guidance of the search of the CM research. “We live in a market economy. Therefore, as a government, you are not in the position to promote a specific industry. We do not engage in ‘industrial politics’ [E9]. Still, a more long-term vision from the government could have facilitated the Dutch CM scene. The government made some significant investments in CM at the beginning of this century, but now, when the world is starting to embrace the cultured meat technology, there are no investments anymore [E4]. Part of this can also be attributed to the fact that the ministries are constantly changing. Every four yours, new Parliament representatives take the lead and possibly adopt plans [E4, E8].

Considering the fact that no one is taking the lead, but everyone is taking their own focus, makes for a ‘low’ guidance of search.

Expectation on further development

Still, at the moment, there is no one taking the lead and determining a direction of development in The Netherlands. The two start-up companies currently have most influence in determining the path of further development. Since there is little overview of what is happening at the two start-ups, their (alignment in) paths of development are difficult to determine. All of the interviewed experts agree on the fact that the CM should become cheaper, and qualitative and taste-wise competitive with farmed meat. Different paths can be taken to achieve this, and most likely the start-ups are optimizing this through their own visions. When there is a viable and competitive CM product available, the vast majority of the interviewed experts agree on the way this product should be produced. While they prefer to have localized and small-scale production, they recognize the need for some large-scale production facilities [E1, E2, E4, E6, E7, E12].

So, the interviewed stakeholders are quite aligned on the further development, but the major players here, the two start-up companies, are difficult to track. Therefore, the expectation on further development of CM is ranked ‘moderate’.

(Alignment of) visions/expectations of key stakeholders

Nevertheless, the visions and expectations of key stakeholders are not always well aligned. Even though, all interviewed experts express their environmental concerns and recognize the potential of CM as a more sustainable solution, or a transition pathway towards a more sustainable solution, their visions on CM are still quite different. Already within the government, we can recognize clashing Ministries. In 2017, Ira van Eelen cooperated with the US-based start-up Just in organizing the first cultured meat tasting in The Netherlands. The Ministry of LNV was highly enthusiastic about this idea. For this, Just asked for a ‘tolerance situation’ for two years. This was not to sell the meat, but rather to gather the views of different stakeholders on the cultured meat. Still, at the last moment, the NVWA put a stop to the scheduled tasting. Moreover, a conflict arose between the ministries of LNV and VWS. At this point, the Ministry of LNV realized how closed off the Dutch system was. Due to the VWS interfering, no proposals ended up at the Ministry of EZ [E1](Ysebaert, 2018). Moreover, different interests can be pointed out for universities and companies [E4, E5, E8]. Even within the university landscape a dichotomy can be observed. While some researchers and groups are highly enthusiastic about a future with CM, some claim that plant-based alternatives eliminate the need for CM [E1, E7].

Clashing views within the university and ministries, and little communication between the start-ups, make for ‘low’ alignment of key stakeholders.

Evaluation of Guidance of the search

The previously discussed rankings and their scores are summarized in Table 22, and averaged to a total functioning.

Table 22 Evaluation of Function 4. Evaluation of Guidance of the search

Indicator	Score
Targets set by government or industry	Low
Expectation on further development	Moderate
(Alignment of) visions/expectations	Low
Total functioning	**Low**

5.5. Function 5. Market formation

Market formation is mapped through two indicators: (expectations on) market size and efforts to create market.

(Expectations on) market size

When the final CM product is able to compete with farmed meat, in price, quality and taste, all of the interviewed experts see market potential for CM. In the current situation, there is already a market for cultured meat. The market does not have to change, since it is the same product, same meat, that has a market [E1, E2]. Still, a majority of the experts expect farmed meat to keep some market share, next to the CM on the market [E1, E3, E4, E6, E7, E8, E11, E12]. However, this will not be on large-scale, but more in the form of a niche product [E3, E6, E7, E11]. On top of that, experts believe that (plant-based) alternatives will also keep some market share [E5, E7, E8, E10]. In contrast to the majority of the experts, Mosa Meat believes that in time CM can replace all conventional meat. The first cultured meat products are likely to be ground products, which make up approximately 50% of the global meat market, and other cuts of meat will follow [E5].

Much academic research has been performed on monitoring the consumer acceptance of CM. Specifically for The Netherlands, Van der Weele and Driessen researched consumer acceptance in the government-funded project in 2014. From this research could be concluded, that the age and level of involvement in the food scene of the participants influenced their meat preferences, while urban or rural origin made little or no difference. Persons professionally involved with food (through studies or work), were more hesitant towards cultured meat. Moreover elderly (60+) were less open to the idea of cultured meat than youth (15-25) (Van der Weele & Driessen, 2013a). More recently, research at the UM concluded that when people are well-informed about CM, almost 40 percent is willing to pay more for CM than farmed meat. Therefore, they call ‘awareness’ the best predictor of acceptance of CM (Rolland, Markus, & Post, 2020).

In short, with a suitable approach (educating consumers), market acceptance is expected high, and the experts emphasize the major potential for CM to take over market share. Therefore, this indicator ranks ‘high’.

Efforts to create market

However, before CM products could reach the market, legal trajectories have to be taken. Currently, Mosa Meat is running EFSA applications to get CM on the market. If Mosa Meat will choose the Dutch market as their target market after EFSA approval, remains to be revealed. Meatable seems to be in an earlier stage of the development compared to Mosa Meat. This was also brought up during the interview with some experts. Whereas Mosa Meat was highly motivated to apply for CM tastings at the government, Meatable was more reserved for this proposal [E1, E2]. However, the duration of EFSA applications makes it likely that Meatable is also already applying for CM products. On the other

hand, the companies are not in direct contact with potential consumers, to already spread awareness or create market potential there. As already mentioned, the experts rather expect the CM producers to 'force' CM to the consumers, by just launching the product on the market [E1, E2, E4, E7]. However, efforts are made to reach the public through initiatives as the CM tastings [E9].

So, legally the companies are going through a significant efforts to reach the market, while consumers are harder to reach, but some efforts are made. In the end, the market does not have to change, since it is the 'same' product. Therefore this indicator is scored 'high'.

Evaluation of Market formation

The previously discussed rankings and their scores are summarized in Table 23, and averaged to a total functioning.

Table 23 Evaluation of Function 5. Market formation

Indicator	Score
(Expectations on) market size	High
Efforts to create market	High
Total functioning	**High**

5.6. Function 6. Resource mobilization

Resource mobilization is mapped through five indicators: availability of financial resources, change in amount of investments, availability of human resources, change in amount of human capital and availability of physical resources.

Availability of financial resources

First looking into the financial resources, the two start-ups fore mostly receive their capital, from seed funds, (corporate) venture capitals or business angels. Whereas the start-up companies are able to attract those types of investors, the universities are less commercialized and more focused on building a research basis and publishing, therefore less attractive for many investor types. Currently we can observe high amounts of money flowing into the Dutch cultured meat scene. However, this is mostly towards the start-ups, raising millions by attracting investors themselves. The research at the universities decreased, or even stopped, when the government cut the funding around 2014 [E4, E7, E8]. The foundation of the research has been funded, but the market development phase is more difficult to intertwine for government funding. Multinationals or other businesses are expected to finance in this further stage of development [E9]. Since there had not been sufficient funding form a public sector standpoint in the beginning for the companies, it would be unmanageable to ask the start-ups themselves to build an entire full-stack production facility anywhere near time, without a financial basis. They are attracting investors now, but the time line is greatly expended [E5, E12].

On September 26th 2018, the House of Representatives debated the future of cultured meat in The Netherlands together with representatives from business (start-ups), society and science. In this meeting, the parliament was informed about the current state-of-art and thereby asked for their support and funding, to stimulate CM developments in The Netherlands. As framed during the meeting: "The Netherlands has been a world leader in cultured meat for 20 years. We have grown the world's first cultured meat hamburger. While we used to be a leader in the cultured meat developments, the opportunity to introduce cultured meat to the market, is about to pass us." However, the government remained hesitant to invest more money in the CM scene ("Kweekvlees en vleesvervangers," 2018). This results in that currently research mostly takes place at the two start-ups.

Whereas the CM research was initiated, and thereby a substantial basis of information was formed, at the universities, this shifted towards the start-ups [E4 and E8]. This is what happens when a technology becomes more commercialized and a market is forming, then the focus will shift towards companies and there will be heavily invested [E4].

Summarizing, nowadays a significant amount of money is around for the companies, but they had to put in much efforts to retrieve this money. However, due to the current availability of the money, this indicator scores 'high'.

Change in amount of investments

While at first, CM research was funded by two grants from government (800.000 and 2M euros), now millions of euros are invested by private funders. This is what usually happens when a technology becomes more commercialized and a market is forming, then focus shifts towards companies and there will be heavily invested [E12].

The major increase in (private) investments ranks this indicator 'high'.

Availability of human resources

Turning to the human resources, a strong talent pipeline is available with universities as Wageningen, Leiden and Delft [E12]. Moreover, The Netherlands is one of the most important countries concerning agricultural developments [E1]. We can also recognize the amount of knowledge created at the university, with WUR as the highest publishing university worldwide on the area of social sciences. At the moment, knowledge development on the technology mostly takes place at the two start-ups. Despite the fact that students are educated in topics or areas closely related to CM, there is currently no place to study 'cultured meat' specifically.

Considering all the aspects, there is a strong talent pipeline, but no specific CM education, rating this indicator as 'moderate'.

Change in amount of human capital

The technology development heavily takes place within the start-up. However, the start-ups are bound to the rules of their investors, making it challenging educate the next generation [E1]. Therefore, no major changes in the amount of human capital are expected, scoring 'low'.

Availability of physical resources

Currently, the two start-ups are both hosted on different campuses, Meatable at Biotech Campus Delft and Mosa Meat at Brightlands Maastricht. These campuses provide for an interesting knowledge transfer spot, but also for support in physical resources. Recently, Mosa Meat announced to collaborate with Medace, making for more facilities and a flexible and all-round infrastructure (Medace, 2020). Zooming into the 'raw' materials in the production chain, it starts off with the animal cells. As major agricultural nation, sufficient animal cells are available. For the other materials, we have to turn to the laboratory. Several growth medium products, as well as analytical and technological machinery is required. One of the major and costliest hurdles being a large-scale bioreactor. For this, Mosa Meat announced their cooperation with Cell-tainer ("CELL-tainer single-use rocking bioreactor applied for cultured meat," 2020). Looking further into the future, when CM could be produced and potentially reach the market, CM is essentially the same product as farmed meat. Therefore, CM is expected to benefit from the highly developed farmed meat infrastructure to the market.

Summarizing, physical resources for the companies are facilitated by the campuses, more companies are forming around bottlenecks in physical resources, and for the way to the market, CM could benefit from farmed meat infrastructure. Therefore, physical resources is ranked 'high'.

Evaluation of Resource mobilization

The previously discussed rankings and their scores are summarized in Table 24, and averaged to a total functioning.

Table 24 Evaluation of Function 6. Evaluation of Resource mobilization

Indicator	Score
Availability of financial resources	High
Change in amount of investments	High
Availability of human resources	Moderate
Change in amount of human capital	Low
Availability of physical resources	High
Total functioning	**High**

5.7. Function 7. Counteract resistance to change

Counteract resistance to change is mapped through two indicators: amount of lobby activities by advocacy coalitions (for/against technology) and result of those lobby activities.

Amount of lobby activities by advocacy coalitions (for/against technology)

The lobby activities around CM in The Netherlands are very minimal. Amanda Govers, originally known through her website 'evengeenvlees.nl', started lobbying for CM about one and a half year ago via the network of the VVD (Dutch political majority party) ("Onze organisatie," n.d.) [E1, E2]. Apart from her lobby activities, no more lobby groups can be traced. The interviewed Parliament member also confirms that currently no significant lobby for CM takes place [E9]. Despite giving (unofficial) advice to the Parliament and Ministries, no further external parties are involved here. Furthermore, the GFI claims to lobby worldwide. However, this lobby is less significant in The Netherlands [E12]. Also no anti-cultured meat lobby groups could be traced.

Interestingly, the lobby for farmed meat is significant. Especially in Brussels, a strong farmed meat and agricultural lobby scene is present, forming a significant barrier towards CM. A small and recent example of this farmed meat lobby in Brussels, is the lobby to keep subsidizing farmed meat commercials. Due to this lobby, the European Committee decided to continue its support for meat commercials (Van de Wiel, 2020).

Due to the little CM lobby activity, this indicator is assigned a 'low' score.

Result of those lobby activities

Since no significant lobby activity can be traced for or against CM, no results can be analyzed.

Evaluation of Counteracting resistance to change

The previously discussed rankings and their scores are summarized in Table 25, and averaged to a total functioning.

Table 25 Evaluation of Function 7. Counteracting resistance to change

Indicator	Score
Amount of lobby activities	Low
Result of lobby activities	N/A
Total functioning	**Low**

5.8. Conclusion

The total functioning for the seven independent IS function indicators is summarized in Table 26.

Two of the seven functions scored a low total functioning: F4. Guidance of the search and F7. Counteract resistance to change. Currently, no central guiding for the direction of research is present. The companies and universities working on CM, all determine their own research path and direction. Moreover, central players in the system do not have their values and visions aligned, slowing down research and causing missed opportunities. This includes the communication between the involved Ministries, but also between the start-up companies. The counteract resistance to change scores a low functioning, due to the absence of lobbying activities. There are some minor lobbying activities for CM in The Netherlands, but not comparable to the long-standing farmed meat lobby. Both can be pointed out as a bottleneck in the current development of the system.

Entrepreneurial activities, knowledge development and knowledge diffusion, all scored a total functioning of moderate. These knowledge and development activities, are mostly centered at the start-up companies.

Lastly, market formation and resource mobilization score high. The market for CM is similar to farmed meat. Between plant-based alternatives and farmed meat, CM is a compromise for an already existing market. Despite the high score on resources, this still affects and has already affected the development of the system. Financial resources were scarce in the early phase of CM, which significantly slowed down the research activities. Moreover, no specific CM educational activities are present, which would be necessary to educate new potential talent for the companies.

Table 26 Total evaluation of the Dutch CM innovation system according to the seven system functions

Innovation system functions	Total functioning	Elaboration on functioning
F1. Entrepreneurial activities	Moderate	- No new entrants - Moderate to low diversification of the two start-ups
F2. Knowledge development	Moderate	- Low no. of patents and research convergence - High amount of publications and R&D investments
F3. Knowledge diffusion	Moderate	- Small networks, but high intensity - Annual conferences on CM
F4 Guidance of the search	Low	- No central guidance in development process - Visions/expectations of key stakeholders not fully aligned
F5. Market formation	High	- There is available space on the market for CM - Well-informed consumers open to CM
F6. Resource mobilization	High	- Sufficient financial resources due to venture capitals and business angles - Similar physical infrastructure as farmed meat - Sufficient human capital, but low amount of new specific CM education activities
F7. Counteract resistance to change	Low	- Limited lobby activity

Conclusions on the IS structure and functions

Research part 1 aimed at describing the Dutch CM innovation system. Currently, the Dutch cultured meat system still makes up for a small scene. Research and development activities are focused within the two stat-ups – Mosa Meat and Meatable – and limited amount of suppliers and stakeholders along the chain, due to the fact that no feasible product is available yet.

In this system, the fact that no central guidance in the development process is present, and that lobby is limited to gain more attention and perchance more resources, forms a bottleneck in the further development of the system. On the other hand, the availability of resources, among others financial resources via private investors, and the availability of space on the market, present an opportunity for the further development of the CM innovation system.

6. The influence of actor strategies and values on the IS

In this part of the study, the external influences are described and connected to actor strategies and values. Due to the major potential future influence of farmers and famed meat (multinational) companies, those actor groups are also taken into account in this results chapter.

By exploring the external influences on the system, linking to actor strategies and values, the third sub question will be answered:

SQ3: How have strategies and values of the different actors evolved over time and how has this influenced the development of cultured meat in The Netherlands?

6.1. Landscape and regime developments

The behavior of the actors in the system, is strongly dependent and influenced by the regime and landscape developments and their expectations on these developments. While the regime (here food regime) entails the 'rules' that guide the activities within the system, the landscape refers to the wider set of external factors. Those landscape factors change more slowly than regime influences (Geels, 2002).

6.1.1. Landscape developments

The landscape factors can positively or negatively influence the foods regime, embedding the current farming system and technological niches as CM. From the interviews a few landscape factors came forward that affect the foods regime: environmental issues, animal welfare and ethical considerations, and COVID19. An additional landscape factor has been identified via desk research, namely globalization.

Environmental issues

The perception of the consumer on food and its environmental footprint is changing. Consumers are becoming more and more aware of in specific the environmental burden of animal products [E8]. While decades ago, people were already aware of the world's environmental problems, only more recently farmed meat production is associated with these rising issues [E4, E8]. Moreover, more and more people are protesting the climate changes and related topics as the nitrogen discussions, closely touching the conventional meat industry. Currently, a lot is happening in this area. The increasingly aware society, and increase in climate protests are making it more difficult for the farmers, and force them to reconsider their day-to-day business [E2]. This opened a field to more sustainable meat alternatives as plant-based, insect-based, hybrid and CM, as well as forcing the farmers in becoming more sustainable. Despite the fact that consumers are looking for more environmental friendly alternatives, the conventional meat consumption is still not decreasing [E1, E2, E4, E10].

Animal welfare and ethical considerations

On top of the environmental issues, society is becoming more concerned about animal welfare. This is heavily intertwined with the foods, and in particular with the conventional meat production [E3, E4, E5]. The current meat industry does not make up for an 'elegant' industry; situations of animal cruelty, small stables, mistreatment of animals and slathering methods make up for questionable animal welfare [E3]. Meat alternatives could offer more animal friendly alternatives to the current situation. In particular for CM as meat alternative, the animal welfare has been highly debated. The major bottleneck in the animal friendliness of CM was the use of fetal bovine serum in the growth medium [E10, E11]. However, multiple companies, including Mosa Meat during the interview, claim to have

overcome this bottleneck [E4]. Moreover, animals are still required for an initial biopsy of cells, to start the CM process chain. However, the procedure of taking the cells from the animal are suggested not to harm the animal, and happens under anesthesia [E4].

COVID19

On top of the demographic trends and consiterations, the current pandemic of the corona virus touches the food regime in multiple ways. Society is becoming more concerned with their health due to the virus, while a meat market in China is pointed out as the starting point for the virus. This makes people more hesitant towards our current meat system. Moreover, a significant part of society confuses viruses and bacteria, linking viruses directly to farmed meat. This could work in the advantage of meat alternatives [E1]. Apart from negatively linking the virus directly to farmed meat, the vulnerability from the current meat industry is exemplified due to the pandemic. In this business model, animals can become ill, putting down the entire system. When there is a hitch in the process, the current system is left with their animals to feed. Even when they cannot go to the slaughterhouses, they keep requiring resources. In the current system the animals are being killed when there is a hitch, while with CM only a batch of grown meat might be lost [E2]. The long-term effects of this pandemic can be debated. While this could be a positive turn for the meat alternatives, this might also be very short-term [E2]. Instead of getting everything from China and therefore being dependent on other countries during the pandemic, more local work is attracting attention. For CM in particular, more local 'breweries' could be established [E1]. However, the more regional or local policies and facilities might be outcompeted by the benefits of our current globalization [E6].

Globalization

As shortly mentioned ahead, the globalization and internationalization of the food market, affect the arrangement of the foods regime. On one hand, the food supply has been greatly expanded, while on the other hand the majority share food is more and more produced by a few large multi-international companies. Due to take-over/fusions and centralization of power, smaller companies or food producers are outcompeted (Gladek et al., 2017; Zantinge, van Bakel, van Loon, & Ocke, 2017).

6.1.2. Regime developments

In this study, the socio-technical regime of focus is the foods regime. The regime is a composite of three elements, the institutional framework (formal and informal institutions), the actors and their networks, and the artifacts and infrastructures (Raven, 2007). These elements, together with positive and negative pressures from the landscape, other regimes and niche levels (e.g. CM or plant-based/hybrid alternatives), determine the direction and (incremental) changes of the regime.

Institutional framework

A major share of the formal institutions regarding foods (safety), have been set on a European level. Zooming into the foods regime-embedded meat and agricultural system, also European and national-scale formal regulations can be identified. These European- and national-level regulations, applying to this study of CM, have been discussed in Paragraph 4.3.1.

Besides the direct formal laws applying to the food sector, developments in (international) treaties and conventions, can also influence the regime. In relation to increasing the sustainability of the foods sector, we can recognize the Convention on Biological Diversity (CBD) aiming at higher biodiversity, the Sustainable Development Goals and the Paris Agreement ("Convention on Biological Diversity," n.d.; "The Paris Agreement," n.d.; "Sustainable Development Goals," n.d.).

The informal regulations consists of culture, social norms, visions and beliefs, rather than tangible rules. These are much harder to recognize, since these are intangible and largely dependent on individual factors (biological, demographical, situational, perceptions). However, currently some general developments can be observed, as changing diets for health, environmental and animal welfare reasons, as well as the search for increasing convenience to decrease preparation time, and the wish for low-cost products. Consumers claim to choose the best options for environment and health, but when doing their groceries, most consumers will simply choose for the lowest priced product.

Actors and their networks

As a consequence of the globalization, (agro-)foods markets and networks have grown and have become more internationalized, while the power started to concentrate in the hands of a few major multi-international companies. Processes are standardized, allowing prices to be low. This industrialized standardization and large-scale production, also allows farmed meat prices to be relatively low. As all the interviewed experts emphasize, CM should be priced in the same range to be able to compete farmed meat. Overall, the meat alternatives on the market are priced a bit higher than farmed meat, but are in the same price range, and therefore able to compete. Currently, the low meat prices are debated, and the TAPP Coalition has made it their mission to ask for fair meat prices, representing costs for the environment, health and animal welfare.

For the embedded actors to maintain their positions, lobby, networks and alliances are key. Policy making can be highly influenced by wealthy actors in the system. However, not only the multinational companies have all the power, in this case farmer organizations also play their part. Copa-Cogeca, the major European farmer organization, closely monitors the Common Agricultural Policy, the policy that aims to support farmers and assure food security in Europe ("Copa-Cogeca," n.d.). On the contrary to the strong (inter)national farmers lobby, lobby for meat alternatives are much weaker.

The actors and networks within the CM innovation system have been described in paragraph 4.1 and 4.2.

Artifacts and infrastructure

The third component of the regime entails the dominant practices and their integrated supply chains and distribution networks. In the foods regime, these processes have been highly standardized and the infrastructure is well-established. However, the consumers are reacting more and more against this industrialized agro-system, due to their changing perceptions on sustainability. This development asks for more local and organic production methods, but on the other hand should be able to compete the current dominant practices.

An interesting example of how difficult it is to compete the dominant agro-food practices, is shown in the 2013 paper of Immink et al.. The current meat supply chain in The Netherlands, experiences high barriers to transform the livestock into a system with higher animal welfare. Currently the meat sector benefits from an optimized economy of scale, while costs have to be made to increase the animal welfare. The costs have to be made over the whole animal, while only some parts of the animal (steaks and fillets, 25% of pork) can be used to recover those expenses. The current thin margins for all actors and the high fixed cost of the slaughterhouses, causes the stakeholders to stick to the status quo (Immink, Reinders, van Tulder, & van Trijp, 2013).

6.2. Actor strategies

The different actor groups can all hold different strategies to reach their core values and fulfil their missions. Sometimes, the strategies may diverge within a specific actor category. These strategies are based on landscape and regime developments, but also on the actor's expectations for regime and landscape developments. The higher the power of the actor, the more effect their strategy will have on the entire system. Individual consumers can hold their own strategies, but this will not affect the system. Whereas the CM start-up companies or government executing a certain strategy, or changing strategy, could change, destabilize or even determine the further direction of the CM innovation system. The governmental organizations, CM start-ups and investors, are the highest influencing parties in the development of the Dutch CM system. The second highest power group is formed by the current farmed meat actors: farmers and farmed meat companies. They in direct competition with the CM product. Therefore, they also have a major interest in the development, and should be managed closely by the CM system for possible collaborations. These groups are closely followed by the meat alternatives. Other meat alternatives than CM have the same goal as CM: providing more environmentally and animal friendly alternatives to animal protein. Some (plant-based) meat alternatives are even completely mimicking farmed meat, forming direct competition to CM. More and more supermarkets are establishing their own meat alternative brands, also forming a significant influence as being a competitor for the CM product. However, their influence is less direct during the process than from farmers and meat companies, since up to now, these products do not entail the exact same product. The influencing power of influencers and NGOs will largely dependent on their size and network base. Lastly, the consumers and restaurants will more or less undergo the transitions, without having a major influence or stake in changing the process (Figure 19).

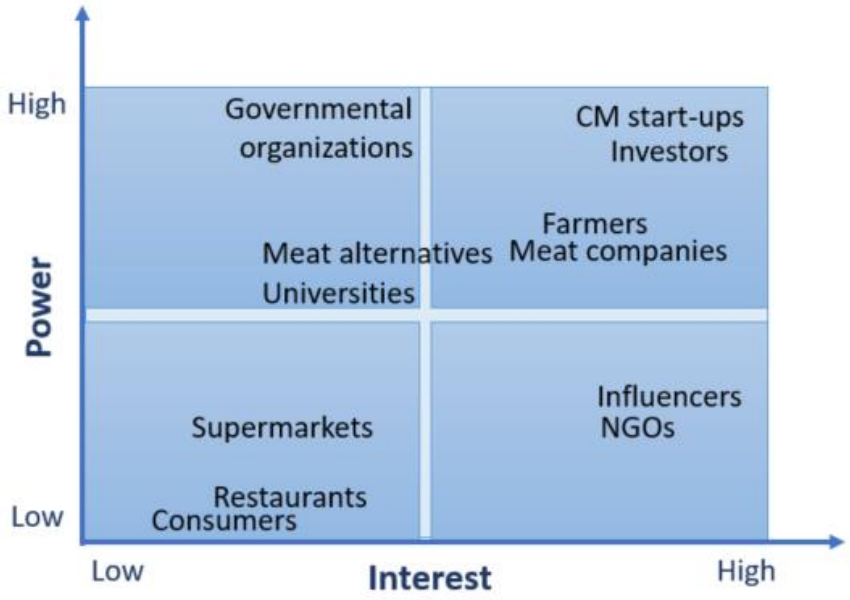

Figure 19 Power and interest of the actor groups involved in the Dutch CM system

Below, the strategies regarding CM of the most influential actor groups will be discussed.

Start-up companies

As COVID19 uncovered the fragile current meat system and the pressure for more sustainable and animal-friendly alternatives rises from the landscape and regime. While people are still not expected to completely cut meat out of their diets, CM could fill the gap between sustainable plant-based alternatives, current meat industry and the wish for sustainable 'meat'.

Around 55 CM start-ups are located over the world, that are using about 60 different techniques and strategies [E1, E12]. While some start-ups aim at developing only the CM technology, other companies aim at producing the final, eatable, CM product themselves. Mosa Meat is for instance not aiming at selling hamburgers, but at selling factories [E1]. Moreover, some companies focus on a specific part of the CM production chain, while others – including Mosa Meat and Meatable – are full stack companies. Not all of these 55 start-up companies around the world will reach the market. Most probably, only the first CM start-ups that are able to produce tasteful, and well-priced meat, will be the ones to make it to the market [E12]. Therefore, the foremost important factor for these CM start-ups, is being first, keep innovation, and above all not being scooped by others. Major determinants in becoming the first company with product, are sufficient human, financial and physical resources for research. Both Mosa Meat and Meatable are cooperating with other institutions for this. Both start-ups are located at campuses, providing them working spaces. On campus, Mosa Meat even cooperates with other companies – Medace – to increase their workspace. Moreover, the partnership between Mosa Meat and Nutreco, allows them to decrease the cost of production, due to the supply of cheaper raw materials.

On top of that, the companies have to remain relevant to attract investors and continue their research. This means that the companies have to keep innovating. Mosa Meat has the advantages of the fact that it was the first company to launch a CM hamburger to be tasted in 2013, and is therefore worldwide known. Mark Post search for publicity and keeps drawing attentions with events and interviews, to remain in this well-known status. In contrast, Meatable is less well-known and has more recently drawn the attention of major investors. Instead of searching for publicity, Meatable focuses on their specific technology of using IPS cells.

Their strategies can be summarized as following:
Mosa Meat – Full-stack, mimicking farmed (beef) meat, partnerships, innovating, publicity, selling factories
Meatable – Full-stack, mimicking farmed (beef) meat, partnerships, specific technology, innovating

Investors

Following the landscape and regime trends of changing consumer perceptions regarding sustainability, and the thereby expected increasing demand for sustainable alternatives, meat alternatives offer an interesting field to invest in for private investors.

The majority of the investments into the Dutch CM field, stem from venture capitals and business angels. Both of these types of investors, aims at receiving an as high as possible return on their investment, in an effective time span. Especially the venture capital companies spread their changes on returns. Instead of investing in one CM start-up they invest in multiple companies in multiple investment rounds. For instance, Unovis Partners/New Crop Capital made 8 investment rounds, including to Mosa Meat. The investors try to create an investment portfolio with the highest yield. Due to the fact that little of the CM research around the world is government-funded, the opportunities for private investors are high. Because of this high amount of private funding, start-ups keep their research outcomes confidential, instead of sharing their findings.

Venture capitals & Business angels – High-yield investment portfolio

Governmental organizations

The government funded the first few projects on CM in The Netherlands, when CM was still little known around the world. The Netherlands was leading, and retained that position through amongst others, the government funding. The Dutch CM research was significantly slowed down, when government funding was cut [E4, E7, E8]. The CM companies were trying to do their research, as well as attracting investors to obtain money for this research [E12]. Technology is increasingly important in sectors as the agricultural sector, to be able to compete internationally. Moreover, innovation could bring along economic growth, employment opportunities and solutions to societal problems, as food security and environmental issues. Still, the government is hesitant to keep investing in certain technologies or ideas, to transform them into real life opportunities. This might be, because The Netherlands thinks to 'small' about themselves [E4].

From the government's standpoint of view, the initial base of CM research was funded, and after that, new investment money was expected to come from the business side. However, CM is still debated within the Parliament, and initiatives are opposed by several members. One initiative is to allow CM tastings, to increase awareness and potential acceptance among society [E9]. Both the Dutch and European food and safety authorities, stick to their specifically set rules, to assure the safety of CM. Those agencies have a more target-oriented strategy or task than the ministries.

Government & Ministries – Get promising technologies started with funds, initiatives to help technologies

Universities

As an academic institution, the priority is set on sharing your academic research by means of publications [E8]. Universities are focused around developing and sharing knowledge. The research they perform, and the amount and quality of the publications they perform, is an important criteria in multiple university rankings, as the Times Higher Education World University Rankings[5]. Despite the many criticism on these rankings, universities still aim at a high spot in these rankings, for their international positions. So, when no new money was attracted for CM research at the universities, the research at the universities was halted. The universities have no specific interest or value to CM as at the start-up companies, their goal is rather to develop knowledge on all kind of topics. These topics follow from landscape, regime and niche expectations. Besides the research and publications, the university's goal is also to provide accessible and top-notch education.

Universities – Publish research in high-esteemed journals, gain international recognition, top-notch education

Conventional meat companies

Similar to the meat alternative producers, conventional meat companies are following the landscape and regime developments, including the consumers becoming more and more environmentally aware and looking for higher animal welfare. Even major multinationals have to innovate, following their landscape/regime/niche expectations, to keep relevant in business. As the regime is expected to develop towards an improved animal welfare and sustainability, the business also have to deal with these topics. We can see the two major farmed meat processors, making steps to become more sustainable in their own ways. Vion describes their strategy as: "Building Balanced Chains". These balanced supply chains include organic branches, as well as their recently announced meat alternative supply chain (Vion Food Group, 2019). Likewise, the strategy of VanDrie is described following five themes: market position, sustainability, animal welfare, food security and good employment practices.

[5] https://www.timeshighereducation.com/how-participate-times-higher-education-rankings

Whereas Vion increases their sustainability and portfolio by launching a meat alternative branch, VanDrie aims at making the current agricultural sector more sustainable by applying new technologies.

Vion FoodGroup – Increase sustainability through meat alternatives

VanDrie Group – Increase sustainability through conventional meat system

Farmers

Landscape (more attention to animal welfare, increasing environmental awareness) and niche pressures (meat alternatives) force the farmers to innovate to maintain their prominent spot in the agro-food sector. In order to do so, the farmers will partly have to respond to regime, as well as landscape developments. More and more sustainable and well-priced options are following from other regimes and putting pressure on the conventional meat production chain to innovate. Farmers suggest new machinery (robots, tractors) or sensors to make the current faming system greener (CRM partners, 2020). They aim at creating an ecologically responsible, and thus sustainable, agricultural sector. On the other hand, farmers are represented by strong lobby activities in Europe and The Netherlands, securing their current position.

Farmers – High lobby activities, Increase sustainability by innovating the conventional meat sector

Producers of meat alternatives

The strategies for the plant-based and insect-based alternatives are aimed at obtaining and maintaining market share and profit. One of the biggest plant-based alternative producers, The Vegetarian Butcher, was overtaken by Unilever at the end of 2019. This deal marks the start of Unilever's new direction into the meat alternatives. Due to changing consumer wishes, major companies as Unilever have to follow these wishes to stay in the game. The producers of meat alternatives, respond to the landscape developments and subsequent changing consumer wishes, for more sustainable food. Earlier, competitor Nestlé had already expanded their portfolio with meat alternatives, by buying Tivall in 2016. In 2017, its name was changed to Garden Gourmet, to make the product more accessible for the international market (Garden Gourmet, n.d.). The same can be observed for Vivera Foodgroup, originally producing farmed meat. at the end of 2019, Vivera divested their meat branch to completely focus on meat alternatives. This allows Vivera to invest more in the product development and production chain of the meat alternatives, and better respond to the consumer wishes (Segaar, 2020). Moreover, the supermarkets have started to sell their own private labelled meat alternatives. This offers an usually affordable alternative to meat.

Unilever (The Vegetarian Butcher) – Add meat alternatives to portfolio, respond to consumer wishes

Vivera Foodgroup – Respond to consumer wishes, solely focus on meat substitute development

Nestlé (Garden Gourmet) – Add meat alternatives to portfolio, respond to consumer wishes

Supermarket private labels – Respond to consumer wishes, affordable alternative

6.3. Overview of actor strategies

The actor strategies of the most influential actors are summarized in Figure 20. Expectations on landscape and regime changes lead, together with the actor values, to their strategies. According to this set strategy, actors will conduct their operations.

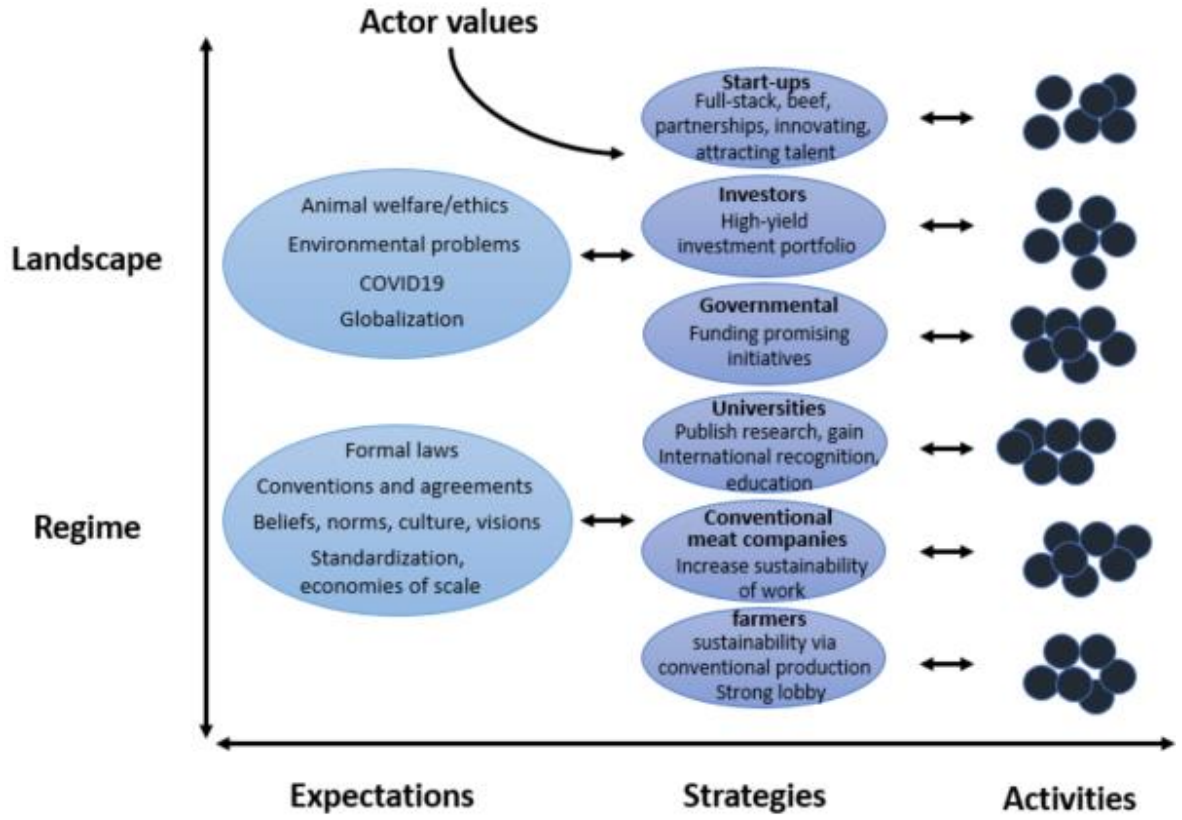

Figure 20 Overview of landscape and regime developments and expectations on actor strategies for the Dutch CM innovation system. Adopted from Budde et al. (2012).

6.4. Conclusions on actor values and strategies

As can be concluded from this chapter, not only activities within the IS, but also influences from outside the IS can have its positive or negative impact on the IS development. The specific aim of this chapter was to describe potential system changes, due to actor strategies. These actor strategies closely relate to and are partly determined by their values, which are described in Chapter 4.

Animal welfare and environmental issues are two values that are widely shared among the different actor groups and drive many of the actor strategies. Embedded actors (farmers, conventional meat companies) have to adhere to these values to some extent to remain relevant to the expected growing group of environmental aware consumers, while niche actors (meat alternatives) strongly hold these values in the basis of their development process. Due to the strong farmed meat lobby activities and the global networks formed in the current agro-cultural system, the embedded actors secure themselves in the regime-embedded position. They benefit from economies of scale, while niche actors have to obey these low product prices to be able to compete on the market. On the other hand, the investor's foremost interest is to obtain a high return on their investments. To achieve this, they invest in technologies or products with high potential and expectations to become successful, as in this case the meat alternatives branch.

7. Opportunities and bottlenecks for the Dutch CM innovation system

Despite the fact that the IS developments, and actor strategies and values have been discussed separately, they all influence and affect each other. These can be either facilitating or hindering the development of the Dutch CM innovation system. By coupling the previous research parts, an answer to sub-question 4 will be formulated:

SQ4: How can the opportunities and bottlenecks be managed and by who, to facilitate the development of the Dutch cultured meat innovation system?

7.1. Bottlenecks for the Dutch CM innovation system

First zooming into the factors that are hindering the development, we can recognize the effects of *globalization, standardizations* and the benefits of *economies of scale* in the embedded food regime. High barriers have formed for the embedded companies to invest in animal welfare and the environment, while the prices are so low that alternatives as CM are struggling to compete.

Moreover, there is no *guidance of direction* in the innovation process. Despite the two start-up companies taking very much the same product direction as full-stack beef producers, their research paths are very independent of each other even though their values are clearly aligned. The major bottleneck here, is the involvement of private investors. Their aim is to retrieve as high as possible return on their investments, and therefore need their investment (portfolio) to succeed and lead. In an ideal situation, reinventing the wheel would be halted, and the companies would start sharing information worldwide. However, the competition is too high and this becomes a threat for their independent position and functioning.

The approval of CM to be launched onto the market, is currently in hands of EFSA. To shorten the time span of applying for *novel-food approval*, everything is arranged on a European level since 2018. Despite the fact that the procedure is shortened, this can still take up to 18 months. Whereas safety of the product is an important aspect, also emphasized by the CM start-ups, this long time span could harm their competitive position against other parts of the world.

Moreover, only *minor lobby activities* could be traced for CM, while for conventional farmed meat, the lobby activities are of significant impact. All actors in the system have their own values and ideals, and what to attract money and positive attention for that cause. All these causes eventually ‘compete’ for funding. The conventional farmed meat, plant-based and insect-based substitutes, and the CM. More lobby for meat alternatives as CM could attract more attention and following benefits, as investments in the form of financial or physical resources. Moreover, the strong farmed meat lobby, hinders the development of the foods regime and strengthens the incumbents actor position.

Another point of concern in the CM system development, is the growth in *human capital*. There are no specific educational programs or directions for studying CM at schools, and current research is mostly happening behind closed doors at the start-ups. This conflicts with the start-ups opening up a significant amount of vacancies and wanting to attract talent. New people will always have to be further educated within a specific company or direction, but for the CM field this will be even more due to the highly developing and rather new technology for which no educational program exists. This point of concern is also raised by all of the experts. Eventually looking back and questioning why CM is not yet on the market, brought all the interviewees to the fact that more time and people are required for the CM research.

Eventually, to get the best CM product on the market, *collaborations are key*. These collaborations can speed up the development process and secure its position in the chain. We can already recognize Mosa Meat collaborating with Nutreco and Celltainer, to use their specialties. While the start-ups can excel in the production technology of the CM, other companies may already excel in producing scaffolds, bioreactor, culture medium, etc. It can shorten the innovation cycle to partner up with others, especially larger already established suppliers. However, currently only a low amount of suppliers is in the Dutch CM market yet. From a standpoint of market incentives, it's difficult to get suppliers into the cultured meat market, since the market is not yet there. As the market attract increase, then the incentives will align for larger suppliers.

Another challenge can be recognized in the *current market sphere*. Many substitutes for farmed meat are already on the market, including plant-based alternatives closely resembling farmed meat. Consumers looking for more sustainable alternatives, already have options to pick. Moreover, the conventional meat system is also looking into ways to make their supply chain more sustainable. Do we still need CM on the market?

7.2. Opportunities for the Dutch CM innovation system

Next to, and even following from, the bottlenecks, opportunities for the Dutch CM innovation system can be recognized.

While it might not be a government task to stimulate a specific industry or product, they also have their own targets in mind and will have to monitor new industries, as CM. The government *top-down influence* should not be overestimated, but steps can be taken when necessary for a particular sector. They can execute a 'structure policy' to influence the supply side of the economy. This can be influenced by investments in certain market supplies or infrastructure thereof, stimulate specific education, or measures influencing production capacity of competitive positions. An example of such a government influence can be found in the 'Boerderij 2000'-project, which started in 1980, in which the Ministry of LNV took the lead in facilitating the first developments in the area of automating the process of milking cows. A similar project could be set up for involving farmers in the CM supply chain, by finding an efficient way of adapting their facilities.

In this view, also an *increase in the research convergence* could offer opportunities. Cooperating with other parties was already mentioned as a bottleneck: difficult to attract others when there is no market yet and the private investor structure inhibits further connections. However, involving other parties could clearly offer opportunities, for instance looking at the farmed meat infrastructure. Major farmed meat companies already know the market, and have their infrastructure laid out for a quick start. Involving the conventional meat sector, could also avoid being taken over by these companies. As the innovation process at the start-ups takes time, the bigger companies could already have started their own CM research, development and production lines. An example of this can be found in the automotive industry: while multiple already embedded companies were aiming at producing an electric vehicle, Elan Musk showed his guts with Tesla by just jumped into the market with their electric cars, stepping on the others R&D processes. The same could happen to the currently two embedded Dutch start-ups in sphere. Moreover, in The US pilots are already running to include farmers into the process, by rebuilding their facilities to fit CM production needs.

Despite the challenge of government representatives changing every four years, *a long-term vision* and investment plan, could bring more structure and utility to their investments. Set clear visions on how the government wants to innovate the agricultural sector; invest in circular agriculture, new machinery for farmers, or new innovations. Moreover, this vision should be aligned between the different Ministries, to avoid clashing Ministries in the future.

Another opportunity can be spotted in the increasing healthy lifestyle of potential consumers, as well as the increasing environmental and animal awareness. Currently, the coronavirus pandemic increases the health concern of consumers regarding farmed meat. This *creates market potential* for CM, as direct farmed meat opponent with the same product, but without the potential pathogens. Despite the widely supported image that more people are following a vegan/vegetarian/flexitarian diet, this is not reflected in todays farmed meat consumption numbers.

Another point of interest, also *involving the consumers*, is their acceptance to CM. Research showed that more well-informed consumers are more accepting towards CM. Therefore, a great opportunity for the CM producers could be, to educate society. Make society more aware of their choices, and what the CM product entails. This helps society in their choice, while this could also increase the acceptance for CM and influence the amount people are willing to pay for CM.

7.3. Conclusions on the bottlenecks and opportunities for the Dutch CM IS

In research part 3, the possibilities and barriers for the development of CM in The Netherlands, have been explored. The previously discussed opportunities and bottlenecks are summarized in Table 27.

Table 27 Possibilities and barriers for the development of the Dutch CM innovation system

Bottleneck	Opportunity
Standardization and economies of scale of embedded actors	Top-down guidance
No central guidance	Increase meat alternative lobby
Limited lobby activities	Respond to landscape changes
Minor developments in human capital	Increase research convergence
Time consuming application of novel food regulations	Involve and educate potential consumers
High competition in current market sphere	
Low amount of collaboration	

To fully use the potential of the possibilities and to overcome the barriers, we can turn these bottlenecks and opportunities into possible actions for certain actor groups. In managing the bottlenecks and opportunities regarding the CM innovation system, the most power is with the governmental organizations and the industry. An overview of the potential actions is shown in Table 28. In the next section (9.2), these potential actions are further elaborated on.

Table 28 Suggested actions for each actor group to stimulate the Dutch CM innovation system following from this study

Who?	Action
Policy makers	- Develop long-term vision on the meat sector - Stimulate sustainability of the meat sector by setting up projects as 'Boerderij2000' - Stimulate multi-disciplinary work - Stimulate education about meat alternatives at schools
Industry	- Stimulate multi-disciplinary work - Cooperate with the conventional meat system - Involve and educate potential consumers - Use landscape changes – as COVID19 – in advantage by quickly responding - Set up more lobby activities for CM (cooperate with research institutes and universities)

Still, the major bottlenecks remain time and money to do research. The fact that government funding was cut after completing the research basis, significantly elongated the development process for the start-up companies and halted university research. Moreover, developing such an innovative and new technology as CM production simply takes time.

8. Discussion

8.1. Discussion of Results

Discussion Research part 1 – Analysis of the Dutch CM innovation system

In this research part, the structure and processes of the Dutch CM innovation system have been characterized.

The Dutch CM scene is still in its infancy. The technology is strongly evolving, the networks are still small, little amount of suppliers are in sphere, and no product is on the market yet. This makes it difficult to compete the embedded actors with widespread networks due to globalization.

Some weak and strong key processes of the IS have been recognized. No 'Guidance of the search' is present in the Dutch CM system, while this is important to align the visions of key stakeholders. This guidance helps to reduce uncertainties, as well as promoting targeted (research and investment) efforts. Moreover, 'Counteract resistance to change', needed to increase the legitimacy of the technology, is identified as weak functioning core process. A strong lobby could help in the competition with incumbent technologies and companies, and turn around institutional structures. On the other hand, 'Market formation' and 'Resource mobilization' are recognized as high functioning processes. Whereas new technologies often encountering obstacles in creating a market, the market for CM already exists, since it entails the exact same product as farmed meat. The main obstacle still here, is the low priced farmed meat. The resources for CM development and diffusion are currently high. The industry attracted interest of many private investors, and sufficient human capital is around. A challenge to overcome, is to educate the next generation on CM, to ensure sufficient human capital in the future. Moreover, the dependence on private investors, makes that little information is shared within the CM scene, potentially slowing down the development.

Discussion Research part 2 – Analysis of actor strategies and their values

In this part, landscape, regime and niche developments have been linked to actor values and strategies.

On a landscape level, increasing awareness for the environment can be observed. Moreover, the current crisis of COVID19 uncovered the fragility of the current meat system, while globalization and economies of scale give an advantage to the embedded actor. Animal welfare and environmental issues are two values that are widely shared among the different actor groups and drive many of the actor strategies. Embedded actors (farmers, conventional meat companies) have to adhere to these values to some extent to remain relevant to the expected growing group of environmental aware consumers, while niche actors (meat alternatives) strongly hold these values in the basis of their development process. Over time, an increase in landscape and niche pressures on the embedded regime actors for sustainability, animal welfare and health transitions can be observed. These changes can already be observed at a retail level, where supermarkets and restaurants increase the supply of more sustainable foods (Fairtrade, organic) and meat alternatives. On the other hand, by continuing their lobby activities, farmers keep their influence and secure their position in the regime. The farmed meat companies enjoy benefits from economies of scale and global networks, allowing for low-priced products and a secured position in the market.

The CM start-ups and other alternative meat producers are taking the strategy to mimic all the aspects of farmed meat, without its harmful effects. This allows them to stick to their values to create a more sustainable and animal friendly product. A major hurdle here, is the low-priced farmed meat to compete with. Interestingly, the two Dutch start-ups show very similar business concepts. They are both innovating, full-stack CM, beef companies. As earlier concluded in research of Rabl, Mosa Meats has more years of experience, due to their early start. For newer companies, it would be recommended

to focus on a specific part of the chain (Rabl, 2020). An interesting value in this whole, are the wishes for a vegan diet. Vegan values might conflict with the concept of CM, still being animal product in nature. For this group, plant-based alternatives could be more attractive than CM.

For now, the development of CM might be slowed down because of the independently operating start-ups and the time-consuming novel foods regulation. Sharing information and cooperating with other universities, institutes or companies could speed up parts of the CM development. However, none of the start-ups want to be scooped, and the start-ups have to stick to their confidentiality agreements with investors.

Research part 3 – Coupling research part 1 & 2
Coupling the TIS analysis, actor strategies and actor values, resulted in a list of identified bottlenecks and opportunities for the Dutch CM innovation system.

The fact that the current farmed meat system benefits from standardization, global and their strong lobby activities, as well as the high competition with other upcoming meat alternative niches, puts up some major challenges ahead for CM. Meat prices are low, making it difficult to compete for alternatives. Moreover, in the particular case of CM, time-consuming novel food regulations has to be obeyed, while competition in market sphere is increasing. Plant-based products are already able to mimic the texture, taste and juiciness of farmed meat, forming a direct competition to CM. Moreover, no central guidance is present to promote targeted efforts, and lobby activities of meat alternatives are inferior to the strong farmed meat lobby. On the other hand, opportunities can be found in more (multi-disciplinary) research work, a more central guidance of the search to determine viable research direction and more alliances to strengthen the position of meat alternatives in the field. Moreover, an unexpected opportunity has risen for the meat alternative producers with the introduction of COVID19. The fragility of the current meat system is uncovered, while societal awareness of the potential health and environmental harm of farmed meat increases. Lastly, an opportunity can be recognized for the industry to educate society. Make potential consumers aware of their options and benefits meat alternatives can offer for them. It has been shown for the case of CM, that an increase in society's knowledge about CM, caused an increase in their acceptance towards a potential CM product.

Following from the discussed opportunities and bottlenecks, recommendations have been made for the most influential actor groups: policy makers and industry. These will be further discussed and elaborated on in Paragraph 9.2.

8.2. Reflection on integrated framework of FIS, MLP, Actor values & strategies

A rather static description of the Dutch CM scene is obtained by applying the chosen frameworks, while an upcoming and quickly changing field is analyzed. For example, the removal of the fetal bovine serum, was an important technological development, that also changed some actor perspectives on CM. Moreover, feedback creation between the functions of FIS, as described through the motors of innovation, is still limited. The TIS is developing slowly, legitimacy is low and competition in the food (alternative) sector is high. Still, this analysis of the IS resulted in useful insights to the weaknesses and strengths, that hamper or can be used in its advantage for the development and diffusion of CM.

Integration of MLP adds levels to the analysis in the form of landscape, regime and TIS/niches. However, the focus was on describing the CM innovation system, and therefore not the entire (foods) regime has been taken into account, but only the part of interest for the TIS. Despite the fact that a potential relationship with other parts of the (foods) regime, especially other animal products, are highly possible between the regime and the TIS, this has not been taken into account in the scope of

this research. MLP tries to explain the outcome of transitions. While the framework does explain how technologies become embedded within the regime, it fails to fully explain why others do not become embedded within the regime.

Consumer wishes form the base for responsible research and innovation. Once there is a clear picture of society's values, a combination of these values and technological experimental knowledge should be puzzled together to answer to these values of society or other stakeholders. Despite the integration of a systemic RRI approach, the 'real' values of society have not been analyzed here, but rather based on the values of influential organizations as the Dutch association for veganism, Wakker dier and religious organizations.

Especially when applying a FIS approach, one should be aware that actors are not acting to fulfill the system functions, but rather execute their own strategies. The system functions are the observers point of view, while the actors have their own will. The lack of focus on actor strategies in the aforementioned frameworks, was complemented for by integrating a separate actor strategy analysis. This offered the opportunity to link actor values, strategies and expectations in and around the CM innovation system.

Lastly, the combined framework utilized here, is not a clear transition framework. It does not show the potential transition from one to another. It rather shows the development of the technology, CM here.

The addition of both actor strategies and actor values to the integrated framework of Markard and Truffer (2008), resulted in a new integrated framework. While this framework usefully complements for each other's strengths and weaknesses, its full potential, benefits and difficulties should be evaluated through more empirical research.

8.3. Limitations of this research

Besides the reflected limitations of the framework, some methodological limitations can be pointed out.

Due to time limitations, only a limited amount of experts have been interviewed. The aim was to interview experts from each actor group. However, no current market actors have been interviewed (farmers, farmed meat producers, meat alternative producers), leaving out a significant group of interest during the interviews. These gaps have been filled by extensive desk research, analyzing company reports and websites.

Moreover, different interview questions of the functional part were picked for different experts, since those experts belonged to different actor groups, with different interests and areas of expertise. This approach of interviewing caused some of value judgements of the functions to depend on only one or two expert opinions.

The seven functions of the innovation system have been assessed by scoring them high-moderate-low. The scoring assigned to each function is based on interpretation of the researcher, rather than quantitative measurements. Therefore, a researcher bias could be present.

8.4. Scientific contribution

Getting back to this study's problem statement, many academic articles have been published on different aspects of cultured meat, including the technique, consumer acceptance, ethics and its sustainability, but not on coupling all of those aspects to analyze a potential CM scene or industry. In

this research the separate elements have been coupled, and bottlenecks and opportunities of such a system have been pointed out for the Dutch CM scene. It emphasizes the influential role of certain actor groups (investors, government and start-ups) on the development of a new technology as CM, but it also illustrates the fragmentation of current research. Even though our current challenges are difficult to tackle and ask for different disciplines to work together, including input from people (society) who experience the problem, evolution is fragmented.

Moreover, this study does not only contribute to the pile of CM research, but also presents and exemplifies a new integrated framework. The potential of combining TIS and MLP has been exemplified before by Markard and Truffer (2008). However, the integrated framework presented in this study, complements for both actor strategies and values, two elements that are lacking in solely an integration of TIS and MLP. When turning to the fact that our current major problems, and the success of their solution, is highly dependent on stakeholders as the society to embrace it, their values have to align. While its full benefits and difficulties should be evaluated through more empirical research, its potential has been shown.

9. Conclusion and recommendations

9.1. Conclusion

The Dutch CM innovation system is still in its infancy. The amount of actors and networks are small, and the technology is still highly developing. The fact that the current farmed meat system benefits from standardization, global and their strong lobby activities, as well as the high competition with other upcoming meat alternative niches, puts up some major challenges ahead for CM. On the other hand, opportunities can be found in more (multi-disciplinary) research work, a more central guidance of the search to determine viable research direction, more alliances and responding to landscape changes as COVID19. Moreover, the fact that CM is exactly the same product as our current farmed meat, can work in its advantage. The market is already there and current infrastructure can be adapted to fit CM purposes. Over time, an increase in landscape and niche pressures on the embedded regime actors for sustainability, animal welfare and health transitions can be observed. This forces the strongly embedded actors to reconsider their activities to stay relevant in business and to avoid being completely overtaken by more sustainable niche transitions as CM. The bottlenecks and opportunities ahead of CM, can be managed by policy makers, as well as industry. Policy makers can stimulate a more sustainable meat sector by stimulating (multi-disciplinary) research projects, by introducing research projects or grants. On the other hand, industry can take its role here, by cooperating between sustainable meat (niche) alternatives and the embedded farmed meat actors, involving and educating society, and increasing lobby activities for meat alternatives. Thereby, these parts together have formed an answer to the main research question: "How has the Dutch socio-technical system of cultured meat been developing and under which circumstances could it grow?"

Overall, the environmental benefits of CM remain to be proven, but the experts are clear: something has to change in our current way of farming to reduce the burden on the environment. A change of the current farming system is inevitable. The opinions of experts on how this sustainability should be introduced into the Dutch meat sector widely diverge from improving the current farming system to switching to radical innovations as CM. By extending the analysis of the innovation system with MLP, actor strategies and actor values, allows for a more broader range of recommendations to different actor groups than only policy makers. The most powerful actor groups –policy makers and industrial actors– can all contribute to the development of the CM system through specific actions. Altogether, the development of the Dutch CM scene and subsequent industry, requires more time and more money to do research.

9.2. Recommendations following from this research

As discussed in Research part 3, by coupling the activities and events from in (Research part 1) and outside (Research part 2) the Dutch CM innovation system, a few recommendations can be made to stimulate the development of the system. Supplementing the FIS analysis with MLP and actor values and strategies in this research, allows us not to only make recommendations for practical strategic implications for policy makers, but also for other actors in the system. Here, we distinguish recommendations to two actor groups: policy makers and industry.

Recommendations to policy makers

A long-term vision for policy makers is key in determining the direction of and investments in the sector. This also applies for the Dutch meat sector. Currently much of the lobbying power is in hands of the farmed meat scene, while new meat alternatives are struggling to compete. Policy makers can stimulate the development and sustainability of the sector by grants, subsidies or by the establishment of projects as 'Boerderij2000'. Moreover, multidisciplinary research projects can be stimulated though

via for instance cooperative research programs or introducing cooperative grants, to accelerate the development of sustainable initiatives as CM. Lastly, education on meat alternatives is scarce compared to education on improving the current farming system. This could be stimulated more in the form of new education or training programs, or by stimulating universities to adapt/extent relevant programs with information about meat alternatives (projects/workshops). In particular, no specific education is yet available for CM.

Recommendations to industry

Economies of scale, large global networks and strong lobby activities offer advantages for the embedded meat sector. For new technologies as CM, cooperating with the conventional meat system could help to also benefit from these large networks, their knowledge and well-build Dutch agricultural system. The meat alternative industry could also benefit from alliances with parties focusing on specific parts of the chain. For CM, this can relate to the upscaling machinery or culture medium. Moreover, lobby activities for meat alternative should be invested in, on both a national and international (European) level, directly competing with the current meat lobby for market place and funding. Next to this, quickly respond to landscape changes, to use in its advantage for meat alternatives as CM, or disadvantage of the current status quo. An example could be the current coronavirus pandemic. Lastly, meat alternative producers could benefit from informing and educating civil society. It has been shown for the case of CM, that an increase in society's knowledge about CM, caused an increase in their acceptance towards a potential CM product. An interesting existing example here is, the national week without meat.

9.3. Potential future research directions

Next to the proposed actor recommendations, some recommendations for future research directions can be established.

- Elaborate this study with (sustainable) entrepreneurship research
  This could give a more deeper insight on the influence of the entrepreneurship strategies and how those strategies influence the development and transition. This is especially interesting in an emerging field as the Dutch CM scene, since a high amount of the power is in the hands of the entrepreneurs, and therefore a major influence on the development. Explore the strategies and patterns for entrepreneurial success. This could be compared between different parts of the world.
- Further investigate the organization and functioning of a future CM industry
  Ira van Eelen and Cor van der Weele are already making steps in researching the role of farmers in the potential future CM industry. Similarly, the role and collaboration with other incumbent farmed meat companies or suppliers can be explored to investigate and explore physical infrastructure for CM.
- Compare the emerging of the Dutch CM scene to the rise of meat alternatives transition system
  Can we learn from the way the meat alternatives (successfully) reached the market? Compare the strategies and development of the meat substitute system to the development of the CM system.
- Further explore the use of such an integrated framework as used in this study
  Combining different transition frameworks, including integrating IS and MLP, has shown useful in the past. However, the integrated framework used here has not yet been widely explored. Therefore, this framework needs more empirical research to confirm its potential and investigate its drawbacks and advantages.

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Appendices

A. Overview of the interview questions

a. Dutch interview questions

- **Introductie**

Korte introductie naar geïnterviewde:
Het onderzoek focust op het in kaart brengen van de Nederlandse kweekvlees sector, en hoe een toekomstige Nederlandse kweekvlees industrie vormgegeven kan worden. Hiervoor zijn de huidige ontwikkelingen/knelpunten, en de idealen en ideeën van verschillende partijen actief in de Nederlandse (kweek)vlees industrie cruciaal. Deze zullen getoetst worden door middel van de interviews.

1. Wat is uw rol in de kweekvlees sector?
2. Waarom bent u geïnteresseerd in de ontwikkeling van kweekvlees?
3. Wat is uw persoonlijke visie op kweekvlees?
4. *Indien relevant: Wat is uw bedrijf/organisatie zijn visie op kweekvlees?*

- **Ontwikkelingen**

5. Wat zijn de belangrijkste ____ ontwikkelingen voor/in de Nederlandse kweekvlees sector?
    a. Technologische
    b. Beleids- (wetgeving)
    c. Markt
    d. Maatschappelijke
6. Wat ziet u als de grootste barrières en drijfveren voor de verdere ontwikkeling van de Nederlandse kweekvlees sector?

- **Technologie**

7. Wat zijn de belangrijkste kweekvlees technologieën?
8. Wat zijn de grootste hindernissen en kansen omtrent de kweekvlees technologie?

- **Actor and networks**

9. Wie zijn volgens u de andere meest relevante actoren in de Nederlandse kweekvleessector op gebied van ____
    a. Kennisontwikkeling
    b. Regelgeving
    c. Zakelijk/bedrijfsvoering
    d. Maatschappelijke organisaties
10. Met welke van deze andere actoren bent u actief in contact, en om welke redenen?
11. Wie zijn internationaal belangrijke actoren en met welke heeft u contacten?

- **Regelgevig**

12. Welke regelgevingen raken de ontwikkeling van kweekvlees in Nederland (negatief of positief)?

- **Waarden en strategieën**

13. Wat zijn uw voornaamste eisen aan (kweek)vlees?
14. Hoe zou naar uw idee de toekomstige Nederlandse (kweek)vlees industrie eruit moeten zien? Is dit beeld voor u over de afgelopen tijd veranderd?

15. *Indien relevant (organisatie): Door middel van wat voor een strategieën probeert u uw idealen te bereiken?*

- **Verwachtingen**

16. Hoe verwacht u dat de ____ voor kweekvlees in Nederland zich gaat ontwikkelen?
    a. Technologie
    b. Regelgeving
    c. Markt
    d. Maatschappelijke organisaties
17. Ziet u mogelijkheden voor samenwerkingen met de huidige vleesmarkt (vleesvervangers/vlees)/kweekvlees?

18. Wat is volgens u, op dit punt, het gene dat de ontwikkeling van kweekvlees in Nederland echt verder zou kunnen helpen?

- **Afsluiting**

19. Heeft u nog verdere suggesties/tips voor dit onderzoek? (Of iets waar u zelf tegen aan loopt?)
20. Met wie moet ik zeker verder praten over dit onderwerp?

Interview Deel II - Functies

F1 – Ondernemingsgerichtheid in experimenteren en produceren
(Entrepreneurial experimentation and production)

1.1) Zijn er veel nieuwe toetreders tot de sector?
1.2) Wat voor een innovatie activiteiten vinden plaats in bedrijven/universiteiten/instituten in Nederland?
1.3) Is de hoeveelheid innovatie en experimenteren met kweekvlees in Nederland vergelijkbaar met het buitenland?
1.4) Weerhoudt de hoeveelheid onderzoek en nieuwe projecten naar kweekvlees door entrepreneurs de verdere ontwikkeling van de sector?

F2 – Kennisontwikkeling
(Knowledge development)

2.1) Wat is de belangrijkste kennis die nodig is in deze fase van ontwikkeling van kweekvlees?
2.2) Voldoet de hoeveelheid en soort (toegepast, wetenschappelijk, patent, enz.) kennisontwikkeling aan de vraag? Indien 'nee', welke kennis mist?
2.3) Hoe wordt uw (bedrijfs) intellectual property beheerd?

F3 – Kennisuitwisseling
(Knowledge exchange)

3.1) Is er voldoende kennisuitwisseling en samenwerking tussen wetenschap enproducenten?
3.2) Is er voldoende kennisuitwisseling tussen gebruikers en producenten?
3.3) Welke belangrijke mogelijkheden voor verdere samenwerking of netwerken ziet u?

F4 – "Sturing van de zoektocht"
(Guidance of the search)

4.1) Is er een duidelijke visie op hoe de industrie en markt moeten ontwikkelen (bijvoorbeeld door doelen van de regering, sector of sleutelfiguren)?
4.2) Welke acties of regelingen zou u graag van de overheid willen zien?
4.3) Zijn de wensen van de 'lead users' duidelijk?
4.4) Liggen de visies en verwachtingen van verschillende betrokken actoren in de sector voldoende op dezelfde lijn?
4.5) Hoe anticipeert u op politieke en sociale ontwikkelingen?

F5 – Markt vorming
(Market formation)

5.1) Is de verwachtte markgrootte voor kweekvlees in Nederland voldoende?
5.2) Hoe verhoudt deze potentiele markt voor kweekvlees zich tot de huidige markt voor vlees en vleesvervangers?
5.3) Wat zijn de grootste hindernissen voor het vergroten van de potentiele kweekvlees markt in Nederland?

F6 – Mobilisatie van de middelen
(Resource mobilization)

6.1) Zijn er voldoende "human resources" voor ontwikkeling en diffusie van de technologie in Nederland?
6.2) Zijn er voldoende financiële middelen voor verdere ontwikkeling van de technologie in Nederland?
6.3) Zijn er voldoende fysieke middelen (infrastructuur) voor verdere ontwikkeling van de technologie in Nederland?

F7 – Weerstand tegen verandering tegengaan/creatie van legitimiteit
(Counteract resistance to change/legitimacy creation)

7.1) Is er veel weerstand tegen de kweekvlees technologie (opzetten van nieuwe projecten of aanvragen van vergunningen)?
7.2) Zijn er veel lobby groepen voor kweekvlees in Nederland?
7.2)1. Hoe actief zijn deze?
7.2)2. Zijn deze gegroeid over de afgelopen tijd?
7.3) Hoe is volgens u de publieke opinie tegenover kweekvlees?
7.3)1. Hoe speelt (social) media een rol in het beïnvloeden van deze publieke opinie?

b. English interview questions

- **Introduction**

Short introduction/recap of research aim to interviewee:
The aim of this research is to identify the possibilities and obstacles for the further development of the Dutch cultured meat sector. For this, the interview will focus on your current and expected bottlenecks, opportunities, and your thoughts on the development of the sector.

1. What is your role in the cultured meat sector?
2. Why are you interested in the development of cultured meat?
3. What is your vision on cultured meat?
4. *If relevant: What is your companies vision on cultured meat?*

- **Developments**

5. What are the most important ____ developments for the Dutch cultured meat sector?
    a. Technology
    b. Policy
    c. Market
    d. Social
6. What do you see as the main obstacles and drivers in the further development of cultured meat?

- **Technology**

7. What are the most important cultured meat technologies?
8. What are the current technological bottlenecks and possibilities?

- **Actor and networks**

9. Who are, according to you, the other most relevant actors involved with ____ in the Dutch cultured meat sector?
    a. Knowledge development
    b. Policy making
    c. Business developments
    d. Social developments
10. Which of the other involved actors are you actively in contact with and on what grounds?
11. Are there also important international connections for the Dutch cultured meat sector? If so, who are the relevant international actors?

- **Institutions**

12. What policies, positively or negatively, affect the development of cultured meat (sector)?

- **Values and strategies**

13. What would be your most stringent requirement to cultured meat (can be in relation to the production process, or the product itself)?
14. How would your 'ideal' meat sector look like (which products would be in it: plant-based/cultured/farmed, in which ratios)? And has this picture changed over the past few years?

15. *If relevant: Through which strategies do you strive to reach your companies visions/values?*

- **Expectations**

16. What major next ____ development in the Dutch (cultured) meat sector do you expect?
    a. Technology
    b. Policy
    c. Market
    d. Social
17. What possibilities do you see for cooperation between the current meat market and cultured meat?

18. Do you have any further recommendations to look into, or people I should really talk to for this project?

Part II - Functions

<u>F1 – Entrepreneurial experimentation and production</u>

1.1) Are there many new entrants in the sector?
1.2) What kind of innovation projects are currently taking place within your company, or in universities/institutes?
1.3) Is the amount of innovation and research to cultured meat in the Netherlands comparable to abroad?
1.4) Does the experimentation and production by entrepreneurs form a barrier for the Innovation System to move to the next phase?

<u>F2 – Knowledge development</u>

2.1) What is the most important knowledge needed in this stage of cultured meat development?
2.2) Is the amount and type (scientific, applied, patents, etc.) of knowledge development, matching the current demand?
2.3) How do you manage IP?

<u>F3 – Knowledge exchange</u>

3.1) Is there sufficient knowledge exchange between science and cultured meat producers to develop the technology?
3.2) Is there sufficient knowledge exchange between users and cultured meat producers to develop the technology?
3.3) Which opportunities for cooperation or networks do you recognize?

<u>F4 – Guidance of the search</u>

4.1) Is there a clear vision on how the cultured meat industry and market should develop (targets by government)?
4.2) What actions/regulations would you like to see from the government?

4.3) Are the visions and expectations of actors involved in the Dutch cultured meat scene sufficiently aligned to reduce uncertainties? If not, where is alignment mostly needed at the moment?
4.4) How do you anticipate on rising political and social concerns?

F5 – Market formation

5.1) Is the expected future Dutch market size sufficient for cultured meat?
5.2) How does this market opportunity relate to the current meat and meat alternatives market?
5.3) What obstacles for increasing the potential cultured meat market in The Netherlands are most pressing

F6 – Resource mobilization

6.1) Are there sufficient …. resources for development and subsequent diffusion of the technology?
- Human (through entrepreneurship, education, management)
- Financial (venture capital, government funds)
- Physical (infrastructure)

F7 – Counteract resistance to change/legitimacy creation

7.1) Is there a lot of resistance towards the new technology, the set up of projects/permit procedure?
7.2) Are there lobby groups for cultured meat in the Netherlands? If yes, how active are they, and have they been growing over the past few years?
7.3) How is, according to you, the public opinion towards cultured meat? How does (social) media affects this public opinion?

B. Results of bibliometric analysis in Scopus

Scopus results for search term 'TITLE-ABS-KEY ("cultured meat" OR "cultivated meat" OR "In vitro meat") AND (LIMIT-TO (AFFILCOUNTRY , "Netherlands"))', further selected by scanning abstracts, resulting in 24 relevant Dutch CM publications.

Year	Institution	Department	Authors	Title
2011	University of Oxford and **UvA**	**Swammerdam Institute for Life Sciences**	Tuomisto, H.L., **Teixeira De Mattos, M.J.**	Environmental impacts of cultured meat production
2012	UM	Department of Physiology, Cardiovascular Research Institute Maastricht	Post, M.J.	Cultured meat from stem cells: Challenges and prospects
2013	WUR	Department of Social Sciences[a] and Department of Environmental Sciences[b]	van der Weele, C.[a], Driessen, C[b].	Emerging profiles for cultured meat; ethics through and as design
2017	WUR	Marketing and Consumer Behaviour Group[a] and Biometris[b]	Bekker, G.A.[a, b], Fischer, A.R.H.[a], Tobi, H., van Trijp[b], H.C.M.[a]	Explicit and implicit attitude toward an emerging food technology: The case of cultured meat
2014	WUR	Communication, Philosophy and Technology[a] and Bioprocess Engineering[b]	van der Weele, C.[a], Tramper, J.[b]	Cultured meat: Every village its own factory?
2018	**WUR,** Joint Research Centre Ispra, **RIVM[d],** CSIRO Australia, University of Helsinki,	Animal Production Systems Group[a], Operations Research and Logistics[b], Laboratory of Entomology[c]	**Parodi, A.[a]**, Leip, A., **De Boer, I.J.M.[a], Slegers, P.M.[b],** Ziegler, F., **Temme, E.H.M.[d]**, Herrero, M., Tuomisto, H., Valin, H., **Van Middelaar, C.E.[a], Van Loon, J.J.A.[c], Van Zanten, H.H.E[a].**	The potential of future foods for sustainable and healthy diets
2016	Brunel University London and **HAN University of Applied Sciences**	Kenniscentrum Publieke Zaak	Stephens, N., **Ruivenkamp, M.**	Promise and Ontological Ambiguity in the In vitro Meat Imagescape: From Laboratory Myotubes to the Cultured Burger
2017	WUR	Marketing and Consumer Behaviour	Bekker, G.A.[a,b], Tobi, H.[b], Fischer, A.R.H.[a]	Meet meat: An explorative study on meat and cultured

		Group[a] and Biometris[b]		meat as seen by Chinese, Ethiopians and Dutch
2018	Maastricht University	Department of Physiology	Verbruggen, S., Luining, D., van Essen, A., Post, M.J.	Bovine myoblast cell production in a microcarriers-based system
2012	Linköping University Sweden and **WUR**	Department of Social Sciences	Welin, S., **Van Der Weele, C.**	Cultured meat: Will it separate us from nature?
2019	**WUR** and Humboldt Universität Berlin	Department of Social Sciences[a] and Department of Agrotechnology and Food Sciences[c]	**van der Weele, C.** [a]**,** Feindt, P., **Jan van der Goot, A.** [b]**, van Mierlo, B.** [a]**, van Boekel, M .** [b]	Meat alternatives: an integrative comparison
2019	Brunel University London, University of Oxford and **WUR**	Cultural Geography Group	Stephens, N., Sexton, A.E., **Driessen, C.**	Making Sense of Making Meat: Key Moments in the First 20 Years of Tissue Engineering Muscle to Make Food
2018	**Maastricht University** and Nanjing Agricultural University	Department of Physiology	**Ding, S., Swennen, G.N.M., Messmer, T., Gagliardi, M.a, Molin**, **D.G.M.,** Li, C., Zhou, G., **Post, M.J.**	Maintaining bovine satellite cells stemness through p38 pathway
2019	Maastricht University	Department of Physiology	Mehta, F., Theunissen, R., Post, M.J.	Adipogenesis from bovine precursors
2018	University of Malaya, **Maastricht University** and The University of Edinburgh	Department of Physiology	Hamdan, M.N., **Post, M.J.,** Ramli, M.A., Mustafa, A.R.	Cultured Meat in Islamic Perspective
2013	WUR	Department of Social Sciences	van der Weele, C.N.	Meat and the benefits of ambivalence
2015	**University of Nijmegen** and Centre for Society and the Life Sciences (CSG)	Department of Philosophy and Science Studies	Zwart, H.	Tainted Food and the Icarus Complex: Psychoanalysing Consumer Discontent from Oyster Middens to Oryx and Crake
2020	**Maastricht University** and Université	**Department of Psychology**	**Rolland, N.C.M.,** Markus, C.R**., Post, M.J.**	The effect of information content on acceptance of cultured meat in a tasting context

	Bourgogne Franche-Comté			
2020	University of Maastricht, Mosa Meat[c]	Department of Physiology[a] and CARIM[b]	Bodiou, V. [a], Moutsatsou, P. [b], Post, M.J[c].	Microcarriers for Upscaling Cultured Meat Production
2020	Axon Lawyers	N/A	Verzijden, K., Buijs, J.	Meat 3.0 — how cultured meat is making its way to the market
2019	WUR	Department of Social Sciences[a] and Department of Environmental Sciences[b]	van der Weele, C. [a], Driessen, C[b].	How Normal Meat Becomes Stranger as Cultured Meat Becomes More Normal; Ambivalence and Ambiguity Below the Surface of Behavior
2013	Utrecht University	Department of Farm Animal Health[a] and Department of Infectious Diseases and Immunology[b]	Brinkhof, B.[a], Roelen, B.A.J.[a], Haagsman, H.P.[b]	Meet the stem cells: Production of cultured meat from a stem cell biology perspective
2010	WUR	Department of Social Sciences	Van Der Weele, C.	In vitro meat: Promises and responses: Cooperation between science, social research and ethics
2012	UU, WUR	Department of Philosophy, UU[a] and Applied Philosophy Group, WUR[b]	Driessen, C.[a,b] Korthals, M.[b]	Pig towers and in vitro meat: Disclosing moral worlds by design

C. Overview of plant-based meat and hybrid products, supermarkets and restaurants

Plant-based meat (and fish) alternatives

The amount of plant-based meat and fish alternatives has grown significantly over the past few years. Even the supermarkets are creating their own private label meat alternatives.

Table 29 Overview of the plant-based meat alternatives on the Dutch market

Producer	Products
Albert Heijn	Plant-based meat and fish alternatives
Albinsecta	Get proteins out of crickets
Beyond Meat	Plant-based meat alternatives
Bertyn	Plant-based meat and fish alternatives
Bio+	Plant-based meat alternatives
Damhert	Plant-based meat alternatives
Florentin	Plant-based meat alternatives
Fry's Vegetarian	Plant-based meat alternatives
Gardein	Plant-based meat alternatives
Goodbite	Plant-based meat alternatives
Gourmet Garden (Nestlé)	Plant-based meat alternatives
HAK	Plant-based meat alternatives
Healthy Planet	Plant-based meat alternatives
Iglo	Plant-based meat and fish alternatives
Jumbo Veggie Chef	Plant-based meat and fish alternatives
Knakwortel	Plant-based meat alternatives
Lima Food	Plant-based meat alternatives
Ojah (Beeter)	Plant-based meat alternatives
ProLaTerre	Plant-based meat and fish alternatives
SoFine	Plant-based meat and fish alternatives
Taifun	Plant-based meat alternatives
The Vegetarian Butcher (De Vegetarische Slager)	Plant-based meat alternatives
Vantastic Foods	Plant-based meat alternatives
Vegafit	Plant-based meat alternatives
Vegetalis	Plant-based meat alternatives
VegiDeli	Plant-based meat alternatives
Vetera	Plant-based meat alternatives
Viana	Plant-based meat alternatives
Vivera	Plant-based meat alternatives
Wheaty	Plant-based meat alternatives

Hybrid products

In contrast to the major amount of available plant-based alternatives on the Dutch market, Meatless is the only found producer of hybrid products.

Table 30 Overview of the hybrid meat alternatives on the Dutch market

Producer	Products
Meatless	Hybrid meat/plant-based meat and fish alternatives, as well as entirely plant-based products

Supermarkets

The Dutch supermarket scene can be divided into four main categories, the 'regular' supermarkets, specialized supermarkets, wholesale and web shops.

Table 31 Overview of the kind of supermarket in The Netherlands

Category	Examples
Supermarkets	Albert Heijn, Jumbo, Aldi, Lidl
Specialized supermarkets	Biological shops (EkoPlaza), Asian shops (Amazing Oriental)
Wholesale	Makro, Sligro
Web shops	Picnic, vegetarian/vegan shops (veggiedeli)

Restaurants

Overall, five potential sorts of restaurants for the sale of cultured meat can be distinguished. These are: star restaurants, grand-café, bistro, specialized kitchen and fast food chains.

Table 32 Overview of the kind of restaurants in The Netherlands

Category	Examples
Star restaurants	Fred, Niven, De Librije
Grand-Café	-
Bistro	-
Specialized kitchens	Asian, Chinese, Italian
Fast Food chains	McDonalds, Burger King, KFC

D. Past and ongoing technology-related research in The Netherlands

University of Amsterdam (UvA)

Three publications can be found via Google Scholar, searching for "cultured meat" AND the researchers from the UvA that work or used to work on this topic, based on the interviews and searching the internet (e.g.: "cultured meat" AND author:haagsman) (Table 33).

Table 33 Overview of CM publications concerning technical or biological aspects at UvA

Institution	Publications	Year	Authors
University of Amsterdam (UvA)	Production of animal proteins by cell systems	2009	HP Haagsman, **KJ Hellingwerf,** BAJ Roelen
	Life cycle assessment of cultured meat production	2010	HL Tuomisto, **MJ Teixeira de Mattos**
	Environmental impacts of cultured meat production	2011	HL Tuomisto, **MJ Teixeira de Mattos**

As told during the interview by a cultured meat researcher from the Utrecht University, the research at Amsterdam focused on the cell culture medium. The idea was to take the required animal products in the medium from algae. This research angle is confirmed by Ira van Eelen, explaining that her father, Willem van Eelen, originally performed research to algae together with Joost Taxeira de Mattos. The three obtained papers are not specifically written about this algae research, however, the possibilities of using algae cultures for nutrients and energy are mentioned.

Utrecht University (UU)

Using Scopus and Google Scholar, selecting for search term "cultured meat" AND searching for the professors known working on cultured meat in Utrecht, resulted in 6 publications (Table 34).

Table 34 Overview of CM publications concerning technical or biological aspects at UU

Institution	Publications	Year	Authors
Utrecht University (UU)	Identification and Characterization of Adult Porcine Muscle Stem Cells	2009	**KJ Wilschut**
	Production of animal proteins by cell systems	2009	**HP Haagsman**, KJ Hellingwerf, **BAJ Roelen**
	Differentiation of porcine inner cell mass cells into proliferating neural cells	2010	**HP Haagsman, BAJ Roelen**
	Extracellular matrix components direct porcine muscle stem cell behavior	2010	**KJ Wilschut, HP Haagsman, BAJ Roelen**
	Meet the stem cells: Production of cultured meat from a stem cell biology perspective	2013	**B Brinkhof, BAJ Roelen, HP Haagsman**
	Transcriptome Landscapes of Mammalian Embryonic Cells	2015	**B Brinkhof**

CM research at the UU focused on stem cells. Multiple professors, as well as students at the UU have researched this specific part. They investigated the potential to make stem cells from cow or pig embryos. This differs from most of the research that is currently performed, in which stem cells from muscle tissue are used. Meatable uses IPS (induces pluripotent stem) cells which are comparable to embryonic stem cells, but this is still different [E8].

From the 6 obtained publications, the majority of the found papers focuses around stem cells, supporting this as a clear direction of research at Utrecht. Despite the fact that adult (muscle) stem cells were found as most promising type for the production of cultured meat, the research at Utrecht eventually focused on embryonic stem cells. This was mostly due to the major interest from a biological perspective [E8]. From a biological perspective, the proliferation pace is slower and the differentiation capacity is limited for adult stem cells compared to embryonic stem cells (Brinkhof, Roelen, & Haagsman, 2013). However, from a process facilitating view, adult stem cells (satellite cells) seem the most straight-forward candidates, as they can only differentiate into those myocytes, while embryonic cells can differentiate into different lineages. On top of that, these adult stem cells can proliferate while maintaining their 'stemness' (Bodiou et al., 2020).

Maastricht University (UM)

Much more papers in the technological/biological perspective of cultured meat, have been found for the UM compared to the other Dutch universities. Many of these papers have been (co-)authored by Mark Post. A total of 20 publications have been obtained via Scopus and Google Scholar with the search term "cultured meat" AND the name of the know researchers working on cultured meat at Maastricht. In this search, the papers touching the biological and technical aspects were selected (Table 35).

Table 35 Overview of CM publications concerning technical or biological aspects at UM

Institution	Publications	Year	Authors
Maastricht University (UM)	Cultured Meat: Foresight analysis	n.d.	**J Moritz**
	Disruptive Innovation: A Systemic Linguistic Analysis of Two Texts Detailing the Exhibition—Design and the Elastic Mind	2008	**M Post**
	The muscle stem cell niche: regulation of satellite cells during regeneration	2008	KJM Boonen, **MJ Post**
	Essential environmental cues from the satellite cell niche: optimizing proliferation and differentiation	2009	KJM Boonen, KY Rosaria-Chak, FPT Baaijens, DWJ van der Schaft, **MJ Post**
	Meet the new meat: tissue engineered skeletal muscle	2010	KJM Boonen, RB Polak, FPT Baaijens, **MJ Post**
	Cultured meat from stem cells: Challenges and prospects	2012	**MJ Post**
	Cultured beef: medical technology to produce food	2014	**MJ Post**
	Principles of tissue engineering for food	2014	**M Post**, C van der Weele
	Production and supply of high-quality food protein for human consumption: sustainability, challenges, and innovations	2014	G Wu, J Fanzo, DD Miller, P Pingali, **M Post**
	Alternatives for large-scale production of cultured beef: A review	2015	**MSM Moritz, SEL Verbruggen, MJ Post**
	Optimization of bovine satellite cell proliferation on microcarriers	2015	**D Luining, M Post, A van Essen, S Verbruggen**
	Lab-Based Meat Production: Science Fiction or Reality	2017	**MJ Post**
	New sources of animal proteins: cultured meat	2017	**MJ Post,** JF Hocquette

	Bovine myoblast cell production in a microcarriers-based system	2018	**S Verbruggen, D Luining, A van Essen, MJ Post**
	Maintaining bovine satellite cells stemness through p38 pathway	2018	**S Ding, GNM Swennen, T Messmer,, M Gagliardi, DGM Molin**, C Li, G Zhou, **MJ Post**
	Proteins in cultured beef	2018	**MJ Post**
	Adipogenesis from bovine precursors	2019	**F Mehta, R Theunissen, MJ Post**
	From farming to cellular farming: Our future with cellular agriculture and cultured meat	2019	**NS Räty, J Moritz**
	Maintaining the stemness of satellite cells during long-term culture	2019	**S Ding**
	Microcarriers for Upscaling Cultured Meat Production	2020	**V Bodiou, P Moutsatsou, MJ Post**
	Serum-free media for the growth of primary bovine myoblasts	2020	**AM Kolkmann, MJ Post, MAM Rutjens, ALM van Essen**

As already mentioned, most of the publications have been (co-)authored by Mark Post or are written by supervised students of Mark Post. The first research, before 2010 and early 2010's, focuses on exploring the 'basic' cultured meat production process, including regulation, proliferation and differentiation of the cells. More recent research focuses on maintaining cell lines, upscaling production, and removing the animal from the chain, the optimization of the production process. The research reflects the development process of the cultured meat production chain.

As also came forward from multiple expert interviews, this research at UM is highly interrelated with the research at Mosa Meat [E1, E4, E7, E8].

Mosa Meat

Research at Mosa Meat does not focus on innovating or improving a specific part of the production process, but focusses at the entire chain. Mosa Meat is a full-stack solution company [E5, E12].

As mentioned, the research performed at Mosa Meat is highly interlinked with the research at the Maastricht University. The innovation process within Mosa Meat, also closely corresponds to the technological findings from the UM papers. Mosa Meat indicated to have solved the fetal bovine serum-problem over the past year, which is also reflected in the latest UM publication 'Serum-free media for the growth of primary bovine myoblasts'. [E5].

Currently, Mosa Meat is innovating the scaling up of their production equipment, and aiming to get their first products on the market in 3-4 years (Mosa Meat, n.d.)[E5].

Meatable

Meatable was founded in 2018 by Krijn de Nood, Daan Luining and Mark Kotter. In the past, Daan Luining has worked together with Mark Post at UM, as can be traced back from the obtained UM publications. In contrast to Mosa Meat, the Meatable website does not give any information on their current research focus or process, except for explaining the 'basic' production process steps. Also from the interviews not much more information on their current specific focus of work could be retrieved. Multiple of the interviewees indicate the fact that Meatable is pretty restrained in talking about their research [E1, E2, E3, E8]. "Meatable is much more restricted, they don't want to be scooped by anyone else. I talked to Daan Luining a few times, and in these conversations he also pointed out rather not to go into their technological work." [E8]. "Some time ago, there was a company in Leiden (Meatable –

ed.) with the announcement that they were going to produce meat with an entirely different technology. I tried to approach them for an interview, and got a very enthusiastic first response. However, they kept delaying the interview, and finally we never heard back from them. But, they claimed to have an entire different technique".

From previous interviews with Meatable, as well as the interviews performed in this research, it becomes clear that Meatable works with so-called induced pluripotent stem cells (iPS cells). iPS cells are very similar to embryonic stem cells, but don't come from embryos (Watson, 2018). Pluripotent means that cells can differentiate into all the cells of the fetal and adult specie, whereas satellite (muscle stem) cells are multipotent and only give rise to satellite cells or differentiated muscle cells (Brinkhof et al., 2013).