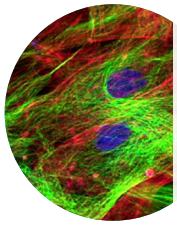
Overview: Research priorities in cultivated

Cultivated meat and fish is produced directly from animal cells. Meat cultivation replicates the processes that happen inside an animal by providing cells with warmth and nutrients to build muscle and fat.

At current production scales, cultivated meat is still more expensive to make than conventional meat. While the literature suggests that economically viable production could be achieved even without breakthrough advancements from current methods, significant chemical and biological engineering challenges remain to further reduce costs and increase yields.

Image: Ivy Farm

Key research priorities for cultivated:



Cell line development to achieve faster cell growth, greater stability and stress tolerance, and higher cell density in terrestrial and aquatic cell lines.

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Reduced cell culture media costs by bringing down the cost of growth factors and sourcing amino acids from cheap plant hydrolysates and other sources.

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Increased bioprocessing efficiency via innovations in bioreactor design and media utilisation strategies to achieve greater scale and bring down costs.

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Improved scaffolding biomaterials that support cell adherence and differentiation which allows the replication of complex animal meat structures.

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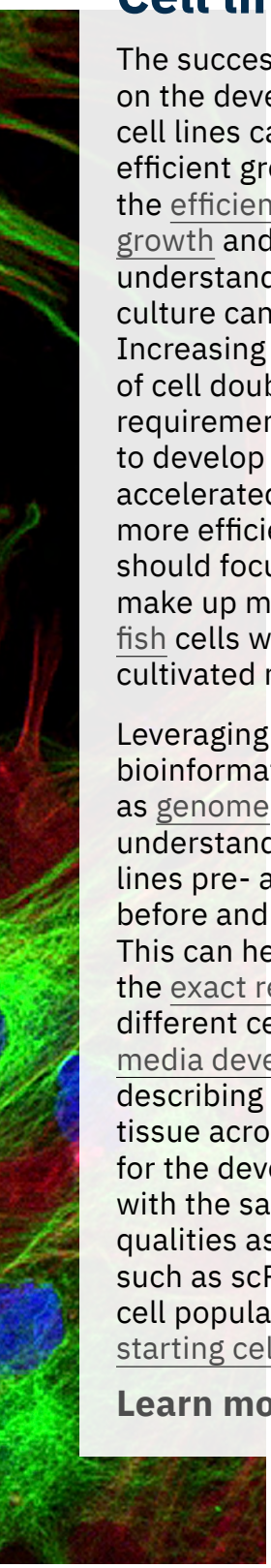
Deep dive: research priorities in cultivated meat and fish



Cell line development

The success of cultivated meat depends on the development of species-relevant cell lines capable of continuous and efficient growth in suspension. Improving the efficiency of adaptation to suspension growth and increasing the mechanistic understanding of non-adherent cell culture can help to unlock this possibility. Increasing the mechanistic understanding of cell doubling time and growth requirements can allow researchers to develop open-access cell lines with accelerated doubling times which grow more efficiently in culture. These efforts should focus on myoblast cell lines, which make up muscle tissue, especially for fish cells which are underrepresented in cultivated meat research at present.

Leveraging technologies such as bioinformatics and omics techniques such as genome and secretome analyses to understand the metabolic profiles of cell lines pre- and post-immortalisation, or before and after suspension adaptation. This can help researchers understand the exact requirements for the growth of different cell lines in culture and guide media development strategies. Equally, describing the genomics of muscle cells in tissue across different species is important for the development of cultivated products with the same composition and sensory qualities as conventional meat. Techniques such as scRNA-seq can distinguish different cell populations to expand the range of starting cell types.

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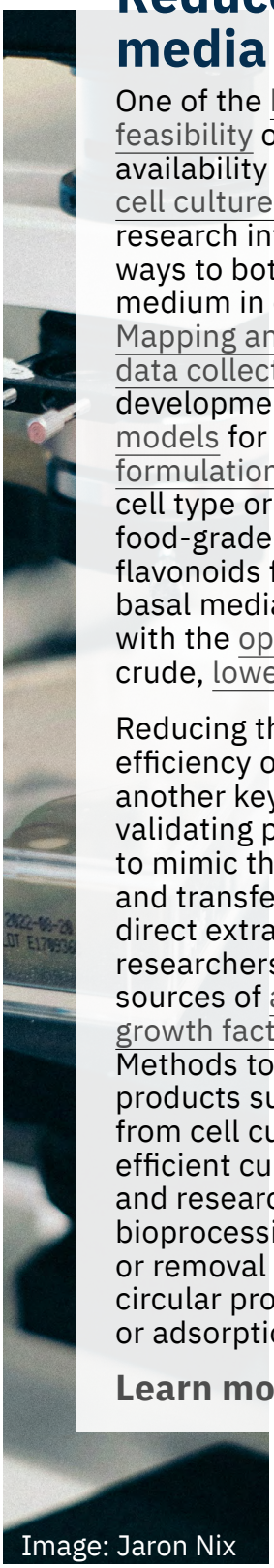

Image: Jaron Nix

Reduced cell culture media costs

One of the key drivers of the economic feasibility of cultivated meat will be the availability of affordable and sustainable cell culture media. This will require research into the most cost-effective ways to both produce and use cell culture medium in cultivated meat production. Mapping animal cell metabolism involves data collection and curation to inform the development of genome-scale metabolic models for the tailoring of media formulation and feed conversion to each cell type or bioprocess design. Testing of food-grade hydrolysates, extracts, and flavonoids for serum replacement and basal media supplementation can help with the optimisation of cell growth on crude, lower-cost media components.

Reducing the cost and increasing the efficiency of use of growth factors is another key challenge. Identifying and validating plant sources of proteins to mimic the roles of serum albumin and transferrin to allow scalability via direct extraction from crops can help researchers uncover economically viable sources of animal-free, non-recombinant growth factors for cultivated meat. Methods to reduce or remove waste products such as lactate and ammonia from cell cultures are also critical for efficient cultivated meat production and researchers should aim to develop bioprocessing strategies for the utilisation or removal of these metabolites via circular processing, co-culture systems, or adsorption.

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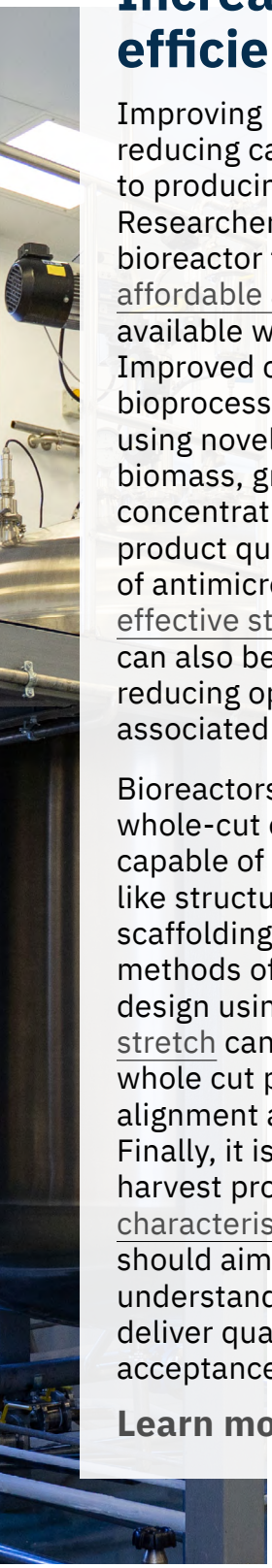

Increased bioprocessing efficiency

Improving bioreactor performance while reducing capital expenditure is critical to producing cultivated meat at scale. Researchers should aim to develop bioreactor technologies which are more affordable and scalable than those currently available with lower construction costs. Improved control over and efficiency of bioprocessing conditions can be achieved using novel sensors or biosensors to assess biomass, growth factor, and metabolite concentrations, or other aspects of end-product quality. Exploring the potential of antimicrobial peptides or other cost effective sterilants or sterilisation methods can also be highly effective ways of reducing operating costs and avoiding risks associated with batch spoilage.

Bioreactors that incorporate scaffolds for whole-cut end products may in future be capable of making products that have meat-like structure and texture via the use of scaffolding biomaterials. More advanced methods of semi-continuous bioprocess design using simultaneous perfusion and stretch can go even further in achieving whole cut products with the desired alignment and maturation of muscle fibres. Finally, it is important to consider how post-harvest processes will affect end product characteristics and safety. Researchers should aim to develop a comprehensive understanding of how these processes can deliver quality products with high consumer acceptance.

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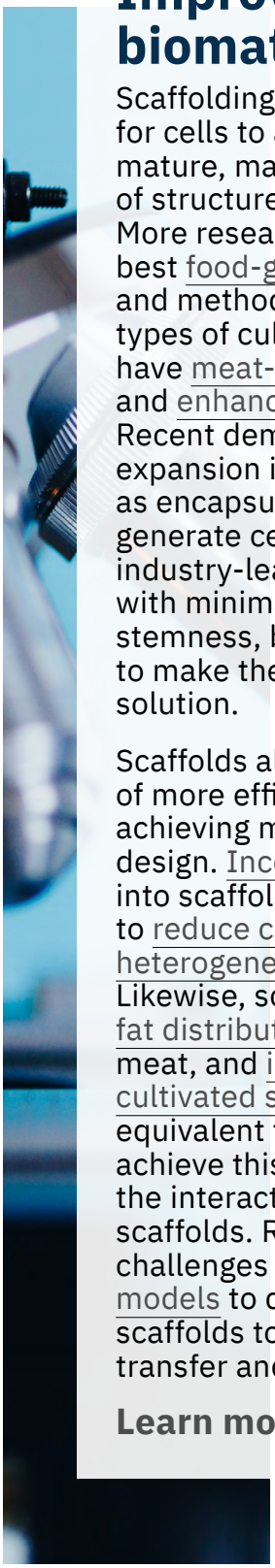

Improved scaffolding biomaterials

Scaffolding provides structural support for cells to adhere, differentiate, and mature, making it crucial for the creation of structured meat products like steak. More research is needed to uncover the best food-grade scaffolding materials and methods for constructing different types of cultivated meat products that have meat-like structure and texture and enhance cultivated meat nutrition. Recent demonstrations of stem cell expansion in 3D microenvironments such as encapsulated spheres or tubules can generate cell densities far higher than industry-leading stirred tank bioreactors with minimal loss of cell viability or stemness, but further research is required to make these technologies a scalable solution.

Scaffolds also offer the possibility of more efficient resource use while achieving more complex product design. Incorporating growth factors into scaffold materials can also help to reduce costs and introduce spatial heterogeneity to cultivated products. Likewise, scaffolds can help to optimise fat distribution and content in cultivated meat, and incorporate omega-3s into cultivated seafood to make it nutritionally equivalent to conventional seafood. To achieve this, we must better understand the interactions of materials within these scaffolds. Researchers can address these challenges by developing computational models to describe fluid flow through scaffolds to better understand mass transfer and shear forces.

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