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PEER-REVIEWED ARTICLE

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Framing Food Safety Considerations in Cultured Meat: An Expert Perspective on Barriers and Opportunities

ABSTRACT

Cellular agriculture is an emerging sector that could significantly impact the future of food production, including meat. While many recent publications discuss the anticipated benefits and limitations of cultured meat (i.e., meat produced through cellular agriculture), research addressing the potential safety hazards associated with its production processes has been limited to date. A formal consultative roadmapping workshop was conducted with 23 food safety experts to identify the barriers, challenges, and short- and long-term research, technological, and policy needs across five thematic areas. Analysis of the discussions showed a consensus on the need for improved cooperation among stakeholders, including industry partners, academia, and regulators. Key activities to strengthen food safety and build consumer trust included increased availability of information on process safety, the establishment of safety standards, and enhanced specifications for ingredients. In addition, the potential for the emergence of novel food safety hazards and the risks posed by spore-forming microorganisms were recurring concerns. Overall, the workshop underscored the urgent need for information sharing among stakeholders to identify and address safety concerns in cultured meat production and for strategic public and private sector investments to facilitate the development of mitigation strategies, workforce training, and large-scale sourcing of ingredients.

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INTRODUCTION

Cellular agriculture, broadly defined as "the production of meat, milk, eggs, seafood, and other products and ingredients, from cell cultures rather than from farmed animals" *(23)*, is an emerging sector of the food system. Meat production through cellular agriculture begins with animal cells that are grown in controlled environments using cell culture techniques, then processed to replicate the physical and sensory properties of conventional meat *(3)*. These products are referred to by several terms, including cultivated meat, cultured meat, cellular meat, cell-based meat, clean meat, and in vitro meat *(23)*. From 2015 to 2023, capital investments in cultivated meat and seafood in the United States totaled $3.1 billion *(32)*, and the sector has seen initial product entry into the market and companies aiming to scale up production *(15, 37)*. To date, studies have emphasized the potential benefits of cellular agriculture, including cultivated meat, in reducing agricultural land use and greenhouse gas emissions while improving food security, production, and safety *(4, 21, 24, 28, 34)*. While it is still too early to draw general conclusions about the overall nutritional benefits of cultured meat compared to traditional meat *(2, 8)*, researchers have developed cultured meat cell lines with increased nutritional benefits *(35)*.

The management of food safety risks within cultured meat production requires further study. For example, safety hazards such as *Campylobacter*, *Salmonella sore* serovars, and *Escherichia coli* O157:H7, persistent risks from fecal contamination in food production systems involving live animals, should be mitigated by cultivated meat production methods *(29)*. However, food safety risks arising from cellular agriculture's novel production methods and manufacturing processes, as well as the specifics of implementing and enforcing food safety practices, standards, and monitoring, require further investigation *(5, 23, 24, 34)* and merit global discussion and action *(6)*. During a 2022 workshop with international food systems experts convened at Purdue University, Indiana, USA, to define the strategic landscape of opportunities, threats, and research priorities for cellular agriculture, participants identified food safety as one of the key drivers for the development of cellular agriculture, second only to climate and sustainability *(30)*. In the United States, the Food and Drug Administration (FDA)and the Department of Agriculture's Food Safety and Inspection Service (FSIS) established a framework for regulatory oversight of cultured meat in 2019. Currently, the FDA has regulatory responsibility for cultured meat processing until cells are harvested from a bioreactor, and FSIS assumes regulatory responsibility from the point of harvest through all post-harvest steps *(7)*.

To proactively identify food safety concerns for the cultured meat sector and develop recommendations for public, private, and government actions and investments, a roadmapping workshop was held in July 2023. Roadmapping is a strategic planning technique widely used by organizations to address complex problems *(12)*. It uses visual representations to align overarching goals and develop priorities for their implementation *(26)*. The specific objectives of the workshop were to discuss priorities for food safety in cultured meat production and outline corresponding short- and long-term research, technology, and policy opportunities for cultured meats. This manuscript presents an analysis of the discussions, highlighting key risks and needs as well as strategic activities to support food safety in cultured meat.

MATERIALS AND METHODS

Workshop overview

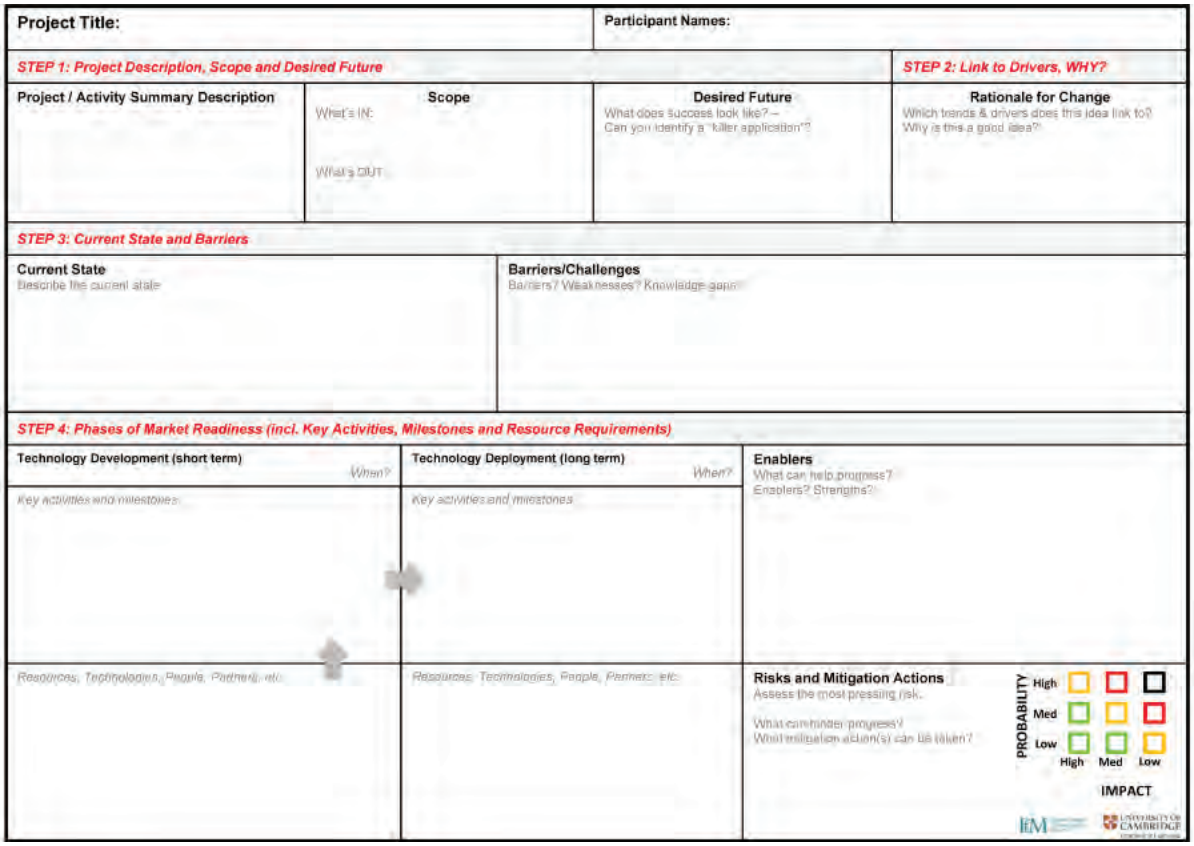
Based on the findings from previous workshops and published literature *(5, 23, 24, 34)*, five key themes were identified for discussion in the cultured meat food safety roadmapping workshop: 1) biological hazards and associated disease; 2) chemical hazards and allergens; 3) safety of media, scaffolds, and other inputs; 4) risk communication; and 5) sanitation/Sanitation Standard Operating Procedures (SSOPs)/equipment design. Food safety experts at the 2023 International Association for Food Protection (IAFP) Annual Meeting in Toronto, Canada, were invited to participate in this workshop. These experts, drawn from the private sector, academia, and regulatory agencies, were selected for either their expertise in the cultured meat industry or their expertise in the workshop themes. The 23 participants were divided into groups to discuss one of the five themes; two groups focused on the theme "biological hazards and associated diseases" due to the perceived importance of this topic, for a total of six groups. Each group discussed their theme using a common template designed to link insights to commercial and research outcomes *(Supplementary Fig. 1)* *(11, 12)*. The workshop's goals were to create topic-level roadmaps for the review and discussion of food safety priorities for cultured meat and to outline corresponding action items.

Brainstorming sessions and guided discussions

The workshop began with a 30-minute introduction to food safety in cellular agriculture as well as the format and purpose of the roadmapping process. Participants then self-sorted into the topic group that aligned with their expertise. In each group, three to four individuals representing various backgrounds (e.g., industry, academia, government regulators, nonprofit work) progressed through the

[1]In this manuscript, the use of the term "meat" refers generally to the cell biomass derived from cultured animal cells (e.g., livestock, poultry, and seafood) for use as human food, unless otherwise specified.

Supplementary Figure 1



roadmapping discussion template *(Supplementary Fig. 1)* over two hours. The template guided participants through the four steps in the roadmapping process: 1) project description, scope, and desired future; 2) link to drivers and rationale for change; 3) current state and barriers; and 4) phases of market readiness, including key activities, milestones, and resource requirements. The template also provided opportunities for participants to identify needs for short-term and long-term technology development and enablers, risks, and mitigation actions for food safety in cultured meat production. Participants used 3 x 3 in. sticky notes on 3 x 4 ft. posters to capture their thoughts relevant to each section of the discussion template. After the group discussion, an additional hour was allotted for the participants to provide feedback on the workshop process.

After the workshop, all participants were invited by email to contribute additional input on their specific topic by providing written responses to guided questions from the roadmap template. The follow-up forms allowed participants to elaborate on or clarify the ideas shared during the session. These first-person responses are provided in *Supplementary Information 1–4*.

Exploration of key topics and analysis

The workshop results were analyzed using a method for focus group-based work *(33)*. Themes were established by reviewing each response from each poster, identifying themes that were consistently present across the six discussion groups, and categorizing all responses by thematic area *(Tables 1–4)*. Data was extracted by determining both the 'frequency' (how many groups discussed a theme) and 'total mentions' (how many times a theme was recorded on a sticky note) for each theme. The data were analyzed to identify the most frequent themes across all groups, the themes with the highest total mentions, and themes that ranked high in both categories.

RESULTS AND DISCUSSION

Trends, drivers, and food safety themes in cultured meat

General responses from the group posters are summarized in *Table 1* and plotted in *Figure 1*. Across all groups and discussion topics, a total of 187 responses (i.e., a single idea on a sticky note) were recorded. Fifteen themes were identified, with total mentions per theme ranging from four to 27. Three themes were raised in at least five of the six groups and had at least 15 total mentions.

TABLE 1. Themes identified across all groups and sections

Theme[a]	Frequency[b]	Total mentions[c]	Examples from group discussions	Examples from follow-up responses in Supplementary Information 1–4
Cooperation between many different parties and stakeholders will be necessary to ensure a safe product reaches the market.	6	27	"Race for funding prohibits industry cooperation" (Group 1) "Strong government support for national policy, including material sourcing for cell ag" (Group 5) "Cultured food association to develop risk comms materials in conjunction with academia and government" (Group 6)	"Research from academic and research institutes is crucial for short-term goals as it provides the industry with valuable insights, scientific advancements, and technological breakthroughs. Collaborating with these institutions facilitates access to cutting-edge knowledge, enabling the industry to stay at the forefront of innovation. Academic partnership accelerates research and development efforts, addressing critical challenges and fostering a knowledge-sharing ecosystem." *(Supplementary Information 3)* "There firstly needs to be more on-going communications between the industry, regulators and consumer groups" *(Supplementary Information 4)*
The development of clear safety standards and specifications for both inputs and the end product are needed.	5	24	"Articulate risk assessment framework that is realistic and pragmatic" (Group 3) "Chemical specifications (codex, etc.) for cell culture input ingredients, scaffold composition" (Group 4) "Food grade standards need to be developed (endotoxin) (purity) (source (salt, GF))" (Group 5)	"The desired future for the cultured meat industry we discussed envisions a complete narrative, spanning from the sourcing of cell lines to the finished products in the shelves. Achieving this requires the generation of robust public evidence to support the development of standardized risk assessment frameworks applicable to diverse processes and products within the industry." *(Supplementary Information 3)*
The possibility of novel food safety hazards in the process of cultured meat production needs to be investigated.	5	15	"Pre-emptively evaluate emerging/new hazards in cultured ag" (Group 3) "Inputs/growth media may be more difficult to remove than in traditional ag systems" (Group 4) "New concerns could be introduced – how to communicate this? Neutral party needed" (Group 6)	"Novel technologies and processes could pose some hazards but until they are measured or become predictable a risk assessment is not possible. Speculation is a valuable exercise but not a replacement for a risk assessment." *(Supplementary Information 2)*

Continued on the next page.

TABLE 1. Themes identified across all groups and sections (cont.)

Theme[a]	Frequency[b]	Total mentions[c]	Examples from group discussions	Examples from follow-up responses in Supplementary Information 1–4
Public information availability is necessary to support research into safe product development and public trust.	5	12	"Disjointed, opaque, many players without info sharing, companies are using pharma grade" (Group 5) "Standardized info sharing from supply chain to consumer" (Group 6)	"Private and public funding for open research is instrumental in advancing scientific understanding, developing new technologies, and overcoming hurdles. Access to data and evidence encourages innovation while allowing for evidence-based assessments of processes and products, which also increases consumer confidence." *(Supplementary Information 3)*
Cooperation with regulatory bodies is needed to develop a more clear and concise regulatory policy for cultured meat.	5	11	"Government partnership (USDA, FDA, EFSA, Singapore Food Agency, MHLW, FSANZ, Israel MLH)" (Group 5) "No official government materials in the USA or Canada" (Group 6)	"More discussion is needed at the global level (FAO/WHO, Codex) on trying to get a regulatory consensus on the global regulation of novel cell ag products. Governments need to find new ways to support the cellular agriculture field and help position their country as a potential future hub for the field. This includes investing in infrastructure to support scaling up innovation and work with regulatory bodies to ensure that the country's regulatory landscape will help products, including cultured foods, come to market." *(Supplementary Information 4)*
A talent pipeline must be developed to meet the needs of a prospective cellular agriculture industry.	5	10	"Talent pipeline for cellular agriculture CIP [Clean-in-Place]" (Group 1) "Regulatory authorities' talent pipeline with diverse background not to support industry" (Group 3) "Training for cell culture industry on chemical hazards and allergens-probably directed mostly to inputs and scaffolds" (Group 4)	"The regulatory authorities' talent pipeline, characterized by individuals with diverse backgrounds, is crucial to ensure a comprehensive understanding of the challenges associated with cultured meat production." *(Supplementary Information 3)*
Proprietary information maintenance greatly impedes the development of a safe product.	5	9	"Intellectual property maintenance/'hoarding' of safety info (Note: not a problem in traditional animal agriculture)" (Group 1) "Lack of evidence-based public info. Current info is proprietary" (Group 3)	"The business that can most closely replicate the end product will be highly successful and as such the processes to get to that result are tightly held secrets. This incentivization of proprietary information maintenance is not a situation conducive to relying on corporate goodwill to provide answers to the basic safety questions that are at hand." *(Supplementary Information 1)*

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TABLE 1. Themes identified across all groups and sections (cont.)

Theme[a]	Frequency[b]	Total mentions[c]	Examples from group discussions	Examples from follow-up responses in Supplementary Information 1–4
The quality of cultured meat must be competitive with conventional meat quality for the industry to succeed.	5	5	"Sensory–if your ingredients are all safe but produce a bad product, it doesn't matter" (Group 5) "Good taste and a variety of products" (Group 6)	"Comprehensive focus groups would have been done on the consumers' preferences for labelling, as well as on taste and texture." *(Supplementary Information 4)*
Safe equipment design is vital to ensure a safe and efficient cultured meat process.	4	16	"Cross-functional engineering/ microbiology" (Group 1) "Lack of bespoke hygienic equipment and facility design" (Group 2) "Research to design equipment to be sanitized easily to better control hazards" (Group 3)	"Novel equipment may perform in unexpected ways and with each company designing their own equipment, it complicates the development and adoption of industry-wide safety standards." *(Supplementary Information 2)*
A commercial pipeline from input and ingredient suppliers to an end product needs to be developed.	4	6	"Develop commercial pipeline for suitable inputs at appropriate volumes" (Group 4) "Globally available, affordable materials, supply chain (safe as well)" (Group 5)	"Sanitation SOPs, Validation Studies, Environmental Monitoring protocols, use cases, and lessons learned amidst pilot scale-ups can support maturation of the field. The transition from bespoke tools and systems to a commercialized equipment and management programs will help tremendously with industry maturation as will the development and stabilization of cost-effective supply chains." *(Supplementary Information 2)*
The possible environmental benefits of cultured meat should be addressed while discussing the product.	4	5	"Pivot from animal agriculture for carbon footprint" (Group 2) "Alleviate supply chain constraints and build climate crisis resilience to address sustainable food systems" (Group 3)	"The future would be one where all the benefits of cultured foods would be very well researched and analyzed and a direct comparison to traditional foods would be made." *(Supplementary Information 4)*
A single food safety issue related to cultured meat could hurt consumer confidence industry wide.	4	4	"A majority safety issue becomes public (e.g., someone gets sick from a commercial product)" (Group 5) "Foodborne illness outbreak" (Group 6)	"Unfortunately, there are many potential risks moving forward. For example, one large foodborne outbreak with a cultured food, that occurs with an unusual or unknown bacteria, could lead to naysayers having a field day." *(Supplementary Information 4)*

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TABLE 1. Themes identified across all groups and sections (cont.)

Theme[a]	Frequency[b]	Total mentions[c]	Examples from group discussions	Examples from follow-up responses in Supplementary Information 1–4
An effective strategy for communicating with the public about cultured meat safety will be necessary for gaining public confidence.	3	21	"Good communication with consumers" (Group 5) "Foodborne illness outbreak" (Group 6) "Hotline and public information on responses that are easily accessed by the public" (Group 6)	"Concern about product safety was the most likely reason to make respondents unwilling to try cultured meat, and currently there is a lack of food safety information out there for consumers. Combating misinformation and groups who are against everything is another barrier to address. The trouble is that there is not enough really good information out there for risk comms people to put together reliable information for the public." *(Supplementary Information 4)*
Cultured meat should strive to be as safe or safer than conventional meat.	3	12	"Equal to or greater than conventional meat in all respects" (Group 2) "Safer/better than original meat" (Group 4)	"Animal-based meat creates a high microbial load up front. Tissue culture is only possible in aseptic controlled environments. In a sense, the aseptic environment is just an alternative pre-harvest control. In cattle for example, probiotics and vaccinations exist as pre-harvest interventions. Those interventions underwent safety assessments just as is being done for tissue cultivation." *(Supplementary Information 2)*
Anti-cultured meat groups could pose a threat to effective public communication about the safety of cultured meat.	3	6	"Organizations that could be anti-cultured meat" (Group 5) "Anti cultured meat activities (e.g., Alabama, South Dakota, Missouri)" (Group 6)	"More countries may decide to ban certain cell ag products. As usual, getting positive food influencers on your side is critical. The social media war can be brutal. Getting out ahead of all the misinformation and 'hate' out there is paramount." *(Supplementary Information 4)*

[a]Themes were determined by analyzing all responses from each group and identifying concepts documented in at least three groups.

[b]Frequency refers to the number of groups in which a theme was mentioned.

[c]Total mentions refers to the number of total mentions of a theme across all groups, individually tallying all mentions across the sections of the discussion template. The relationship between the frequency of a theme's mentions across all groups and the total mentions of that theme is illustrated in *Figure 1*.

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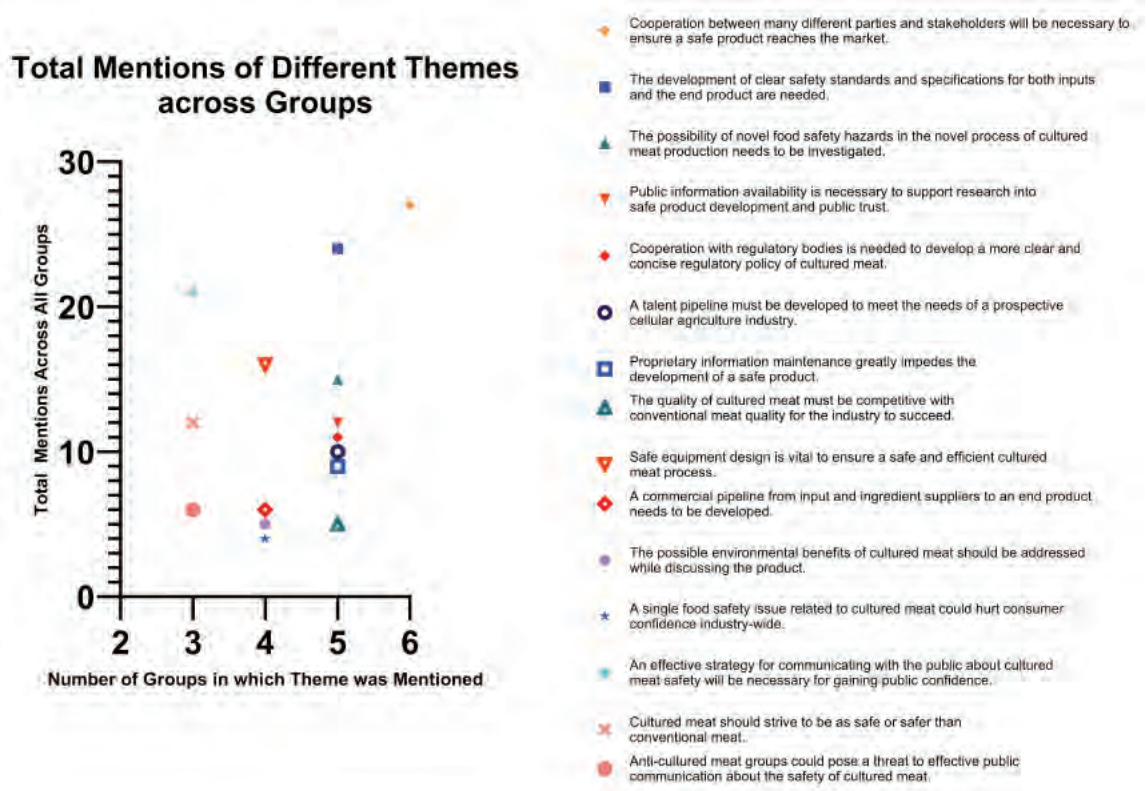


Figure 1. Based on the data presented in *Table 1*, this figure illustrates the variance between topics mentioned across all groups and topics with the highest total mentions.

The most frequent theme was "Cooperation between many different parties and stakeholders will be necessary to ensure a safe product reaches the market" (six groups, 27 mentions). Participants noted the paradox of cooperation in an emerging, competitive industry and the potential benefits to food safety of greater cooperation among government, academia, and the private sector.

The second-ranked theme was "The development of clear safety standards and specifications for both inputs and the end product are needed" (five groups, 24 mentions). Concerns included risk assessment frameworks, specifications for ingredients and scaffold composition, and food grade standards.

The third-ranked theme was "The possibility of novel food safety hazards in the process of cultured meat production needs to be investigated" (five groups, 15 mentions). These potential hazards included bacterial contamination, buildup of chemical inputs involved in cell growth in the final product, and unforeseen sanitation challenges.

The remaining themes addressed issues including the potential for proprietary information to hinder safety research; the need for a talent pipeline, regulatory clarity, and public information on product safety; and potential threats to consumer confidence in cultured meat.

Potential barriers to the advancement of cultured meat production

Four major food safety-related barriers were identified during the workshop:

1) the impact of proprietary information on limiting collaboration on food safety research;
2) the safety and sanitation challenges posed by spore-forming microorganisms;
3) the concern that a lack of publicly-available safety information could decrease consumer confidence in cultured meats; and
4) the need for defined safety standards and specifications *(Table 2)*.

All six groups raised concerns that restrictive proprietary information about practices affecting product formulation, processing, and equipment will slow the development of best practices for food safety. Half of the groups noted

TABLE 2. Themes identified for the category "Current state, Challenges/Barriers, and Desired Futures"

Category	Theme[a]	Frequency[b]	Total mentions[c]	Examples
Current state	Increased focus on development of a safe process is necessary.	3/6	3	"No cleaning SSOPs for upstream" (Group 2) "Start-up companies putting product development over food safety" (Group 3)
	Proprietary information maintenance is slowing safety development.	3/6	3	"Research publications and info proprietary to companies in cell ag" (Group 2) "Disjointed, opaque, many players without info sharing, companies are using pharma grade" (Group 5)
	There is confusion over what government regulation may look like.	3/6	3	"Assessments are case by case" (Group 3) "No official government materials in the USA or Canada (Group 6)
Barriers and challenges	Proprietary information maintenance prevents cooperation on safety research.	5/6	6	"Intellectual property maintenance/'hoarding' of safety info (Note: not a problem in traditional animal agriculture)" (Group 1) "Proprietary nature of filings and applications containing FS plans" (Group 2)
	Spore-forming microorganisms pose a safety/sanitation challenge.	3/6	3	"Spore formers (*B. cereus, C. perfringens*)" (Group 1) "Finish product specifications are safe (*C. bot* an issue)" (Group 3)
	A lack of publicly available safety information may decrease confidence in the safety of the end product.	4/6	4	"Lack of publicly visible hazard analysis, lack of history" (Group 2) "Lack of evidence-based public info. Current info is proprietary" (Group 3)
	There is a current lack of defined safety standards and specifications.	3/6	5	"No 'Appendix A' for cell ag products, need for validation studies" (Group 2) "Food grade standards need to be developed (endotoxin) (purity) (source [salt, GF])" (Group 5)
Desired future and rationale for change	The end product needs to be competitive with conventional meat.	3/6	7	"Mirror traditional food supply chain and service availability" (Group 1) "Equal to or greater than conventional meat in all respects" (Group 2)

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TABLE 2. Themes identified for the category "Current State, Challenges/Barriers, and Desired Futures" (cont.)

Category	Theme[a]	Frequency[b]	Total mentions[c]	Examples
Desired future and rationale for change	The end product should be environmentally friendly.	3/6	4	"Alleviate supply chain constraints and build climate crisis resilience to address sustainable food systems" (Group 3) "Connect to improved outcomes/climate change" (Group 6)
	Standardized safety recommendations and expectations should be available.	3/6	3	"Generate evidence to support development of standardized risk assessment framework for diverse process/products" (Group 3) "Material safety evaluation, framework (fast), particularly growth factors/FBS/BSA" (Group 5) "Material safety evaluation, framework (fast), particularly growth factors/FBS/BSA" (Group 5)

[a]Themes were determined by analyzing all responses from each group and identifying concepts documented in at least three groups.

[b]Frequency refers to the number of groups in which a theme was mentioned.

[c]Total mentions refers to the number of total mentions of a theme across all groups.

challenges related to the maintenance of proprietary information in current safety discussions, and five out of six groups expressed concerns that the maintenance of proprietary information will continue to create barriers and challenges in developing safe meat products through cellular agriculture. The need for transparency and information sharing has been recognized as a challenge for the regulation and commercialization of cellular agriculture in previous workshops, further emphasizing its significance as a barrier for the sector *(9, 24, 34)*.

Spore-forming microorganisms were identified as a specific safety risk in half of the groups. *Bacillus* spp. are recognized as common contaminants in cell culture media and/or ingredients, particularly animal-derived serum *(10, 17)*, and both *Bacillus* spp. and *Clostridium* spp. present challenges in sanitation due to their spore-forming ability *(14, 38)*. The safety concern derives in part from uncertainties about the hygienic performance of custom-made equipment designed and used by individual companies, complicating the development and adoption of industry-wide safety standards. Additionally, half of the groups discussed the need for regulatory and industry standards under the category 'desired future' (i.e., what does success look like?). Given the prevalence of standards in conventional meat production *(13)* and consumer skepticism about product safety as a major barrier to acceptance *(1, 25, 39)*, it is logical for the cultured meat sector to also prioritize standards and specifications. However, the significant knowledge gaps in cultured meat production methods and potential hazards will need to be addressed.

In conventional meat production, standards and specifications are in place for every stage of production, and cover equipment design, ingredient addition, sanitizer usage, process controls, quality standards for end products, critical limits for hazards, and labeling. These regulations are well-established and are based on a long history of harvesting and processing conventional meat *(22)*. Consequently, the 'desired future' for cultured meat articulated by workshop participants included a similar framework of standards and specifications, from the sourcing of cell lines to the finished products on the shelves. Achieving this will require robust published evidence to support standardized risk assessment frameworks applicable to diverse processes and products within the industry *(Supplementary Information 3)*. Given the depth of knowledge necessary for comprehensive safety evaluations, significant publicly available data will be necessary to achieve this goal.

Four out of six groups highlighted how the lack of publicly available safety information on cultured food could lower consumer confidence. In addition, multiple groups discussed the potential for anti-cultured meat activism or a safety-related incident that erodes public trust. A lack of evidence-

based information for consumer education on the safety of cultured meat products was noted as a potential contributor to consumers' wariness of cultured meat *(Supplementary Information 4)*. Therefore, there was broad agreement on the necessity of developing food safety communications, ensuring their accuracy and efficacy, and disseminating them effectively through public participatory forums, in partnership with consumer interest groups to build trust, to promote transparency and apply lessons learned from the biotechnology sector two decades ago *(16)*.

Short-and long-term resources and activities

Participants identified priority resources and activities to support the scaling up of the industry *(Table 3)*. Notably, there was a consensus on the need to develop a talent and employment pipeline in the short term (discussed in five out of six groups) and to establish a commercial pipeline for large-scale sourcing of inputs and ingredients (discussed in three out of six groups). These objectives underscore key educational and supply chain needs to support the expansion of the cultured meat industry. In addition, half of the groups highlighted the need for collaboration with health and safety organizations and regulatory agencies as short-term needs. Half of the groups also identified information sharing among stakeholders and collaboration with government bodies as crucial for long-term success. Establishing a talent pipeline *(36)* and addressing the commercial needs of scaling up production *(27)* are widely acknowledged as significant challenges for the cultured meat industry. Information sharing and reporting on common issues such as safety, environmental concerns, and animal welfare are already integral to conventional meat production *(19, 20)*. Therefore, in both the short and long term, fostering collaboration among different groups, including regulators, government entities, academia, industry, and non-profits, emerged as a recurring theme.

Enablers and potential risks

The discussion sessions on enablers and potential risks/mitigation strategies also highlighted the importance of cooperation between stakeholders as well as the significance of consumer messaging and ensuring consumer confidence *(Table 4)*. Emphasis on cooperation between stakeholders (academia, regulatory, and industry) was highlighted by five out of the six groups as a primary way to ensure safety in cultured meat production. In this section of the roadmapping exercise, the focus on cooperation was more open-ended than in previous sections, with a greater emphasis on the general need for cooperation to proactively ensure the safety of products reaching the market.

Enablers for and risks in ensuring consumer confidence were another notable discussion point. In the enablers category, four out of six groups discussed consumer messaging strategies or the importance of building consumer trust in the safety of cultured meat. Furthermore, in the risks sections, five out of six groups discussed how a food safety issue from any part of the cellular agriculture sector could significantly reduce consumer confidence in the entire sector. Such scenarios mirror a problem that has been seen before in the meat industry, as illustrated by the 1993 Jack in the Box *E. coli* outbreak that sickened over 700 people in four states and led to four deaths *(31)*. The significant consumer backlash from this event led to the implementation of mandatory hazard analysis and critical control points (HACCP) practices for conventional meat processors and the acceptance of government safety inspections as integral to meat safety *(18)*. In addition, workshop attendees highlighted the potential for consumer resistance due to the novelty of cultured meat production methods, drawing parallels to the skepticism surrounding genetic engineering. Ultimately, the success of the cultured meat sector will require effective marketing to consumers about the safety of products which relies, in part, on the establishment of food safety standards and specifications.

Limitations of the analysis

It should be noted that the system used to document the discussions created inherent limitations in analyzing the response frequencies and total mentions across groups. The recording of discussion points on sticky notes was a disadvantage because the limited space for written comments could lead to ambiguity in meaning. Furthermore, the depth of discussion surrounding each recorded mention/comment was not captured unless the group provided supplemental written responses to further explain their thought processes and important points for discussion *(Supplementary Information 1–4)*. In addition, some topics, though deemed worthy of discussion by groups, may have been outside of a group's focus, limiting discussion and resulting in fewer total mentions. For example, the theme "the quality of cultured meat must rival that of conventional meat" was raised in five of six groups but was only mentioned once per group. While this could be interpreted as evidence that quality is less significant compared to other issues, it more likely reflects a limited depth of discussion on quality issues, given the workshop's overall focus on food safety.

Conversely, the theme "cooperation between various parties and stakeholders for product safety" was extensively discussed. This theme encompassed industry-industry, industry-government, industry-academia, and government-academia cooperation, as well as non-profit support. Because this theme broadly addressed the need for collaboration among stakeholders, it was discussed more frequently and was relevant across group discussions of biological hazards, chemical hazards, safety of inputs, risk communication, and sanitation. While analyzing the frequency and total mentions of themes is useful, it is important to interpret the data in light of the focus and depth of each group's discussion.

TABLE 3. Themes identified for the category "Short and Long-Term Resources/Activities"

Category	Theme[a]	Frequency[b]	Total mentions[c]	Examples
Short-term resources and activities	A talent pipeline for the cellular agriculture industry needs to be developed.	5/6	5	"Regulatory authorities' talent pipeline with diverse background not to support industry" (Group 3) "Training risk communicators, PR firms, etc." (Group 6)
	Collaboration with health and safety organizations will benefit the cellular agriculture industry.	3/6	4	"FAO, WHO, CFSA, expert working groups" (Group 2) "FAO, WHO, Codex" (Group 5)
	Focus needs to be made on designing cellular agriculture equipment with safety in mind.	3/6	4	"Validation studies of sanitation and cooking" (Group 2) "Research to design equipment to be sanitized easily to better control hazards" (Group 3)
	Safety standards/expectations for ingredients and process need to be codified.	3/6	5	"Articulate risk assessment framework that is realistic and pragmatic" (Group 3) "Chemical specifications (Codex, etc.) for cell culture input ingredients, scaffold composition" (Group 4) "Which components are novel and which can rely on traditional frameworks?" (Group 5)
	Initial collaboration with regulators is necessary.	3/6	3	"Early engagement with regulatory authorities" (Group 3) "Government partnership (USDA, FDA, EFSA, Singapore Food Agency, MHLW, FSANZ, Israel MLH)" (Group 5)
Long-term resources and activities	The public proliferation of safety information in the cellular agriculture industry will encourage the development of safe products.	3/6	3	"Funding public/private to support open research" (Group 3) "Standardized info sharing from supply chain to consumer" (Group 6)
	Collaboration and cooperation with government bodies is necessary for the industry.	3/6	3	"Strong government support for national policy, including material sourcing for cell ag" (Group 5) "Government subsidy/research grants" (Group 6)
	A commercial pipeline for inputs and ingredients is necessary for the development of the industry.	3/6	5	"Develop commercial pipeline for suitable inputs at appropriate volumes" (Group 4) "Engage in supply chain stakeholders to increase sourcing" (Group 5)

[a]Themes were determined by analyzing all responses from each group and identifying concepts documented in at least three groups.
[b]Frequency refers to the number of groups in which a theme was mentioned.
[c]Total mentions refers to the number of total mentions of a theme across all groups.

TABLE 4. Enablers and potential risks for food safety in cellular agriculture identified in discussion groups

Category	Theme[a]	Frequency[b]	Total mentions[c]	Examples
Enablers	Cooperation between stakeholders is necessary to develop safe products.	5/6	8	"Leaders, founders, stakeholders, and advocates taking proactive steps" (Group 2) "Consensus and prioritizing of needs amongst multiple stakeholders" (Group 5) "Collaboration on pre-competitive issues (e.g., bulk sourcing, definition, and safety assessment)" (Group 5)
	Messaging on the safety and the benefits of cultured meat will be important in generating consumer confidence.	4/6	6	"Better for the planet than live cows, etc." (Group 4) "Good communication with consumers" (Group 5) "Early and consistent messaging based on valid/trusted research" (Group 6)
Potential risks	A public safety issue from any part of the cellular agriculture industry could greatly hurt consumer confidence in the industry as a whole.	5/6	5	"High probability of complications" (Group 2) "A major safety issue becomes public (e.g., someone gets sick from a commercial product)" (Group 5) "Foodborne illness outbreak" (Group 6)

[a]Themes were determined by analyzing all responses from each group and identifying concepts documented in at least three groups.
[b]Frequency refers to the number of groups in which a theme was mentioned.
[c]Total mentions refers to the number of total mentions of a theme across all groups.

The method was sufficient for identifying top priorities for private or public sector investment, but it was less suited for quantitative analysis of the relative importance of other topics.

In addition, the discussion structure and time limitations may have prevented participants from identifying specific hazards and barriers in cultured meat production. For example, in the *Supplementary Information*, in which individuals were provided an opportunity to expand on their discussions after the workshop, specific topics such as the risk posed by biofilms, specific potential foodborne pathogens such as mycoplasmas, labeling requirements for allergens, and the uncertainty about the economics of scaling up production were mentioned. This suggests that, as noted above, the method was sufficient for identifying top priorities but did not capture all important specific risks and challenges facing the cultured meat sector.

CONCLUSIONS

The roadmapping exercise identified several actionable areas for advancing food safety in cultured meat. Cooperation among private, public, and government sectors, the development of clear safety standards and specifications, and the risk of novel food safety hazards were among the top concerns. Current barriers include the lack of defined safety standards and the risk of contamination by spore-forming microorganisms. In addition, participants highlighted the challenges posed by proprietary information in the sector and providing safety information for consumers.

Short-term priorities included developing educational and commercial pipelines to ensure sufficient workforce expertise and large-scale sourcing of inputs and ingredients. The discussion sessions on enablers and potential risks/mitigation strategies highlighted the importance of cooperation between stakeholders as well as the vital need for messaging to foster consumer confidence in cultured products. Based on these discussions, key opportunities include:

1) the creation of mechanisms to foster collaboration among public, private, and government actors to facilitate further discussion of food safety risks and the development of food safety standards;

2) the development of curricula and training programs for the cellular agriculture workforce;
3) commercial investment into ingredient supply chains; and
4) targeted research studies to understand the potential risks posed by spore-forming microorganisms and novel production methods and to develop effective consumer communication strategies.

Roadmapping workshops are a valuable method for translating expertise into actionable priorities. Future food safety roadmapping workshops for cultured meat production could include physical hazards, which were outside the scope of this workshop, as well as specific microorganisms of concern. In addition, workshops using online or hybrid formats could draw on a larger pool of expertise to support food safety in the cultivated meat sector.

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SUPPLEMENTARY INFORMATION 1

Group 1 Follow-Up Response: Sanitation/Sanitation Standard Operating Procedures (SSOPs)/Equipment Design

Describe how you decided what was in vs. out of scope.

While bioreactor design may vary, there are certainly critical hygienic components that should be considered in any system. SSOPs must address the treatment and disposal of bioreactor waste products. Proper management of waste streams is essential in cellular agriculture to prevent cross-contamination by maintaining overall hygienic conditions. Though we recognize there may exist critical external facility considerations when selecting or building a facility, these considerations would be out of scope.

Describe desired future and rationale for change or outcome, current state, challenges and barriers to desired future.

The cellular agriculture industry is young, and the equipment and processes have been adopted piecemeal from other industries including brewing, pharmaceuticals, aseptic food processing and experimental tissue culturing. Since most of the equipment is repurposed and not originally designed specifically for cellular agriculture some essential pieces of equipment were not designed with sanitation processes in mind. The result is a long development period needed; plan for 1–1.5 years after conceptualization of new equipment before sanitation procedures a validated and incorporated into the HACCP plan. Much like the origins of cellular agriculture equipment, sanitation processes are borrowed from a smattering of contexts. CIP, OPC protocols that are the same in a USDA-regulated facility's HACCP plan. In fact, the entirety of the processes downstream of the bioreactor will mirror meat processing hazard controls. It is the bioreactor and other upstream processing steps that present the most pertinent novel food safety challenges. Traditional animal agriculture critical controls will be supplemented; for example, removable pieces of processing equipment that would go through a dishwasher in traditional protein processing facilities may additionally require sterilization.

Single-use sterile consumables are convenient and reduce risk. They are also widely available because they're essential in health care. There is a limit to the value added through the reduction of contamination risk, including from a purely financial perspective. At scale, there will be contamination, and losses can be mitigated more reliably through process compartmentalization and the maintenance of hygienic conditions. The genesis of this industry is rooted in a vision for a sustainable future so the waste inherent to sterile disposable bioreactors and their components may make them a sustainability non-starter at scale.

Short- and Long-Term Opportunities and Enabling Environments

In the short term, the group discussed how to encourage the development of sanitation expertise and equipment made for the cellular agriculture industry. In terms of near-term resources subject matter expertise for cellular agriculture sanitation and the development of a talent pipeline specifically for people with expertise in cellular agriculture clean in place protocols was discussed. Ideally this expertise could greatly increase the efficiency at which new equipment could be designed and decrease the SSOP timeline development, which currently rests at between 12–18 months.

In the long term, our discussion primarily focused on what equipment developments would best support a more robust and thorough sanitation procedure. Any equipment that could automize sensory testing to determine where a sanitation problem may be beneficial. Whether that takes the form of a sensor that can detect persistent biofilm after a sanitation procedure or sensors that can detect CIP efficacy any further ability to detect any flaws in a sanitation system will make sanitation protocols more effective and efficient.

Enablers/Risks and Mitigation

Indeed, the risks associated with poor sanitation, and equipment or facility hygienic designs are due to the harborage of pathogens within biofilms that have been selected to withstand the sanitation processes as executed. Additional questions of significance remain unknown. Could an intracellular pathogen grow, undetected, within the mammalian protein tissue cells? That is, after all, what it does in living mammalian tissues which have the advantage of an intact immune system. The current answer to this question is not definitively negative, which seems like a question essential to the overall safety of cellular agriculture products made from mammalian cells. Similar questions, not as immediately related to sanitation and hygienic design, are posed in the risk group's section and many are similarly unanswered. Our panel echoes their call for an investigation to assess the potential risks that are novel to this industry.

Sanitation procedures are undeniably contingent on the types of equipment and the stages of the production process. The steps to produce a traditional protein product are widely known and best production processes and their associated optimal sanitation procedures are, as well. For example, the process of butchering a cow is not going to be shrouded in secrecy and as a

result experts in food safety can work together and declare food safety a non-competitive issue. Cellular agriculture is different. The business that can most closely replicate the end product will be highly successful and as such the processes to get to that result are tightly held secrets. This incentivization of proprietary information maintenance is not a situation conducive to relying on corporate goodwill to provide answers to the basic safety questions that are at hand.

SUPPLEMENTARY INFORMATION 2

Group 2 Follow-Up Response: Biological Hazards and Associated Disease

Describe how you decided what was in vs. out of scope.

Food Safety is an evidence-based science. Therefore, approaches to be considered "in-scope" ought to be those for which there is already established safety data or criteria. While there are novel processes and steps involved in the production of cultured foods, the exact circumstances under which these systems may be abused and the likelihood of them producing harm thereafter are unknown.

For example, *Mycoplasma* contamination could pose a hazard. This is known because there are some hospitalizations for *Mycoplasma* infections. However, the likelihood of *Mycoplasma* entering the food production line and persisting in the food until it reaches the consumer is poorly defined. There are multiple hurdles innate to the production environment that would need to be cleared before the hazard is realized as a risk. For this and many other potential hazards, monitoring is sufficient.

Out of scope are those hazards for which a hazard analysis is either negative or inconclusive. The hazard must be one which can be measured or observed with some accuracy. Novel technologies and processes could pose some hazards, but until they are measured or become predictable, a risk assessment is not possible. Speculation is a valuable exercise but not a replacement for a risk assessment.

Describe desired future and rationale for change or outcome, current state, challenges and barriers to desired future.

Rationale: The future desired is based on evidence for what may be controlled. In conventional meat production, live animals must bear in indoor and outdoor environments with varied weather and exposure to dirt and filth. As a result, animal-based meat creates a high microbial load up front. Tissue culture is only possible in aseptically controlled environments. In a sense, the aseptic environment is just an alternative pre-harvest control. In cattle for example, probiotics and vaccinations exist as pre-harvest interventions. Those interventions underwent safety assessments just as is being done for tissue cultivation. The evidence is clear that an aseptic environment for cultured meat will be controlled to a higher precision than the outdoor spaces for animal-based meat. Thus, it is a question of how much can be controlled without compromising the value of the meat produced.

Current state: Downstream processes are assumed to be equivalent to those in animal-based meat production. Upstream processes are not completely unfamiliar to U.S. regulators; tissue culture as a form of medicine is not new. Adapting safety procedures used in a medical/pharma context to that of a food production model is a bit precarious. Medicinal process controls and hazard analyses assume the consumer is highly vulnerable and that the product or treatment will be invasive. Food safety programs may include considerations for vulnerable individuals, but the assumption is that the food itself stays external while constituents are absorbed. So, some controls in medicine are not needed in food but which controls and the reasoning for their removal must be made clear, and evidence is needed to reach these conclusions. This is why it may be many years before guidelines are established.

Challenges/Barriers: Live animals have an adaptive immune system, tissue cultures do not. The fate of spore-formers in cultured meats is unknown, but they have the potential to be a persistent hazard in production environments because of their hardiness. Transparency is in increasing demand in food production but often the only way a company has to protect its intellectual property is through patenting of its processes. In doing so, many processes may not be visible to the public which will limit the number of individuals available to understand and counsel on the unique safety requirements cultured meat producers have. Complicating the matter further is that all the upstream equipment is guaranteed to be bespoke in design and highly expensive. Novel equipment may perform in unexpected ways, and with each company designing its own equipment, it complicates the development and adoption of industry-wide safety standards. (Broken record at this point but again and again. We need more evidence to lead implementation and practice.)

Short- and Long-Term Opportunities and Enabling Environments

The tools and technologies to get cultured meats on the same level as abattoirized meat post-harvest already exist. Sanitation SOPs, Validation Studies, Environmental Monitoring protocols, use cases, and lessons learned amidst pilot scale-ups can support maturation of the field. The transition from bespoke tools and systems to commercialized equipment and management programs will help tremendously with industry maturation as will the development and stabilization of cost-effective supply chains. Grants and scholarships can support industry-led efforts to enhance transparency in some cases. Roundtables, workshops, working groups, and research consortia can support these outcomes.

Enablers/Risks and Mitigation

There already are some public/private collaborations happening in industry. Government organizations are in some cases supporting programs that subsidize cultured meat companies and their suppliers. In addition, funding for research and professional development is available but there have been past critiques that these levels of funding were insufficient to cross the gap needed to transition from experiment to working pilot. The biggest existential threat to the cultured meat ecosystem is scale-up. No one has proven how to do that economically and some experts have suggested that it isn't possible. If scale up is possible and economical then there is the challenge of organizing the array of technologies available. Almost everything needed already exists and is used in a regulated space. Organizing and fitting the tools, people, resources, and programs to sustain these operations requires a highly organized and communicative management team.

SUPPLEMENTARY INFORMATION 3

Group 3 Follow-Up Response: Biological Hazards and Associated Disease (Origination to Finished Product)

Describe the desired future and rationale for change or outcome, current state, challenges and barriers to the desired future.

I think for the current state it is important to emphasize that current assessments are case by case due to the difference in processes startups are working on. Due to the pressure from venture capital funding, some startup companies in this sector could prioritize product development to reach commercialization over rigorous food safety measures. Although following pharma processes and practices can be helpful for the initial stages of manufacturing, such as cell proliferation, differentiation and harvest, they might cause difficulties translating their success to the intricacies of the food industry.

One of the biggest challenges the cultured meat sector faces is the complexity surrounding proprietary information. Accessing detailed data about the processes and composition of these products can hinder effective oversight.

From a biological hazard perspective, the dynamic nature of pathogen behavior, which may evolve over time, poses a risk that can be difficult to predict and address. Particularly, when scalability has not been achieved and might introduce a new dimension of hazards that is currently unknown. Additionally, introducing new food ingredients and innovative production processes brings forth the novelty of potential hazards that require further research. The absence of specific methods for inputs or the validation and adaptation of existing ones is required to ensure potential risks are mitigated.

The lack of evidence-based public information further complicates matters, as much of the existing data is proprietary, restricting transparency. Moreover, the lack of public participatory forums highlights the need for collaborative efforts.

The desired future for the cultured meat industry we discussed envisions a complete narrative, spanning from the sourcing of cell lines to the finished products in the shelves. Achieving this requires the generation of robust public evidence to support the development of standardized risk assessment frameworks applicable to diverse processes and products within the industry. By doing so, the sector could proactively address emerging or new hazards associated with cultured meat, fostering a precautionary approach to safety.

Short- and Long-Term Opportunities and Enabling Environments

The regulatory authorities' talent pipeline, characterized by individuals with diverse backgrounds, is crucial to ensure a comprehensive understanding of the challenges associated with cultured meat production.

Research from academic and research institutes is crucial for short-term goals as it provides the industry with valuable insights, scientific advancements, and technological breakthroughs. Collaborating with these institutions facilitates access to cutting-edge knowledge, enabling the industry to stay at the forefront of innovation. Academic partnership accelerates research and development efforts, addressing critical challenges and fostering a knowledge-sharing ecosystem. On the other

hand, private and public funding for open research is instrumental in advancing scientific understanding, developing new technologies, and overcoming hurdles. Access to data and evidence encourages innovation while allowing for evidence-based assessments of processes and products, which also increases consumer confidence.

Enablers/Risks and Mitigation

Enablers discussed included increased information from regulatory bodies and the development of industry standards. With the development of industry standards and information on what regulatory guidelines there would be, much more information on how to efficiently design a cultured meat process that produces a safe product. The development of industry regulations would optimally include feedback from industry partners and input from consumers as well. To this end, it would be best if regulatory bodies participated in any public forums regarding cultured meat approval.

Risks discussed included the linked issues of a lack of regulatory engagement, consumer skepticism, and a safety issue hurting consumer acceptance. These risks all revolve around being able to create a product that is safe and communicating that fact to consumers. Without regulatory guidance, a safe product may be more difficult to guarantee and, importantly, will make communicating product safety to the public more difficult. Likewise, any safety issue in any part of the industry could scare consumers about the industry as a whole. In effect, anything that could hurt consumer acceptance is certainly a risk that needs to be accounted for.

SUPPLEMENTARY INFORMATION 4

Group 6 Follow-Up Response: Risk Communication

Describe how you decided what was in vs. out of scope.

From what I remember, we looked at the obvious things first; so of course, food safety and doing a hazard analysis on each cultured food is going to be the first thing that regulators and the public look at. Labelling/terminology has been brought up consistently in the press and by regulators, so this was included. It is and will be a hot topic as to how these call-based foods are labelled, if at all. Also, how do we refer to these foods on the package label? Another item that has been discussed in the press is whether cultured meats, for example, can be labelled as kosher and/or halal, and therefore consumed by followers of the Jewish or Islamic faiths. I honestly cannot remember the issue with food fraud but, in my opinion, these same issues, for example, come up with traditional meats.

Package labelling and nomenclature were determined to be within scope as it will have a significant impact on consumer acceptance. There will likely be competing interests surrounding how these products are labeled, with "traditional" agriculture groups pushing to label cellular agriculture products as separate types of foods and cellular agriculture groups pushing to label their products as similarly to traditional products as possible. Similarly, food fraud was decided to be within scope as substitution or blending of traditional and cellular agriculture products for economic benefit may become a risk.

With regards to being out of scope, we wanted to stick specifically to cultured foods, as other novel technologies, such as precision fermentation, are becoming very popular, but are very different from cultured foods. Also, we do not want to delve into the functionality, as this was observed as being outside the scope of what is normally included when we discuss food safety issues, i.e., it is a general food science issue.

Describe the desired future and rationale for change or outcome, current state, challenges and barriers to the desired future.

Current State: The problem here is that industry is ahead of the government on the whole cell ag file. Very recently, government regulators have come up with policies on how they will approve cell ag, but not that many. As you are aware, now Italy has banned the production and sale of cultured meat, while also prohibiting the use of terms describing plant-based products as meat. This is going to be an issue for Europe, for sure, and could have spillover effects to other countries. Europeans are very anti-GMO, so maybe not surprising. There is some risk comms material out there, but not much. Consumers do have questions about cell ag, as they are starting to hear more about cultured meats, etc., but there is not much out there right now to answer their questions.

Challenges/Barriers: There are many challenges/barriers to overcome. Firstly, as we have seen in a short consumer survey in Canada, concern about product safety was the most likely reason to make respondents unwilling to try cultured meat, and currently there is a lack of food safety information out there for consumers. Combating misinformation and groups who are against everything is another barrier to address. The trouble is that there is not enough really good information out there for

risk communications people to put together reliable information for the public. They need to be told the benefits of bringing this technology to the fore; and why it makes sense to have these new types of foods available to those consumers willing and able to buy them. The fear of any new products, like GMO foods, must be adequately addressed.

Desired Future: The future would be one where all the benefits of cultured foods would be very well researched and analyzed and a direct comparison to traditional foods would be made. This would enable us to get ahead of anti-cultured groups and provide informed risk-based communications strategies for all cultured foods as well as potentially other cellular agriculture products. Also, comprehensive focus groups would have been done on the consumers' preferences for labelling, as well as on taste and texture.

Short- and Long-Term Opportunities and Enabling Environments

Resources (short term): There firstly needs to be more on-going communications between the industry, regulators and consumer groups. More resources need to be made available for the following: focus-group testing, risk comms training in cell ag; better and more consumer surveys conducted; better global approach to the regulations, including labelling.

Short-term resource determination focused on identifying existing resources for developing food safety communications, verifying accuracy and efficacy, and disseminating these materials to the public, or key stakeholders.

Partnering with food service trade groups, like the National Restaurant Association, will aid in ensuring that any materials developed for food handlers, such as resources on how to safely prepare cell ag-based foods or answer guest questions, are readily accessible by participating foodservice organizations. Similarly, partnering with traditional agricultural trade groups, like the Cattleman's Beef Association or National Pork Producers Council, will be critical to engaging traditional farmers and educating them of the changes and opportunities that may arise as the cell ag industry develops.

Resources (long term): Long-term funding to support the risk communication efforts of both government and industry. On-going risk communications efforts need to have a 3-to-5-year risk communications strategy developed that has been vetted by all affected parties. Also, as products come onto the marketplace, consumer surveys need to be consistent and ongoing. This needs to be done to gauge how the public is viewing and responding to these new products, e.g., do they see any benefits to them in their lives, is the pricing right, texture and taste, are they "green/sustainable" enough, etc.

The development of an easily accessible, non-technical website with food safety information relating to cell ag that is maintained by the government could help reduce the spread of misinformation by providing verified information to consumers. This website should be search engine optimized, similarly to how "foodsafety.gov" is the first link that appears when searching for "food safety."

Key Activities to Clear Gate (short term): There needs to be expert cell ag committees set up consisting of all the affected parties, with open meetings; regular updates to consumers on what is new and what they need to know in the cell ag space; specific courses set up for risk comms people explaining to them what the technology is and how it can be advantageous to many people;

As cellular agriculture technology continues to develop, it is critical that any identified risks be shared appropriately. Food handling guidelines should be developed by academia and regulatory partners targeted to both food service and consumer use. Such guidelines would be needed to help mitigate any novel food safety risks associated with cell ag and prevent cases of cell ag-linked illness.

Engaging the general public through focus groups, surveys, or other means will help determine common concerns, which may serve as a barrier to consumer acceptance and could potentially be exploited using misinformation.

Key Activities to Clear Gate (long term): There needs to be permanent expert cell ag committees set up consisting of all the affected parties, with open meetings. Training courses specific for risk comms people in the cell ag space need to be developed; this could consist of, e.g., a one-year certificate program in risk comms dealing specifically with how to roll out risk comms advice dealing with new cell ag technologies to the public. The fear factor for the public of trying out new technologies needs to be adequately addressed. More discussion is needed at the global level (FAO/WHO, Codex) on trying to get a regulatory consensus on the global regulation of novel cell ag products. Governments need to find new ways to support the cellular agriculture field and help position their country as a potential future hub for the field. This includes investing in infrastructure to support scaling up innovation and work with regulatory bodies to ensure that countries' regulatory landscape will help products, including cultured foods, come to market.

Resources should be developed to help ensure that the foodservice and retail industries of manufacturers' food safety practices will be necessary to get cell ag products to consumers. The majority of consumers will not purchase cell ag products directly from the manufacturers and instead will purchase through restaurants or grocery stores. The food safety and procurement teams for these restaurants and grocery stores will likely desire 3rd party audits verifying manufacturing practices. Additionally, these teams may need to be educated on how production practices differ from the traditional agriculture industry, what should be reviewed during first party audits, and how supplier approval programs may need to evolve.

Enablers/Risks and Mitigation

Enablers: One thing that I did not mention that we discussed was to use many "case studies" as a way of rolling out new technologies to the public. In particular, the experiences that many countries have had regarding why GM foods did or did not make in-roads in their respective countries, would be particularly poignant.

Risks and Mitigation Strategies: Unfortunately, there are many potential risks moving forward. For example, one large foodborne outbreak with a cultured food, that occurs with an unusual or unknown bacteria, could lead to naysayers having a field day. Proactive comms products need to be developed to handle any potential emerging issue. Also, more countries may decide to ban certain cell ag products. As usual, getting positive food influencers on your side is critical. The social media war can be brutal. Getting out ahead of all the misinformation and "hate" out there is paramount.

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