

Building a Science-Driven Safety Framework for Cultivated Meat

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Professor William Chen, the Michael Fam Chair Professor in Food Science and Technology at Nanyang Technological University (NTU), Singapore



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As the global food industry explores sustainable protein alternatives, cultivated meat is rapidly emerging as one of the most transformative innovations in food technology. Produced through advanced cell culture and bioprocessing techniques rather than traditional livestock farming, cultivated meat promises significant benefits in terms of sustainability, food security, and animal welfare. However, its novel production process also raises important questions around food safety, regulatory oversight, and long-term consumer exposure, prompting regulators and scientists worldwide to rethink conventional risk-assessment frameworks.

While several countries are beginning to develop regulatory pathways for these products, ensuring rigorous, science-based safety evaluation remains a critical priority. Traditional food safety systems, largely designed for conventional agricultural products, may not fully capture the complexities of cell-based foods, where production conditions, cell lines, growth media, and bioprocessing technologies all influence the final product.

In an exclusive interaction with NUFOODS Spectrum, Professor William Chen, the Michael Fam Chair Professor in Food Science and Technology at Nanyang Technological University (NTU), Singapore, and Director of the NTU Food Science & Technology Programme and the Singapore Agrifood Innovation Lab (SAIL), discusses the evolving scientific and regulatory landscape for cultivated meat. He highlights the potential of food-relevant New Approach Methodologies (NAMs), AI-driven predictive toxicology, and systems biology to strengthen risk assessment frameworks while supporting innovation and global regulatory harmonisation.

Cultivated meat challenges decades of conventional food safety doctrine. Are existing risk assessment frameworks fundamentally fit for purpose or do they require a regulatory reset built specifically for cell-based systems?

The main challenge for the cultivated meat industry is to scale up. The scale up is not just about producing more animal cells (these are not muscle cells like in the meat) in the bioreactor, but to produce large amount of differentiated muscle cells that function like meat. The regulatory approval currently focuses more on the production system (bioreactor), including contaminations in culture medium from the environment (microbes) or new components from the replacement of animal serum by various substances. I sense that this is important but it remains as providing a list of potential hazards without any proper risk assessment (importantly: Hazard May Not Be Risk). The listing of the potential hazards is currently followed by searching what is known about their risk profile from the existing publications, rather than assessing their risk by proper technology (see NAMs in the later part of my comments). More attention should be placed in the safety assessment of differentiated muscle cells, starting with the emerging New Approach Methodologies (NAMs). This is an animal-free in vitro testing system developed for risk assessment of cosmetics and environmental pollutants.

New Approach Methodologies (NAMs) are gaining traction in pharmaceuticals and toxicology. How can NAMs such as in vitro assays, computational modelling, and omics-based profiling be credibly adapted for cultivated meat safety validation?

Many are trying to simply apply such NAMs (including in vitro assays, computational modelling, and omics-based profiling) to food safety risk assessment. However, there are two fundamental differences between food and cosmetics/environmental pollutants: mixture (foods seldom exist as one ingredient) and digestion (enzymes in the digestive system break down food through hydrolysis, which changes the potential toxicity and allergenicity in foods). For reference, risk assessment of cosmetics and environmental pollutants usually deals with single molecules which do not go through our digestive system. These two differences need to be reflected in the food-relevant NAMs for the data interpretation of food safety risk assessment to be useful and meaningful.

The production process is the product. In cultivated meat, where bioprocessing conditions shape final composition, how should regulators evaluate variability across cell lines, growth media, and scaffold materials?

Proper application of food-relevant NAMs should generate differential risk assessment data based on the conditions of cultivated meat products (cell lines, growth media, and scaffold materials). Again, most of the current literature and published papers on cultivated meat stay at the stage of Hazard Identification, which is the first step of flow risk assessment. NAM's application is moving the needle as we are now talking about Hazard Characterisation. There are 2 other important components involving consumers for the proper food safety assessment: Exposure Assessment and Risk Characterisation. But food-relevant NAMs represent an important step forward in cultivated meat safety risk assessment.

Transparency versus proprietary protection remains a tension. How can companies safeguard intellectual property while providing regulators with sufficient data for rigorous, science-based risk assessment?

Companies may provide cultivated meat products for NAMs analysis through a neutral party (for example, Singapore Future-Ready Food Safety Hub - FRESH). Regulatory approval would now shift to analysing the risk assessment data generated from the NAMs, rather than scrutinising the list of components in the respective cultivated meat production, as such a list is still the hazard identification but means little to the safety risk assessment. This shift would then help the company protect their IP to a large extent.

Global regulatory divergence is emerging. With Singapore among the first movers in approving cultivated meat, what lessons can other jurisdictions draw from its science-driven framework and where are harmonisation gaps widening?

Working with global organisations (FAO, WHO, among others) would help us bridge the gap in global regulatory divergence. One example is the Joint Action Plan between WHO and NTU Singapore on NAMs application in novel foods. Through the joint action plan, there would be greater communication on work done in Singapore and provide greater transparency for discussion and collaboration among regulatory agencies. This would then contribute to the harmonisation of the food safety risk assessment across different countries.

Public trust is as critical as scientific validation. What role should independent academic labs and open-data consortia play in stress-testing safety claims and avoiding regulatory capture?

Having a neutral and trusted party, such as FRESH, involved in the food safety risk assessment, trusted with its technology innovations and partnerships with stakeholders in both public and private sectors, would enhance public trust.

Long-term exposure data for novel proteins is inherently limited. How can predictive toxicology, AI-driven modelling, and systems biology reduce uncertainty without delaying innovation?

While food-relevant NAMs are a huge step forward in food safety risk assessment, it is not the holy grail for the novel food safety assurance. What NAMs do is more or less like a first round of fast and cost-effective profiling of potential risks in an in vitro setting. As it is animal-free, exposure studies in consumers are needed to validate the NAMs data, but with a much smaller sample size. Once in the consumer setting, variability in consumer profile (genetic makeup, composition of gut microbiome) and the resulting data would increase dramatically. Here, machine learning tools combined with a systems biology approach would be extremely important for predictive toxicology.

Looking a decade ahead, do you foresee cultivated meat safety assessments becoming more dynamic and real-time embedded within digital bioprocess monitoring systems rather than relying solely on static pre-market approvals?

Certainly. The current pre-market approval process would need to move on with the advances in technology. Through the ongoing collaboration between the Singapore Food Agency and FRESH, I see a huge potential in moving the cultivated meat safety risk assessment from the current way of hazard identification (list of potential hazards and evaluating their potential risk based on what others have done in a different context, e.g. most likely environmental pollutants) to food-relevant characterisation (NAMs) to exposure assessment. More importantly, proper risk assessment of cultivated meat products should be expanded in hybrid food products where cultivated meat is an ingredient.

Suchetana Choudhuri

suchetana.choudhuri@agrospectrumindia.com