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Cultured Meat in the Social Science Research : A Tentative Classification of the Challenges

Ryynänen, Toni

2019-10

Ryynänen , T , Rätty , N S & Tuomisto , H 2019 , '
Cultured Meat in the Social Science Research : A Tentative Classification of the Challenges '
, 5th International Scientific Conference on Cultured Meat , Maastricht , Netherlands ,
06/10/2019 - 08/10/2019 pp. 38 .

<http://hdl.handle.net/10138/310500>

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5th International Scientific Conference on Cultured Meat



Crowne Palace, Maastricht

Oct 6-8, 2019



DEAR PARTICIPANT

Welcome to the Fifth International Conference on Cultured Meat, to be held in Maastricht 6-8th of October 2019!

The International Conference on Cultured meat is an annual event that attracts more than 150 participants and aims to bring together researchers, funding bodies, investors and companies working with cultured meat and supporting technologies. This year's meeting will take place at Crowne Plaza situated in Maastricht centre.

In 2013 Mark Post burger demonstrated that it is possible to produce meat by tissue engineering techniques, serving the world's first lab-grown burger. Although this burger was expensive and took time to produce, the price has dropped dramatically, and now several start-ups have made advances in the field. There are several obstacles to overcome if it has any chance of succeeding; at the moment, the most notable ones are scale and cost. This conference covers topics such as biomaterials, serum-free cell culture, tissue formation, regulations and social science related to consumer acceptance.

On behalf of the organizing committee we welcome you to the Fifth International Conference on Cultured Meat in Maastricht! We look forward to three days of high-quality science, fruitful interactions, and to meet old and new friends.

Mark, Sissel, Chris and Nynke



5th International Conference on Cultured Meat



Crowne Plaza,
Maastricht, the Netherlands
October 6-8, 2019

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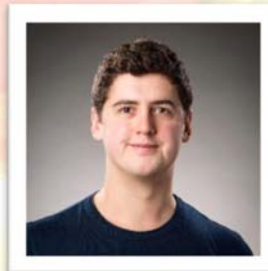
Organizing Committee:



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NYNKE**
Maastricht
University



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Practical information

This year’s meeting will take place at Crowne Plaza Maastricht situated in Maastricht City centre.

The venue is just 10 min walking distance from the Maastricht Central Train Station.

Address: De Ruitery 1, 6221 EW Maastricht

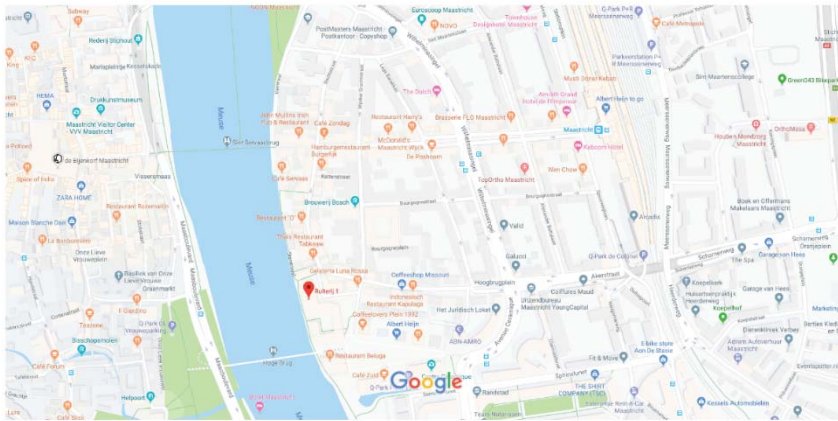
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5th International Conference on Cultured Meat



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Maastricht University



mosa meat



Nofima



UNIVERSITY OF BATH



Program 5th International Scientific Conference on Cultured Meat

Sunday, October 6

16:00 Registration

Chair: Mark Post

18:00 Welcome: Annemarie Penn-te Strake, mayor City of Maastricht

18:15 Keynote David Kaplan, Prof.dr.

Tufts University, USA

"Opportunities and Challenges in Tissue Engineering for Foods"

19:15 Welcome reception

Monday, October 7

Serum-free cell culture

Chair: Chris Bryant

09:00 **Keynote** Richard Parr, Prof.dr.

The Good Food Institute

"Taking action to boost public Research and Development funding for clean meat"

09:30 Rapid Fire Poster Presentations (Max 3 min each)

Topic: Large scale cell production

- Dimitrios Tzimiras, *"Use of lab bench bioreactor for skeletal muscle cells expansion. Potential for cultured meat production"*.
- Scott Allan, *"Scaling hollow fiber bioreactors for the culture of myoblasts"*.
- Nina Buffi, *"From a milliliter-scale perfusion bioreactor to a commercial production unit"*
- Shijie Ding, *"Pig muscle stem cells for cultured meat research"*.

Topic: Consumer Behavior

- Niko Rätty, *"Cultured meat and changing rural areas"*.
- Alexandra Vital Oliveira, *"The future of human food: cultured meat"*.

Topic: Tissue Engineering

- Natalie Rubio, *"Strategies to Enhance Differentiation of in vitro Insect Muscle"*.
- Christel Andreassen, *"Production of edible microcarriers using by-products - one step closer to cultured meat"*.

Topic: Medium

- Keita Tanaka, *"Muscle cell line culture using food grade Dulbecco's Modified Eagle Medium (FG-DMEM)"*.
- Ann-Cathrin Volz, *"A serum-free medium for the culture of adipose tissue"*.

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Topic: other

- Elliot Swartz, *“The Good Food Institute’s Competitive Research Grant Program”*.
- Carolina Bluguermann, *“The perception of the stakeholders of the meat industry in South America on cellular agriculture: insights and policy recommendations”*

10:30 Coffee break

11:00 Regulatory Panel

Chair: Karin Verzijden-Axon Lawyers

- Jens Karsten- European Vegetarion Union, BXL Law
- Laura Wellesley- Chatham House
- Alie de Boer- Maastricht University
- Deepti Kulkarni-Sidely Austin LLP

12:30 Lunch/Poster Session

Biomaterials and Medium

Chair: Sissel Beate Rønning

13:50 **Keynote** Mona Pedersen

Nofima, Norway

“By-products from food industry and the use in serum-free media for large-scale muscle cell growth”

14:20 Ricardo Gouveia

“Promotion of myoblast alignment by mesoscale surface geometries and its potential impact on the production of structured muscle tissues”

14:40 Moein Mir Fakhar

“A scalable method for pseudovascularised myoblast constructs formed from channelled and rolled polycaprolactone sheets”

15:00 Yuta Okamoto

“Cell Cultivation Using Microalgal Extract for Production of Cultured Meat”

15:20 Tea break

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Tissue Engineering

Chair: Sissel Beate Rønning

16:00 Keynote Tatsuya Shimizu

Institute of Advanced Biomedical Engineering and Science, Tokyo Women's Medical University

"Muscle Tissue Engineering-from Regenerative Medicine to Food Production"

16:30 Travis Callue

"Analysis of the Cytocompatibility of Various Biomaterials and Their Development into Scaffolds for Cultured Meat: An Overview of My PhD in Tissue Engineering"

16:50 Simon Kahan

"A roadmap for computational modeling in cell-based meat research and engineering"

17:10 Group Photo

19:00 Dinner

Tuesday, October 8

Consumer acceptance

Chair: Chris Bryant

09:00 Toni Ryynänen

"Cultured Meat in the Social Science Research – A Tentative Classification of the Challenges"

09:20 Daniele Asioli

"Are Consumers' Willing to Pay for Lab Produced Meat? An Investigation of Naming Effects"

09:40 Coffee break

10:30 Consumer panel

Chair: Chris Bryant

- Yvonne Van Everdingen-Rotterdam School of Management
- Matti Wilks-Yale University
- Mohammad Hamdan-University of Malaya
- Ann de Greef- GAIA

12:30 Lunch

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Large Scale Cell Production, Recycling

Chair: Nynke van den Akker

13:30 Keynote TBD
(company)
"title"

14:00 Mila Mandic
"Developing sensors for monitoring cell culture parameters: impedance-based biomass measurements in novel microbioreactors"

14:20 Hanna Tuomisto
"Sensitivity of different parameters on the environmental impacts of large scale cultured meat production"

14:40 Martina Miotto
"Continuous bioprocessing to scale-up cell manufacture"

15:00 Tea break

15:20 Junaid Ali
"Advancing the production of clean beef towards commercialisation"

15:40 Andrew Stout
"Endogenous carotenoid production in bovine muscle: Towards enhanced nutrition of cultured meat"

16:00 Robin Simsa
"A new method to control the color of cell-based meat"

16:20 Kyle Fish
"Meat science analytics for evaluation and optimization of cultured beef"

16:40 Mark Post, wrap up

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Invited Speakers

David Kaplan



David Kaplan is the Stern Family Endowed Professor of Engineering at Tufts University and a Distinguished University Professor. He is Professor and Chair of the Department of Biomedical Engineering, with a joint appointment at Tufts Medical School and in the Department of Chemistry. His research focus is on biopolymer engineering to understand structure-function relationships for biomaterials, tissue engineering and regenerative medicine. Since 2004, he has directed the NIH P41 Tissue Engineering Resource Center (TERC) that involves Tufts University and Columbia University. He has published over 800 peer reviewed papers. He is the editor-in-chief of *ACS Biomaterials Science and Engineering* and serves on many editorial boards and programs for journals and universities. His lab has been responsible for over 100 patents issued or allowed, and numerous start up companies. He has received also received a number of awards for his research and teaching.

Tatsuya Shimizu



Tatsuya Shimizu is now director & professor of Institute of Advanced Biomedical Engineering and Science, Tokyo Women's Medical University (TWMU). He graduated from Faculty of Medicine, the University of Tokyo and got medical doctor (M.D.) in 1992. After two-year clinical training, He made a specialty of cardiovascular medicine including catheterization and got his Ph.D in 1999. After that, he moved to TWMU and started tissue engineering research based on "cell sheet technology" especially for heart regeneration. Now, his recent work is engineering various types of functional 3-D tissues & organs for regenerative therapy, drug screening and food fabrication.

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Mona Pedersen



Dr. Mona E. Pedersen is a research scientist at the Food Research Institute in Norway, Nofima. Her main interests are the extracellular matrix and in particular how this is important for skeletal muscle growth and development, tissue regeneration and food quality. She has more than 18 years of experience in the field of extracellular matrix biology, has trained several students and postdocs, and as a member of staff of one of Europa's largest food research institute, her research explore the possibility of using extracellular matrix components in food and health related issues, as well as exploring novel use of bi-products from food industry. She is currently exploring how bioactive

components recovered from by-products from the food industry can be formulated into serum-free media for large-scale muscle cell growth.

Richard Parr



Managing Director, Europe

Richard leads GFI's work in Europe. He worked as Special Adviser to the UK Prime Minister between 2012 and 2016, and as Special Adviser to the Secretary of State for International Development from 2010-12 and 2016-18. In government, his main focus was on international development policy, and he worked closely on the formation of the UN Sustainable Development Goals. Richard holds an MA in Modern History from Oxford University



Abstracts

Topic: Large scale cell production/recycling

Title: Continuous bioprocessing to scale-up cell manufacture

Martina Miotto^{1,2}, Leo Groenewegen², Che Connon^{1,2}

¹ Institute of Genetic Medicine, Newcastle University, Newcastle-upon-Tyne, UK

² CellulaREvolution Ltd, Newcastle University, Newcastle-upon-Tyne, UK

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It is critical to develop innovative technologies enabling the efficient and cost-effective scale-up of cell manufacturing. This represents one of the main bottlenecks faced so far by several industries, especially in the clean meat field¹. The way adherent cells are grown has not changed in 50 years, and a radical change is required to meet current and future cell demands. Thus, we considered applying the concept of continuous bioprocessing to manufacture adherent cells². This innovative concept is based on the use of smart peptide-based coatings with tuneable cell-adhesion properties. Specifically, we demonstrated that such coatings instructed fibroblast-like cells to adhere and proliferate while regulating their own self-detachment via cleavage from the coating². Cells grown on this system were shown to reach a steady-state, i.e., the number of cells on the coating does not change over time, with cell proliferation matching the continuous self-detachment. In this way, a single surface area can produce cells unremittingly, which are then available for other processes downstream. Moreover, we demonstrated that self-detached cells are able to reattach while maintaining high viability and original phenotype. Such technology has the potential to offer considerable new advantages, such as reduction of culture footprint and consumables, elimination of serum, and high adaptability to automation and in-line QA. Such an innovative technology can have a great impact in scaling-up the manufacture of animal-derived cells to generate clean meat products. In light of this, we have spun-out a new company from Newcastle University, CellulaREvolution Ltd, to validate the technology with cell types that are relevant for companies operating in the clean meat space.

References:

¹ Stephens et al. (2018) Trends in Food Science & Technology 78: 155-166.

² Miotto et al. (2017) ACS Applied Materials and Interfaces 9: 41131-41142.



Title: Scaling hollow fiber bioreactors for the culture of myoblasts

Scott J. Allan,^{1,2} Paul A. De Bank,³ Marianne J. Ellis²

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²Department of Chemical Engineering, University of Bath, Bath, BA2 7AY, UK

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Background: The area of cultured meat has been subject to significant claims regarding the scalability in line with industrial fermentation and therapeutic protein processes using microcarrier-based bioreactors. Limitations to scale exist for the adherent culture of skeletal muscle cells in bioreactors on microcarriers as a result of the inherent shear forces imposed,^[1-2] and scalability in terms of land footprint and manual input. An alternative, high cell density bioreactor option that decouples the cells from the shear force of liquid flow is presented in the form of hollow fiber bioreactors.

Objectives: Demonstrate the applicability of hollow fiber bioreactors for large-scale production of skeletal muscle stem cells. Provide proof of concept for the *in situ* dissociation of cells, sequential seeding within a larger hollow fiber bioreactor and the re-use of synthetic polymer scaffolds to reduce operating expenses (OPEX).

Methods: Porous polystyrene hollow fibers were produced in-house by dry-wet spinning. Hollow fibre bioreactor modules were used with porous polystyrene fibres as scaffolds to expand C2C12s with lumen media flow (DMEM + 10% FBS). TrypLE was used for cell dissociation.

Results: Results on three different methods of scaling hollow fiber bioreactors will be presented for the expansion of C2C12s. i) Scaling by increasing bioreactor size, performed via *in situ* cell dissociation and seeding in larger bioreactors. ii) Numbering up, verified by the operation of multiple bioreactors in parallel. iii) Process intensification, by decreasing the size of the hollow fibers to increase the maximum cell density attainable. Bioreactor optimization was performed by incorporation of continuous on-line and discrete in-line instrumentation and sampling for off-line analysis.

Conclusions: The bench-scale hollow fiber bioreactor was successfully used as a proof of concept for the expansion of myoblasts and further study has demonstrated methods of scale-up.

References

- 1) Hu, W., et al., *Cytotechnology*, 2011, 63, 445-460
- 2) Venkat, R.V., et al., *Biotechnology and Bioengineering*, 1996, 49, 456-466

Acknowledgements: New Harvest and the EPSRC for financial support.



Title: From a milliliter-scale perfusion bioreactor to a commercial production unit

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In the next years the cultured meat field will face a crucial challenge: scale-up and scale-out muscle and fat cell production, while reducing its costs. Currently, most of the cultured meat bioprocesses are in the R&D phase, and thus carried out on a milliliters scale, but the goal is to develop bioprocesses having commercial working volumes and to produce cell mass at a competitive price, i.e. less than 10\$/kg.

When scaling up, several key points must be considered. First, medium filtering and a feeding system replenishing the fast depleting component of the medium must be integrated into the bioreactor system, while the bioreactor system itself needs to be integrated into the whole production chain. Furthermore, despite autoclaving the fluidic parts is practical for lab-scale devices, for larger bioreactors only sterilization in place is feasible. For scaling out, a centralized system simultaneously controlling all the units involved in cultured meat production is needed.

Most probably, it is not wise to hope to produce cultured meat in existing large reactors designed for pharma applications. The product are the cells themselves, not an expensive substance produced by the cells: the bioprocess and the bioreactor must be co-developed around this key point. At OSPIN we are developing together with our cultured meat customers the technology steps required to move from a modular R&D perfusion bioreactor to a fully automated production unit tailored to the bioprocess needs, a route that will lead to production of culture meat at a competitive price.



Title: Sensitivity of different parameters on the environmental impacts of large scale cultured meat production

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A few studies have estimated the environmental impacts of cultured meat produced in large scale bioreactors (Tuomisto and Teixeira de Mattos, 2011; Tuomisto et al., 2014; Mattick et al., 2015; Smetana et al., 2015). The results of those studies vary depending on the system design, e.g. type of bioreactor, source of nutrients for the growth medium, source of energy, etc. As the development of cultured meat is still at the laboratory scale and it is not possible to collect data from large-scale production systems directly, the environmental impact estimates rely on many assumptions.

This presentation will illustrate how each assumption (e.g. regarding metabolic rates, medium requirements, composition of the medium, source of energy, recycling rates of medium) impact on the environmental impacts of cultured meat production.

The results show that most critical factors impacting on the greenhouse gas emissions of cultured meat production were the medium use efficiency and source of energy. The most efficient ways of reducing the water footprint of cultured meat were recycling of water in the growth medium and use of seawater instead of fresh water as cooling water if possible. This study provides valuable information for identification of the hotspots of the environmental impacts of cultured meat production and the most efficient ways to reduce them. The detailed information regarding the sensitivity of different parameters on the total impacts help cultured meat developers to estimate the environmental impacts of their own systems.

References

- Mattick et al. 2015. Anticipatory Life Cycle Analysis of In Vitro Biomass Cultivation for Cultured Meat Production in the United States. *Environmental Science & Technology*, 49, 11941-11949.
- Smetana S., Mathys A., Knoch A., Heinz V. Meat Alternatives: Life cycle assessment of most known meat substitutes. *International Journal of Life Cycle Assessment*. 2015;20:1254–1267.
- Tuomisto H.L., Teixeira de Mattos M.J. 2011. *Environmental Science & Technology* 45, 6117-6123
- Tuomisto, H.L., Ellis, M.J. & Hastrup P. 2014. In (Schenck, R., Huizenga, D. (Eds.), 2014. *Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector (LCA Food 2014)*, ACLCA, pp. 1360-1366,



Title: Can cell-based lean fish help meet the future demand of animal protein?

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More than 20 new ventures have been formed to advance the field of cell-based meat since Mark Post debuted his lab-grown hamburger in 2013. In the cell-based seafood space, in particular, companies have revealed that they are targeting high-value fish including Atlantic bluefin tuna and a species of salmon, and another company is focusing on shrimp.

In early 2018, Clean Research identified uncharted territory in cell-based seafood - lean fish - a set of species with 2% or less muscle fat. In this presentation, we make the case in favor of lean fish over other mass-consumed animals for cell-based animal protein production.

To do this, we lead with definitive general information on advantageous aspects of fish cell culture derived from reported experimental findings. These qualities of fish cells relative to mammalian and avian cells include but are not limited to reduced susceptibility to senescence, increased karyotypic stability, and suitability to growth in atmospheric air. After that, we present potential upsides of cell-based fish for research and industrial-scale production, which focus on cell temperature growth range, oxygen requirements and their respective implications on bioprocess design.

Inefficiencies of conventional aquaculture production methods are then explored, and we discuss newly proposed metrics - protein and calorie retention - as they relate to lean fish species. We then emphasize further compelling reasons to pursue lean fish, which include the technical challenges of co-culturing muscle and fat cells, and lean fish flavor profiles that are easier to achieve than higher fat fish species. Finally, we discuss critical information on the amenability of lean fish for *in vitro* tissue growth on a scaffold due to the repeated patterning of the muscle tissue.



Title: Advancing the production of clean beef towards commercialisation

Junaid Ali¹, Christopher J Hewitt¹, Mariana Petronela Hanga¹

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Two of the greatest current challenges hindering the commercialisation and affordability of clean meat are the lack of a scalable and cost-effective bioprocess and its biological complexity. Significant quantities of cells will need to be produced in order to bring clean meat to the market. Additionally, meat is a complex tissue consisting of several different cell types interacting with each other that give it its nutritional value, texture and taste. Both of these challenges are addressed in this project. We will develop a scalable and cost-effective bioprocess in small scale bioreactors that is directly transferable to litre scale bioreactors. Bovine adipose-derived mesenchymal stem cells (bAMSCs) (Cellider Biotech) were cultured for 6 consecutive passages and evaluated for their population doublings and specific growth rates. Additionally, the bAMSCs were characterised in monolayer by differentiation towards adipogenic and osteogenic lineages and by determining their clonogenic potential to establish the baseline of growth and cell quality. Subsequently, the cells were then seeded into spinner flasks on microcarriers testing a variety of different surface areas and cell seeding densities in order to determine the optimal growth. Moreover, the feeding regimes were assessed through an examination of glucose and lactate in the culture with cell counts and live/dead imaging at regular time points. Once the bAMSC culture on microcarriers was optimised, a one-step bioprocess for the expansion and subsequent differentiation of bAMSCs towards adipose cells was developed. A variety of factors including agitation, feeding regimes and bead-to-bead transfer were investigated to maximise the differentiation efficiency. The produced adipose cells were then harvested and cryopreserved to produce a master cell bank. The next steps within this project are to develop a one-step bioprocess for production of muscle cells and the co-culture of muscle and fat.



Title: Use of lab bench bioreactor for skeletal muscle cells expansion. Potential for cultured meat production.

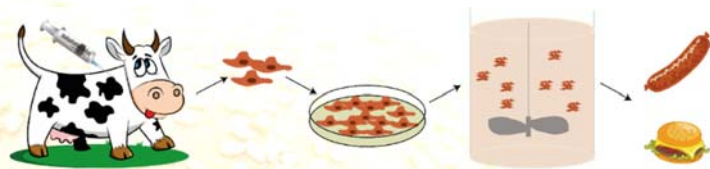
D. Tzimos², R. C. Andreassen¹, T. Hagen¹, R. S. Berg¹, M. E. Pedersen¹, E. Veiseth-Kent¹, N. Solberg¹, S. B. Rønning¹

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There is an increasing pressure on the world's livestock sector to meet the growing demand for high-value animal protein. A revolutionary new alternative to the traditional way of producing animal protein is cultivation of muscle cells outside the living animal in a bioreactor, thus by-passing animal production. Optimistic estimations suggest that using this modern technology, 10 000 kg cultured meat can be generated from as little as 1 g of beef muscle. The methodology for culturing meat is inspired by techniques used for medical purposes such as tissue reconstruction of damaged muscle tissue and large-scale production of biopharmaceuticals using mammalian cells. Although bioreactors are widely used for large-scale production of biopharmaceuticals using mammalian cells, this technology must be modified before it can be used for edible animal protein production. The basic technology includes the following steps: 1) Sample and harvesting of the muscle stem cells, 2) multiplying the number of cells in a bioreactor (expansion), and differentiation of the satellite cells into muscle cells and fibers, before 3) assembly into a final food product (See figure for overview).



Our aim is to expand skeletal muscle cells in a lab-bench bioreactor and make one step closer to cultured meat.

We isolated bovine skeletal muscle cells from newly slaughtered cattle at an industrial abattoir using a well-established method. Previous work demonstrate that it is possible to culture bovine muscle cells in small bioreactors (up to 250 ml) using microcarriers to achieve high surface area to volume ratio. We have up-scaled this culturing to bench bioreactors (up to 700 ml), using commercial Cytodex[®]1 microcarrier beads from Sigma-Aldrich, using two seeding conditions: 1) 650 cells/cm²microcarriers. The pH was set to 7.8, DO to 35%, sparging with a combination of gases (CO₂, NO₂ and compressed air), temperature 37°C and agitation 40 RPM. 2) 1800 cells/cm² microcarriers. The pH was set to 7.3, no sparging but using a set combination of overhead gases (CO₂, and compressed air), temperature to 38°C and agitation to 40 RPM. Parameters analyzed included glucose consumption, lactate production as well as DNA and cell growth.

We demonstrated that the bovine skeletal muscle cells were able to attach to the beads and that the cells were multiplying in both seeding conditions. We also observed that not only did the number of empty beads drop, also the number of beads with more than 3 cells attached increased. The cells consumed glucose and produced lactate demonstrating cell activity after as long as 20 days. Although we did observe initial cell growth and live cells during the whole period for the first alternative seeding conditions, the cells reached senescence, and foaming was a challenge. Foaming was produced from day 1. The seeding conditions were important for cell expansion, as the cell growth and DNA amount increased more using the second alternative, and no foaming was produced. In addition, the pH was maintained with no addition of base and the media used were antibiotic and antifungal free.

One of the main challenges during our experiments using the first seeding alternative was the foaming, leading to microcarrier losses from the bioreactor. This probably also had impact on the medium composition. Secondly, a major challenge with these cells, is how to achieve a longer and optimized expansion period. Our preliminary results show that although the cells did multiply, they reached senescence and started dying after some time. The reason for this could be attributed to low seeding densities, to microcarrier losses or to medium composition changes due to foaming. The second seeding alternative, using higher number of cells per cm²microcarrier, lower



pH and no sparging overcame the foaming problems and resulted to higher cell growth. Overcoming these optimization challenges is vital in order to efficiently produce animal proteins as a feeding strategy.

Title: Pig muscle stem cells for cultured meat research

Shijie Ding¹, Haozhe Zhu¹, Ling Lin¹, Zhongyuan Wu¹, Guanghongzhou¹, Mark Post²

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Traditional animal agriculture has a substantial contribution to climate change and air pollution, to land degradation, soil and water and to the reduction of biodiversity. Cultured meat is a promising technology with the potential ability to solve traditional animal agriculture problems. China is the biggest country of pork production and consumption. Here we use pig as the animal model and evaluate pig muscle stem cells for cultured meat research.

Mononuclear cells were isolated from muscle tissue by commercial pig 'large white' at 1- and 25-week old. Pig muscle stem cells were isolated by fluorescence-activated cell sorting (FACS). The purity of satellite cells were confirmed by flow cytometry and immunofluorescent(IF) staining. Proliferation assays were performed by cell counting during serial passaging. The differentiation experiments were set in 2D and 3D conditions.

The mononuclear cells per unit mass isolated from 1-week old pig are 10-20 times more than 25-week old one. The FACS strategy enrichs satellite cells with 95% PAX7 positive. Surprisingly, cultured mononuclear cells from 1-week old pig showed high CD56, CD29 positivity, which is more than 90 percent, after several passages. The isolated satellite cells can differentiate into multinuclear myotubes and decreased myotube formations abilities in late passages. In 3D conditions, the pig muscle stem cells can compact in 3D collagen gels and differentiated in 3D conditions.

Conclusion: 1-week old pig have more mononuclear cells per unit mass. Purification steps may not be necessary for newly born pigs. Pig muscle stem cells can differentiate into myotubes and are suitable cultured meat research.



Topic: Biomaterials

Title: Analysis of the Cytocompatibility of Various Biomaterials and Their Development into Scaffolds for Cultured Meat: An Overview of My PhD in Tissue Engineering

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Myogenic progenitor cells require a scaffold on which to anchor themselves, proliferate, and differentiate. An ideal scaffold for the purposes of in-vitro culture of muscle tissue for consumption as meat would be eaten along with the product. This work analyses the cytocompatibility of various edible biomaterials, and methods of producing scaffolds that can be used for myogenic cell culture.

2D zein films were prepared by casting a 1% (w/v) solution of zein, in 70% (v/v) aqueous ethanol into multi-well plates, and allowing to dry. Silk and chitosan films were prepared similarly; silk being dissolved in water and chitosan in 1% (v/v) acetic acid, both to 1% (w/v). Films were seeded with C2C12 myoblasts; proliferation was measured via metabolic analysis, spreading via image-analysis, and differentiation via MHC immunostaining. 3D matrices were produced from 20% (w/v) zein solutions via electrospinning and post-treated to overcome instability in aqueous media. Carrageenan discs were produced by allowing 2% (w/v) k-carrageenan to gel with subsequent crosslinking in 5% (w/v) KCl. Alginate discs were prepared by exposing dry films to 2% (w/v) CaCl₂. Carrageenan and alginate discs were coated with chitosan and silk, separately.

Zein, silk, and chitosan showed good cytocompatibility with C2C12 myoblasts; cells were observed to proliferate, spread, and to differentiate. When stable electrospun fibres were produced from zein, cells were also shown to grow well thereon. Carrageenan discs showed limited cytocompatibility. This, as well as their structural instability, showed improvement after coating with chitosan and silk.

Animal-derived materials such as chitosan and silk show good cytocompatibility and can likely be used to produce scaffolds for myogenic cell culture. Zein also shows good cytocompatibility and, if the structural instability of electrospun fibres can be overcome, may hold significant potential for use as a highly renewable, plant-based bioscaffold for cultured meat applications.



Title: Production of edible microcarriers using by-products - one step closer to cultured meat

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Large-scale bio production of edible animal proteins, based on culturing skeletal muscle cells, requires suspension of high-density cell cultures in bioreactors. Skeletal muscle cells are adherent and microcarriers provide a high surface area to volume ratio for these cells to grow on. Microcarriers are small beads, typically 100-200 μm in diameter, where both proliferation and differentiation of bovine muscle cells can occur. Commercial microcarriers are usually made of nonedible synthetic materials, which requires a detachment step when harvesting the cells from microcarriers, making the protein production process less efficient and increasing the cost. Edible microcarriers on the other hand can be left in the culture and included in an end food product. By-products from the food industry such as turkey tendon and eggshell membrane (ESM) consist of extracellular matrix compounds and are low-cost and food-safe, and thereby promising biomaterial for use in production of edible microcarriers.

In the current study we aim to produce edible microcarriers of two food grade by-products (collagen from turkey tendon and eggshell membrane) and examine muscle cell growth in spinner flasks.

We isolated collagen from turkey tendons and established a simple cryo-technique to produce spherical microcarriers further strengthened by UV riboflavin cross-linking. ESM powder-like microcarriers were produced by milling and sifting the powder to a particle size of 100-200 μm . The edible microcarriers were tested in spinner flasks with primary bovine skeletal muscle cells and compared with commercial microcarriers Cytodex 1 and 3. We analyzed muscle cell development over time using fluorescence microscopy and by measuring the concentration of DNA, protein, glucose, lactate, ammonia and L-glutamine. Our preliminary data show that ESM powder and cryo-collagen beads are both suitable matrixes for bovine muscle cells growth in spinner flasks.



Topic: Medium

Title: Muscle cell line culture using food grade Dulbecco's Modified Eagle Medium (FG-DMEM)

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Cell-based meat is anticipated as a sustainable protein source with minimal environmental footprint. However, the high cost of cell culture medium and lack of industrial scale processes have been hindering commercialization. Conventional culture medium in the market is designed to meet the strict standards of medical and research use. If culture medium can be re-formulated for food application using “food grade” materials, it makes cell-based meat less expensive and a more feasible option.

Dulbecco's Modified Eagle Medium (DMEM) was re-formulated using food grade materials. Myoblast cell line was cultured to evaluate the effectiveness of “food grade DMEM (FG-DMEM)”.

FG-DMEM was composed of materials labeled and sold as “food additive”. Several materials of DMEM were not recognized as food additive, and they were replaced with equivalent materials. Murine myoblast cell growth in conventional DMEM and FG-DMEM was compared.

Murine myoblast cells proliferated in FG-DMEM. There was no significant difference in cell growth between DMEM and FG-DMEM, but some differences in metabolites such as lactate concentration were observed.

Conventional in vitro cell culture experiments for molecular biology and medicine require ultrapure materials¹. Since no significant difference in cell culture properties was observed, it can be concluded that basal media can be formulated using widely available inexpensive food additives to produce cell-based meat as a viable alternative protein.

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Title: Cell Cultivation Using Microalgal Extract for Production of Cultured Meat

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It is predicted that the demand for meat will increase more than 70% going towards 2050, because of the global population growth and the rising middle class in the world. Additionally, climate change, environmental pollution, and the diseases of livestock have threatened the stability, safety, and sustainability of meat production using cattle husbandry. Recently, cultured meat has been proposed as an innovative food that can significantly reduce environmental loads and the risk of infectious diseases. However, in order to obtain the nutrient for cultured meat, it is necessary to grow grains, and this process is insufficient to construct a truly sustainable production system in the unforeseen environmental changes.

For the cultivation of myoblasts, we extract essential nutrients, glucose and amino acids from microalgae instead of grains.

Green algae were expanded in a bioreactor and collected by centrifugation. Glucose and amino acids were extracted from the collected algae by acid or alkali hydrolysis method. C2C12 mouse myoblast cells were used for cell culture.

Glucose was efficiently extracted from green algae and 19 out of 20 proteinogenic amino acids were also extracted. Almost mouse myoblasts died by cultivation using the medium without glucose and amino acids, on the other hand, the additional algae extract rescued the cells. The cell viability was confirmed to be approximately equivalent to the minimal essential medium containing conventional glucose and amino acids.

This study showed the algal extract was used as an alternative to glucose and amino acids for animal cell cultivation. In the next step, we will construct a new cell culture system without conventional culture media containing fetal bovine serum, glucose, amino acids, and vitamin by using the algal extract and serum substitute. The establishment of the culture media with algae extract will lead to a truly sustainable production system for cultured meat.



Title: A serum-free medium for the culture of adipose tissue

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Background:

The incorporation of fatty tissue compartments is an essential step in order to adjust the taste and texture of in vitro cultured meat to regular animal-derived meat products.

As the motivation of cultured meat is among other reasons based on the reduction of factory farming, the use of animal-derived products should be excluded from the setup of in vitro products equally. Therefore, the replacement of fetal bovine serum (FBS) is needed. The exclusion of FBS could additionally lead to improved standardization of artificial meat production, as its composition is unknown 1.

Objectives: In this approach, completely serum-free media were developed for the adipogenic differentiation of adipose-derived stem cells and the culture of mature adipocytes.

Methods: A serum-free adipogenic differentiation medium was developed by supplementation of growth factors, plasma proteins and trace elements and applied in adipogenic differentiation of human ASCs (hASCs) for 14 days. Further an adipocyte maturation medium was developed, which was applied in a 3D setup of mature adipocyte in a collagen type I hydrogel for 14 days. Results were compared to serum-containing controls.

Results: It was shown that hASCs keep their stem cell characteristics, proliferation capacity, stem cell marker expression and multipotency also after serum-free/xeno-free expansion. The serum-free medium lead to an efficient adipogenic differentiation of hASCs, which was proven by a high percentage (79.9 %) of perilipin A expressing cells and leptin release (77.7 %) compared to serum-containing controls at simultaneous lipid storage. The maintenance medium allowed the culture of mature adipocytes and the maintenance of adipocyte characteristics until day 14.

Conclusions: In the current study, we could implement the efficient in vitro generation of mature adipocytes out of hASCs and their maintenance based on serum-free media for the first time. The reported data represents a promising basis for the implementation of serum-free conditions for the setup of fatty tissue in the artificial meat production based on animal cells.

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Topic: Tissue Engineering

Title: Strategies to Enhance Differentiation of *in vitro* Insect Muscle

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Previously, we demonstrated invertebrate (e.g., insect) cells may allow for scalable, cost-efficient cultured meat cultivation relative to vertebrate (e.g., avian, mammalian, piscine) cells due to (1) innate tolerance to fluctuations in environmental temperature, pH and osmolarity, (2) low medium requirement, (3) capacity to transition between adherent and single-cell suspension culture, (4) adaptability to serum-free media and (5) integration with plant-based scaffold systems¹⁻³. While administration of insect hormones can regulate proliferation and differentiation to a certain extent, the differentiation efficiency of insect muscle cells *in vitro* is remarkably low³. Muscle tissue formation is important for production of structured cultured meat products and may impact nutritional value and density. Insight into *in vivo* insect myogenesis and observations from early studies indicate direct contact between muscle and neuron cells may be necessary for *in vitro* muscle maturation^{4,5}. Electrical pulse stimulation and micropatterned substrates reliably increase differentiation in mammalian cells⁶. We aim to implement multiple strategies, individual and coupled, to increase *in vitro* insect muscle differentiation efficiency. Strategies include (a) hormone administration, (b) micropatterned substrates, (c) electrical pulse stimulation and (d) neuron co-culture. Experiments are performed both continuous *D. melanogaster* adult muscle precursor cells and primary *M. sexta* embryonic precursor cells. Differentiation efficiency is evaluated via fusion index and immunocytochemistry for insect muscle biomarkers. Successful strategies will be implemented on cell-scaffold constructs via sponges fabricated from mushroom chitosan and mycelium.

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Title: Promotion of myoblast alignment by mesoscale surface geometries and its potential impact on the production of structured muscle tissues

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Meat palatability is an important determinant of consumer acceptance. This attribute is in turn determined by the highly-ordered structure of the tissue's complex cellular and matrix components. Current strategies to reproduce these intricate features *in vitro* usually rely on intricate and costly setups with limited scalability potential. Recently, we demonstrated that tissue templating using mesoscale substrate curvature represents a simple but efficient strategy to control the behaviour of stromal stem cells *in vitro* to create highly-ordered connective tissue equivalents with multiple applications (Gouveia *et al.*, 2017a).

We applied the concept of tissue templating (Gouveia *et al.*, 2017b) using curved surfaces to control myoblast organisation, aiming at producing larger, denser, and easily-recoverable structured muscle tissues with an organization and composition reproducing the texture of natural meat, as recognized by the consumers' palate.

C2C12 mouse myoblasts were grown on custom-made concave cylindrical surfaces with different diameters ($\varnothing = 5-50$ mm) or on planar control substrates, using previously developed materials and techniques (Gouveia *et al.*, 2017a), to provide a cell-adhesive template for myoblasts to attach and grown in established aseptic tissue culture methods.

Myoblasts responded to substrate curvatures with $\varnothing = 5-20$ mm, presenting preferential circumferential alignment along the cylindrical short axis, and with optimal cell organisation on substrates with $\varnothing = 12$ mm. Conversely, cells on planar surfaces were randomly organised. Alignment on curved surfaces was maintained even after myoblasts differentiated into myosin II- and myogenin-positive, multi-nucleated tubular cells after 7 days in low-serum medium conditions.

This proof-of-concept system represents the basis for developing a simple and cheap method to produce large free-floating skeletal muscle tissues that recreate the native-like structure, composition, texture, and palatability of meat.

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Title: Endogenous carotenoid production in bovine muscle: Towards enhanced nutrition of cultured meat.

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Environmental, ethical, and public-health concerns surrounding animal agriculture have been the primary drivers behind cultured meat development in recent years^{1,2}. However, there is a concurrent interest in tailoring cultured meat to offer novel nutritional benefits. To date, this has most commonly been proposed through the addition of omega-3 fatty acids or vitamins to culture media; however, the tools of metabolic engineering offer exciting mechanisms for endogenously imparting novel nutritional functionality to cultured meat³. Here, we demonstrate the endogenous production of dietary carotenoids in bovine muscle cells to enhance meat's nutritional value. Specifically, we genetically engineer cells to produce several of these compounds from native precursors. As important dietary antioxidants and provitamins, carotenoids are particularly promising targets for several reasons. First, the endogenous production of nutrients enables nutritional enhancement without the costs of media supplementation. Second, the antioxidant capacity of these compounds could address key mechanisms behind both red meat-associated pathogenesis and the decline in nutritional and sensory quality of red meat during storage. Specifically, lipid peroxidation associated with heme-iron in red meats has been implicated in colorectal carcinogenesis and quality degradation, thus the ability of endogenous nutrients to scavenge reactive oxygen species could help mitigate these concerns^{4,5}. Finally, while plants are the main source of carotenoids in most diets, their bioavailability is often higher in foods that are not from plant origin. It is therefore possible that engineered cultured meat would provide a more bioavailable source of carotenoids⁶. Here, we verify carotenoid formation and show yields comparable to those present in high-carotenoid foods. We also explore cell growth and carotenoid functionality in vitro. This approach offers a proof-of-principle for the use of metabolic engineering in cultured meat and emphasizes the value of cultured meat as a platform for offering novel nutritional functionality in meat products.

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Title: Meat science analytics for evaluation and optimization of cultured beef

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Producing meat through cell culture and tissue engineering offers a promising means of supplying sustainable products that mimic their animal-derived counterparts. To accurately recapitulate the sensory properties of animal-based meat and encourage consumer acceptance, comparative evaluations are necessary for various product qualities, including texture, taste, nutrition, coloring, moisture-retentiveness, response to cooking, and more. Here, we culture bovine muscle cells on edible mushroom-chitosan scaffolds to generate cultured meat constructs, then assess tenderness, water-binding capacity, and thermogravimetric properties by adapting relevant meat science techniques. Water holding capacity (WCH) of meat correlates positively with juiciness and consumer preference, and was assessed in this study with a filter paper press method. Warner-Bratzler Shear Force (WBSF) was conducted to analyze meat texture, and thermogravimetric analysis was performed to determine response to and stability during heating. Toughness of cultured samples was found to be higher than animal-based meat, and water-holding capacity was lower. To demonstrate possibilities for optimization, tenderness was tuned by altering the chitosan concentration used for scaffolding. Our results aid in establishing a systematic approach for cultured meat analytics to guide future developments in the field. Additionally, we discuss limitations of current testing methods and suggest opportunities for ongoing product analysis and innovation.

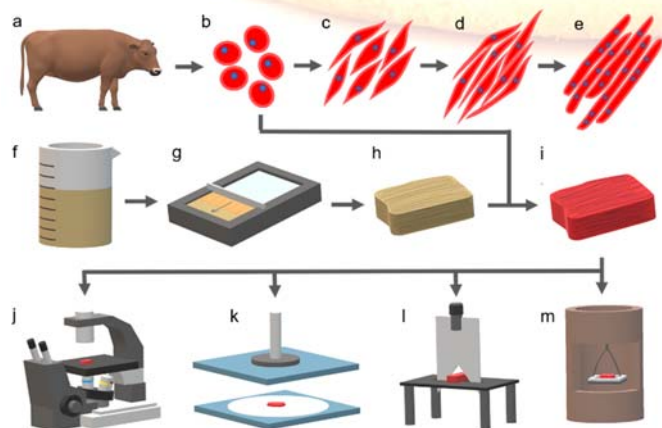


Figure 1. Process overview. a,b) Isolation of satellite cells. c-e) Differentiation of cells into myotubes. f) Chitosan solution for scaffold production. g) directional freezing of chitosan. h) unseeded scaffold. i) Chitosan scaffold seeded with satellite cells. j) Immunofluorescent imaging. k) Water-holding Capacity analysis. l) Warner-Bratzler Shear Force. m) Thermogravimetric analysis.



Title: A scalable method for pseudovascularised myoblast constructs formed from channelled and rolled polycaprolactone sheets

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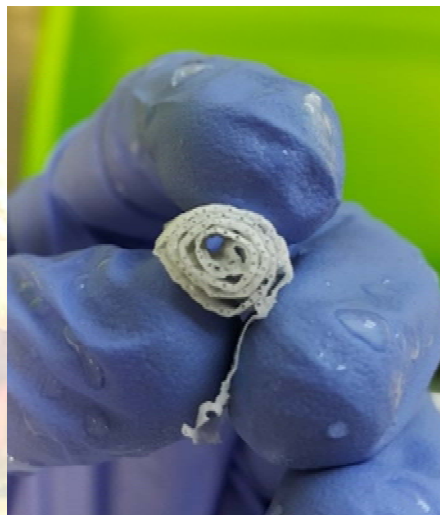
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The production of large 3D tissue constructs is one of the biggest challenges in tissue engineering [1-3]. This work introduces a novel method for making 3D, vascularized scaffolds to be used in perfusion bioreactors in order to make large cultured meat (myoblast) constructs.

Production of channelled, porous polycaprolactone (PCL) sheets that can be rolled into an X cm long and Y cm diameter cylindrical scaffold. The work provides a proof of concept for the use of channelled scaffolds as both a means of media supply and the scaffold for myoblast expansion and differentiation.

Channelled PCL sheets were produced by employing sheet casting methods by phase inversion [4]. NaCl particles were used as a porogen and water as the non-solvent and to leach the porogen. C2C12s were cultured in media (DMEM + 10% FBS) on 2D flat sheets, and 3D rolled sheets with flow through the channels and recycling.



The PCL sheets were porous and the channels were intact, as observed on SEM images. The PCL sheet demonstrated good mechanical properties such that they could be rolled without damage. Fibrin was used as a hydrogel to achieve high cell seeding within PCL porous sheets. Attachment and proliferation of C2C12s was tested in 2D before, and 3D after rolling. Proliferation of C2C12s on the scaffold inside a perfusion reactor was assessed using histological methods.

Porous channelled PCL sheets support C2C12 culture, and can be rolled without damage, and utilised with flow as a scaffold within a perfusion bioreactor.

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Acknowledgements: University of Bath for all kind helps including financial support.



Title: Developing sensors for monitoring cell culture parameters: impedance-based biomass measurements in novel microbioreactors

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The most significant cost driver for cultured meat production is the cell culture medium¹. The challenge to decrease expenses is not only in designing lower cost medium formulations, but also in **developing methods to increase the yield of cells per unit medium volume (UMV)²**, such as incubating cells in bioreactors. In addition, optimizing bioreactor design, instrumentation and **monitoring features via sensors** can provide maximum cell production capacity per UMV.

To develop new generation of low-cost sensors for monitoring cell yield (biomass concentration) using miniaturized bioreactors (microfluidic devices) as a tool to obtain process-relevant data during early-stage process development

Microbioreactor is fabricated using rapid microfluidic fabrication technology that combines a cost-effective xurography technique and a laser micromachining process, and allows easy integration with the sensors, detection circuit and electronics³. Biomass is estimated in two ways - based on impedance sensor measurements (ISM) in radio frequency (RF) range and on absorption measurements (AM) in near-infrared (NIR) spectra.

Presented work highlights various tested impedance sensor configurations within transparent microfluidic bioreactors, cultivation of MRC-5 fibroblasts (as the model adherent cells) in the fabricated microreactors and results of ISM and AM.

Viable cells are polarizable and act as dipoles, thus ISM can provide information of the cell concentration and consequently of biomass. In the RF range of 0.1- 40MHz polarization is very pronounced, but varies very strongly necessitating frequency scanning to obtain precise data. To record reliable and more accurate results, which is critical in such small-scale systems, we combine ISM method with AM - based on the light scattered from the cells. Further studies will include integration of both methods in a single chip and data analysis for precise interpretation of the measurement results.

Research performed within REALSENSE1 project (2019-2021; Good Food Institute 2018 Competitive Grant Program).

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Title: A roadmap for computational modeling in cell-based meat research and engineering
Cell-Based Meat Modeling Consortium (CMMC)

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Engineering competitive cell-based meat tissue products will require optimizing bioprocesses for efficiency and end-products for marketable characteristics. Optimization requires thorough and continued exploration of the design space as it evolves with innovation. Exploration is achieved through experimentation. Reducing cost and time required for experimentation is therefore paramount to industry success. Virtual experiments on computers using domain-specific software modeling tools accelerate exploration and reduce waste in most technology-dependent product industries. A number of cell-based meat companies and academic institutions recently formed a consortium to support the development of computational modeling tools specific to the industry. At its first gathering the consortium pinpointed bottlenecks in the production process and explored modeling solutions to these problems:

Medium composition. To aid the development of a well-defined replacement for the unwanted animal-based growth medium, several different computational techniques (including gene network and protein signaling network modeling and machine learning) can be applied.

Fluid flow through scaffolds. Necrosis owing to oxygen and nutrient depletion is a major problem in tissue engineering of muscle cells. Using fluid flow modeling coupled with optimization algorithms will enable exploration and optimization of scaffolds and reactor shapes.

Metabolic pathways. Understanding how cells in meat (muscle and fat) process nutrients internally is the key to optimizing production. Several existing metabolic modeling techniques can be applied to muscle and fat tissue to optimize input/output relationships.

Data collection and sharing. Modeling a process requires data, both qualitative (in the form of biological knowledge) and quantitative. It is thus critical to gather, standardize and document these data on a platform dedicated to modeling cell-based meat.

This presentation will report on the initial roadmap for computer modeling of cell-based meat charted by this consortium.



Title: A new method to control the color of cell-based meat

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Skeletal muscle tissue engineering applied in cell-based meat production for human consumption needs to be optimized for efficient growth and likeability to traditional meat. The color of meat is a major indicator for consumer buying decisions, and cell-based meat needs to closely resemble traditional meat color to avoid consumer rejection. The native color of meat is controlled by the content of heme proteins, and while several natural colorants such as beet juice have been applied in the past to mimic meat color, the addition of heme proteins to plant-based meat alternatives (“Impossible Burger”) has been shown to increase meat-like color, savory and taste. To evaluate whether heme proteins also have a positive effect on cell-based meat production, bovine muscle satellite cells (BSCs) were grown in the presence of hemoglobin (Hb) or myoglobin (Mb) in a fibrin hydrogel in 3D printed constructs to generate bioartificial muscles (BAMs). The heme protein influence on proliferation capacity, tissue formation, cell viability, biochemical activity and tissue color were analyzed. The proliferation of BSCs was significantly increased in the presence of Mb, while Hb had no effect or a slightly decreasing effect. All constructs showed high cell viability and alignment on the surface of the BAMs, while dead cells were observed within deeper layers of the tissue. Mb led to increased differentiation of BSCs into adult muscle cells, which was observed to a lesser extent with Hb. Both Mb and Hb led to a change of color in the BAM, which closely resembled the color of cured beef. Color can be further modified by amount, incubation time and the redox-form of heme protein applied. Taken together, these results indicate a potential benefit of adding heme proteins to growth media during cell-based meat production for cell proliferation and meat coloration.



Topic: Consumer behavior

Title: Are Consumers' Willing to Pay for Lab Produced Meat? An Investigation of Naming Effects

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In-vitro meat (IVM) technology could overcome some of the main concerns linked to conventional meat production, including the increasing demand for meat products, environmental impact, and animal welfare. Currently, there is an ongoing, uncertain and controversial debate related to whether IVM products should be labelled and communicated differently from conventional meat products and how.

In this research, we aim to investigate for the first time consumers' perception and willingness to pay (WTP) for IVM products as well as examine whether the use of different names for the IVM technology will lead to different consumers' WTP values. Our major contribution is to provide useful insights both for future labelling policies as well as for marketing and communication strategies of IVM products.

We conducted an online choice experiment in the United States on 625 participants to elicit consumers' WTP for IVM chicken products. To test naming effects, we used a between-subjects approach by randomly assigning respondents to three treatments. The treatments differed only on the name used to describe IVM technology (i.e. "cultured", "lab-grown" and "artificial").

Results show that consumers prefer chicken products produced with conventional production technology and tend to generally reject the IVM technology. However, the name "cultured" is less disliked than the names "lab-grown" and "artificial" and in turn, the name "artificial" is less disliked than the name "lab-grown". Findings also suggest that there is heterogeneity in consumers' valuation across different consumers' characteristics.

These findings have important implications for future labelling policies both for policy makers as well as IVM producers.



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Title: The future of human food: cultured meat

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The present study intends to analyze the results on the reactions of the consumers in relation to the concept and consumption of cultured meat in Brazil, a subject that stood out in the world after the tasting in 2013 of the first hamburger created with cells grown in the laboratory ^[1]. Mosa Meat (MAA), along with many other research centers around the world, is actively working on the cultured meat ^[2]. The first goal is to reduce costs and identify the most efficient technologies to improve production, making cultured meat retain the intrinsic characteristics of traditional hamburgers.

The cultured meat has been studied mainly because the world faces critical food shortages soon, as the demand for meat is expected to increase by more than two-thirds, according to the FAO ^[3]. However, the cultured meat has some barriers to be broken down before it is marketed, such as enriching stem cell research, food technology and 3D printing, fetching biomaterials, developing cell manufacturing, and gaining consumer acceptance ^[2].

The objective of the study was to evaluate the acceptance of a sample of the population on in vitro meat consumption to verify the position of this population in the face of the tendencies of the Brazilian ^[4] consumer market.

In this study, 170 participants were invited through online platforms to answer questions that consisted of images, texts and videos structured in 3 main themes that reflect emotions and beliefs as components of the formation of consumers' reactions.

Due to lack of product experience, consumers expressed their expectations on the transfer of information received by the online questionnaire.

The main initial consumer reactions in learning about cultured meat were supported by feelings of curiosity and considerations of lesser animal suffering. Consumers predicted many direct personal benefits of cultured meat and recognized possible global social benefits.

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Title: The perception of the stakeholders of the meat industry in South America on cellular agriculture: insights and policy recommendations.

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Cellular agriculture is considered one of the most important disruptions in the agrifood and agribusiness sector. It has the potential to change the nature of the meat markets and it could have significant effects in terms of food security, sustainability and health. One of the key topics to be explored is consumers' preferences and acceptance of cultured meat and the views and perspectives of different stakeholders of the meat industry. Consumers' preferences and stakeholders' views on cultured meat has been extensively studied in Europe and North America, using media-coverage methods, surveys or experimental methodologies (Bekker and Fisher, 2017; Bryant and Barnett, 2018; Stephens and Silvio, 2018). The results are far from being conclusive and more research is needed, especially exploring the influence of framing in the results. The situation in South America, on the other hand, is different.

To our knowledge, there are only a couple of studies that analyzed the phenomenon of cultured meat in South American countries (INTAL-BID, 2017; CEDEF, 2018). South America is an interesting case because the region is the world's leading exporter of beef and chicken and the consumption per capita of beef is the highest in the world. Moreover, the region is a leader in technology and genetics in the meat industry and the consumption of meat has a strong cultural significance. The objective of this paper is to analyze the consumers' views and acceptance of cultured meat and the views of different stakeholders (bureaucrats, technological institutions, consumers associations, NGOs) on the future of cultured meat. In-depth and online surveys are used in the countries of Argentina, Brasil, Chile, Uruguay and Paraguay. Preliminary results show that cross-cultural differences matter and the cultural resistance and political interests of the main stakeholders of the meat industry can delay the penetration of cellular agriculture in the region.



Title: Cultured meat and changing rural areas

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Global population growth, climate change and current livestock production creates “wicked problems” (Rittel & Webber, 1973) that change the food production systems. Novel food production technologies like cellular agriculture, where agricultural products are manufactured utilizing cell culturing techniques are essential in trying to solve these problems (Tuomisto & Teixeira de Mattos, 2011). These novel solutions, like cultured meat, challenge farmers to evaluate the possibilities and challenges they offer.

An objective of this abstract is to study what kind of changes these novel technologies would bring to the rural areas (Cor van der Weele & Tramper, 2014). A research about the impact of cultured meat on rural areas practically is non-existent. We aim at building a future scenario to understand possible changes. The future food production technologies are based on moral and ethical values that have not been collectively defined. What is the function of the farm animals in our food production if the cellular agriculture replaces animals?

Cellular agriculture is free from restricting factors like, growing seasons, production is not place-bound, and it could improve the environmental sustainability and the overall resilience of the future food system. Furthermore, to support this development the traditional and novel food production methods could utilize an advanced symbiotic relationship: solutions that combine farming, clean energy production and cellular agriculture (Tuomisto, 2018).

Change in the food systems has influence on the economics by creating new jobs in cell line management, production, and infrastructure, which will have regional impacts on rural areas. The essential question is how to prepare the food production system for changes that cultured meat brings? What are the requirements for the farmers of the future and how these novel technologies will impact to the regional change in societal, regional and local levels?

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would prefer to present the paper as:



Title: Cultured Meat in the Social Science Research – A Tentative Classification of the Challenges

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Cellular agriculture (CA) or technologies using cell cultivation to produce agricultural products are trending in the academia and public discourse. Products such as cultured meat are challenging to study from the social science perspective: products are not available, people have not tried them and the imagined product attributes are difficult to conceive. Novelties are often susceptible to fears, conspiracy theorising and the precaution principle: existing practices define the acceptable. The public has rejected competitive technological solutions being ahead of their time. Changes in the social and cultural meaning making systems tend to be slow and currently asynchronous with the rapid cultured meat development.

The objective is to present a literature-based analysis of the challenges of cultured meat in the social sciences. A search phrase including cultured meat concepts (Rätty et al. 2019) was utilised to retrieve a convenient sample of data consisting 101 peer-reviewed articles from the EBSCO, WoS and Science Direct databases (2005–2019). The data will be expanded and analysed later with a systematic literature review method (Tranfield et al. 2003).

The tentative review indicated five challenges how to:

1. influence consumers' perceptions and create marketing prospects (Bryant & Barnett 2018)
2. combine the novel foods with the current cultural and social expectations (Chiles 2013)
3. create consistent and informative media publicity (O'Riordan et al. 2017)
4. address philosophical, regulative and religious aspects related to ethical and moral issues (Schaefer & Savulescu 2014)
5. canvas credible and realistic future possibilities and scenarios (Bajželj et al. 2017).

The mass utilisation of CA necessitates a systemic shift. Early and clear introduction of the origins of cultured meat to social and cultural meaning systems will facilitate its acceptance. Addressing cultured meat from the perspectives of the market possibilities, integration to cultural and social codes of conduct, the means of representation, ethical and moral practices and positive visions for the future will likely level out the identified challenges.

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Title: The Good Food Institute’s Competitive Research Grant Program

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To date, the vast majority of money contributing to the development of cell-based meat products has come from private venture capital sources. Given that innovation is needed across multiple scientific areas, the cell-based meat industry would be best served by supportive research and development programs throughout academia. To this end, The Good Food Institute (GFI) has implemented a research grant program focused on addressing key technological areas for cell-based development, sponsoring new research projects in six labs across six different countries. Here, we provide an overview of the funded research projects and introduce information on the second call for proposals. We additionally discuss the implementation of a GFI-sponsored jobs board that will assist cell-based meat companies and researchers in academia in attracting new scientists and talent to their programs.

5th International Conference on Cultured Meat



Crowne Plaza,
Maastricht, the Netherlands
October 6-8, 2019

Participants list:

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ALLAN	Scott	Bath University	UK
AMIT	Michal	Accellta	Israel
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DING	Shabana	Merck Group	Germany
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HAMDAN	Mohammed	University of Malaya	
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SIMSA	Robin	Verigraft	Austria
SOLBERG	Nina	Nofima	Norway
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