

Cultured meat production: insights from a tissue engineering perspective

Prof. dr. ir. Lieven Thorrez
Tissue Engineering Lab
Dept. Development and Regeneration
KU Leuven, Belgium

KU LEUVEN

kulak

Very short history of cultured meat (mainstream version)

1932



“We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing; by growing these parts separately under a suitable medium”

2013



Prof. Mark Post

2016 Fast expansion with many startup companies

Very short history of cultured meat (science version)

1980ies

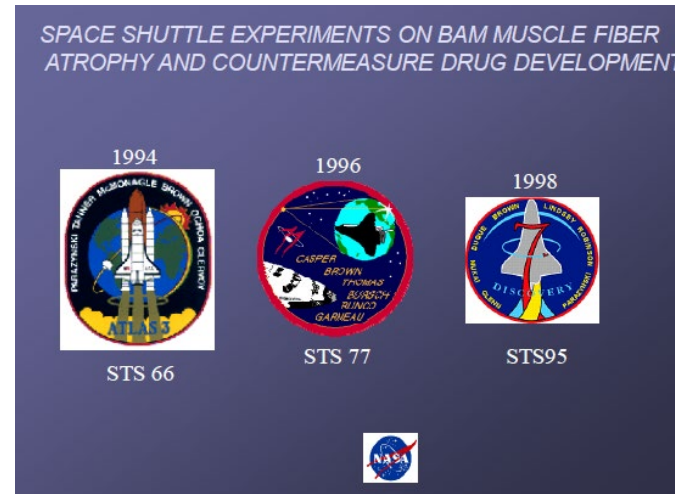
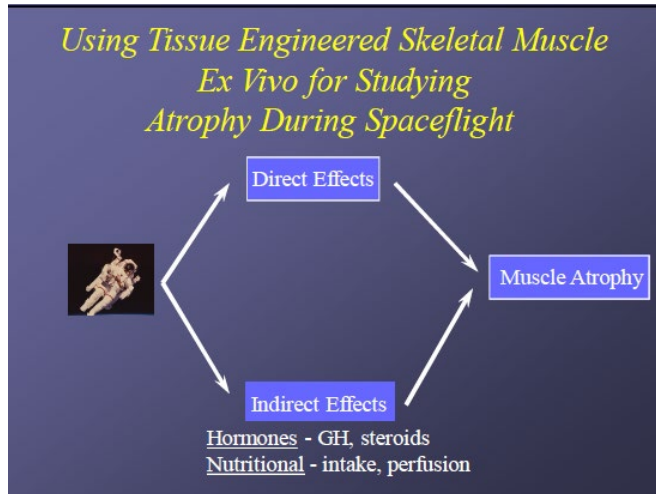


Prof. Herman Vandenburg

In vitro model for stretch-induced hypertrophy of skeletal muscle, *Science* 1979

Protein degradation in embryonic skeletal muscle.
Effect of medium, cell type, inhibitors, and passive stretch, *J Biol Chem* 1980

Maintenance of highly contractile tissue-cultured avian skeletal myotubes in collagen gel
In Vitro Cell Dev Biol 1988



History

2000s



Acta Astronautica

Volume 51, Issue 12, December 2002, Pages 879-889



In vitro edible muscle protein production system (mpps): stage 1, fish

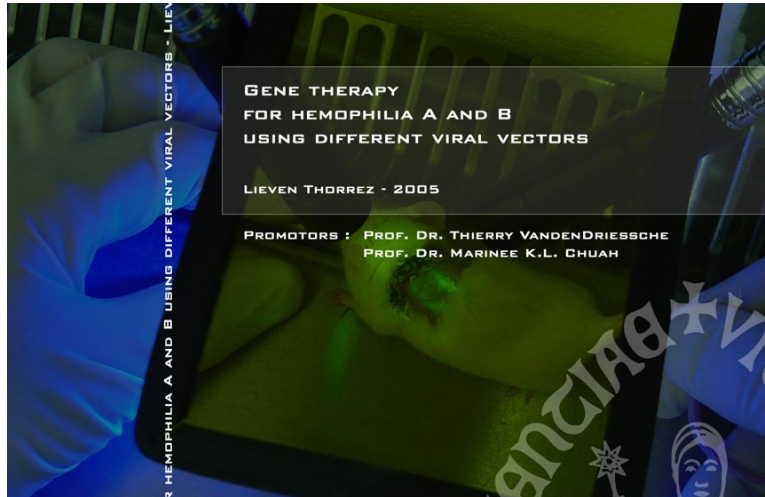
M.A Benjaminson & J.A Gilchrist, M Lorenz

TISSUE ENGINEERING
Volume 11, Number 5/6, 2005

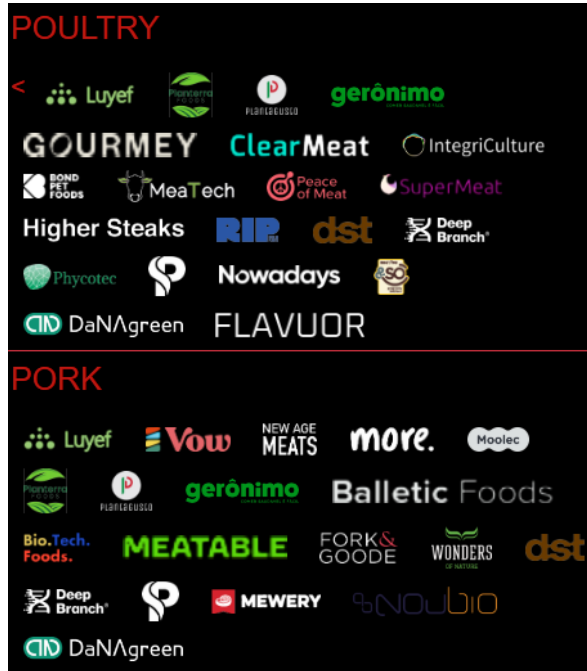
Commentary

In Vitro-Cultured Meat Production

P.D. EDELMAN, M.Sc.,¹ D.C. McFARLAND, Ph.D.,² V.A. MIRONOV, Ph.D., M.D.,³
and J.G. MATHENY, M.P.H.⁴



About \$3 billion of total investment



<http://protein.ketmaps.com/>

Next to many others claiming to produce pet foods, scaffold materials, culture media, ...

Currently only GOOD Meat has a product “on the market”

Definition

Strict sense: Biological tissue (often muscle) -created in the lab or an industry setting, without killing an animal - that is exactly the same as the tissue in an animal

Broad sense: creation of a meat-like product, using animal cells as part of the ingredients, “hybrids”
(but: challenges for definitions)

The first “hamburger”



For the patty, tens of thousands of these beef circles were turned over to Peter Verstrate, a self-employed food technologist in the Netherlands, who cut the rings to produce shreds of meat about a centimeter long, which he ground up. He added **breadcrumbs** and some **binder** to improve the texture, but color was a problem: Because of a lack of myoglobin—the oxygen-carrying molecule that makes muscle tissue red—the meat looked white. A mix of **beetroot juice**, **saffron**, and a little bit of **caramel** made the raw burger look a pinkish red and helped it turn brown while cooking.



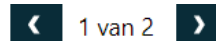
Prof. Mark Post €250000 burger

Kupferschmidt K. Food science. Lab burger adds sizzle to bid for research funds. Science, 2013.

Hamburger uit labo kost over drie jaar nog maar elf euro

11/10/2016 om 06:00 door Van onze redactrice Myrte De Decker

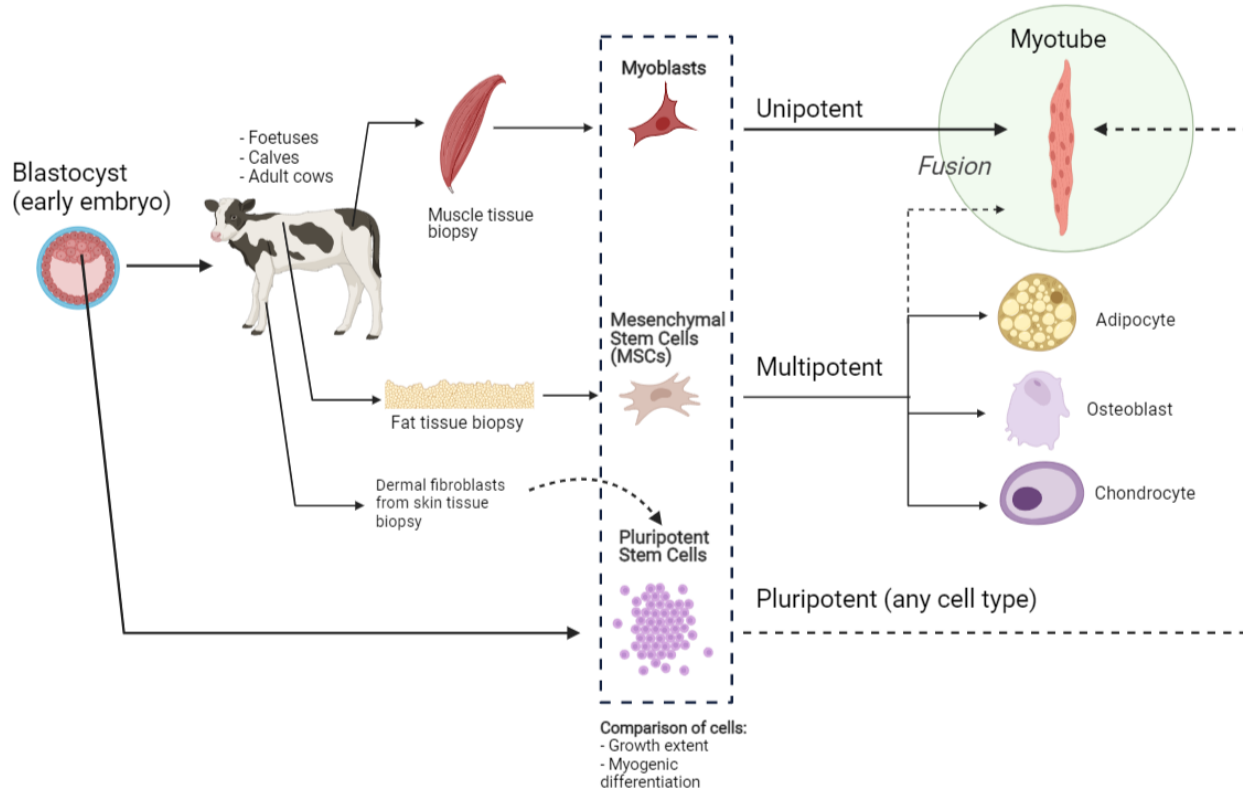
Mark Post: 'Deze burger heeft geen schadelijke stoffen.' Foto: belga



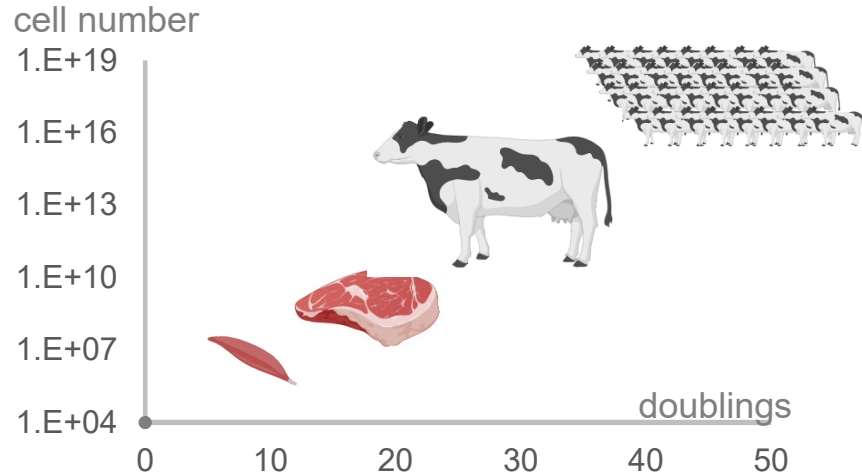
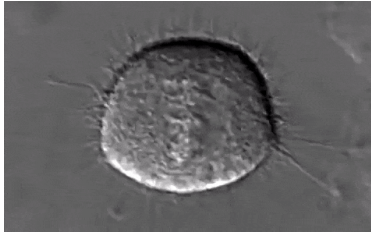
Nog een drietal jaar en dan zou de ‘kweekvlees’-burger erkend moeten zijn door de Europese Commissie. ‘Ik ken de inhoud. De burgers hebben geen schadelijke stoffen.’

De Standaard Oktober
2016

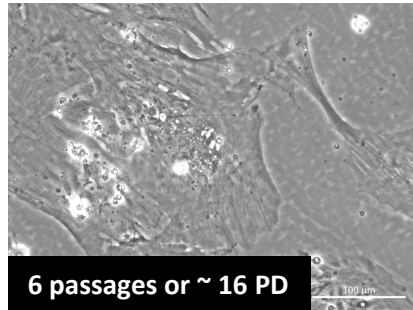
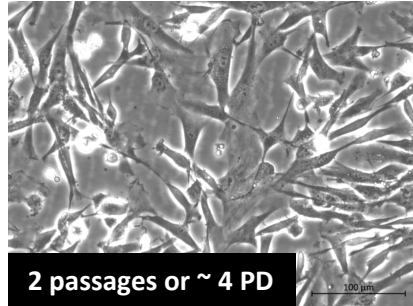
Cell source



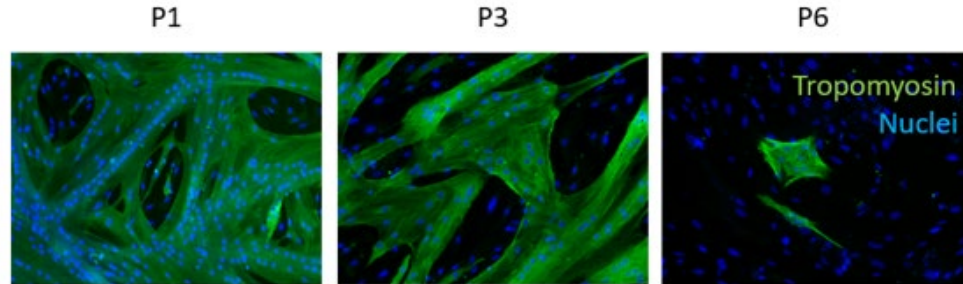
Cell expansion



Properties of expanded bovine myoblasts



- Increased doubling time
- Increased cell size
- Reduced function (myotube formation)



P – passage
PD – population doubling

Maria Olenic Retaining myogenic capacity during myoblast expansion:
another challenge for cultured meat production
- 8th International Scientific Conference on Cultured Meat - 10.10.2022

Use of pluripotent stem cells → genetically engineered for differentiation

Cell culture media

Liquid with glucose, amino acids, salts, vitamins,...
Basal + serum (replacement) : amount -- COST !!!



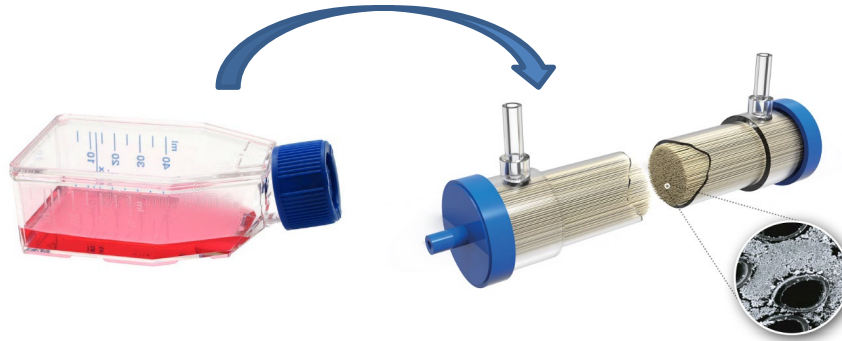
“ Clean culture media for clean meat: We did it ! Our R&D team managed to develop a 3-product portfolio for myosatellite cells”

However:

” Cells stop growing after 4 to 5 passages. The growth rate is 15% to 20% of what I have observed from FB containing medium. ” (personal communication, 10/2019)

Note: cows convert waste streams -> human nutrition. Not clear if waste streams can be used for cultured meat

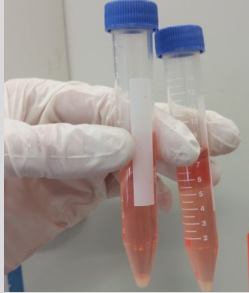
Bioreactors: cell expansion



Terzake docu Kweekvlees
(26/12/2018)

Scaffold materials - structuring

a bunch of cells \neq muscle



Biomedical applications: collagen & fibrin

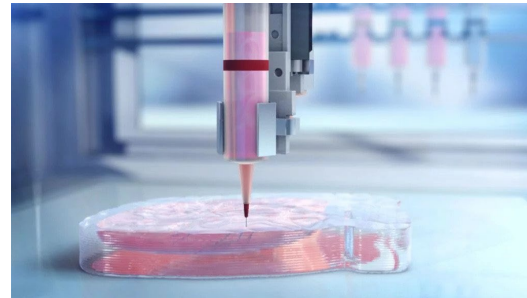
Hydrogels versus more stiff matrices

Food-grade materials



Ben-arye et al 2020

Tools for structuring

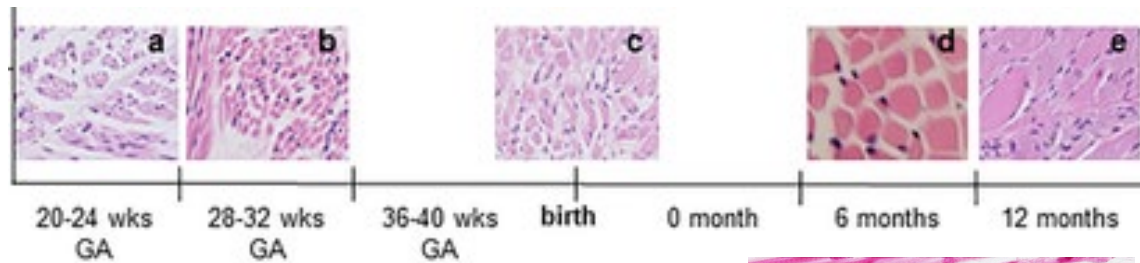


Tissue maturation

Muscle development (Romero et al. Handb. Clin. Neurol 2013) :

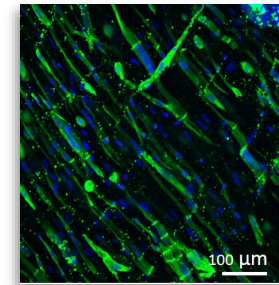
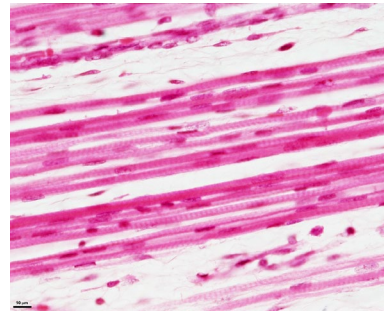
10 -13 weeks of gestation: fusion of myoblasts generates primary myotubes with central nuclei

15-18 weeks of gestation: myotubes become myofibers with peripheral nuclei

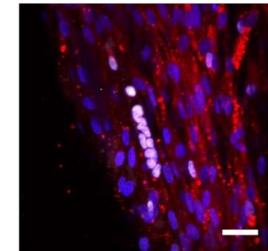


Verbeek et al. (2020) PLOS ONE

Pre-birth longitudinal muscle histology:
<https://embryology.med.unsw.edu.au/>



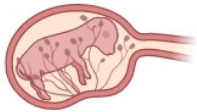
Tri-culture



Ben-arye et al. 2020

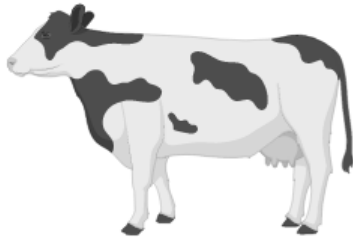
Tissue maturation

embryonic

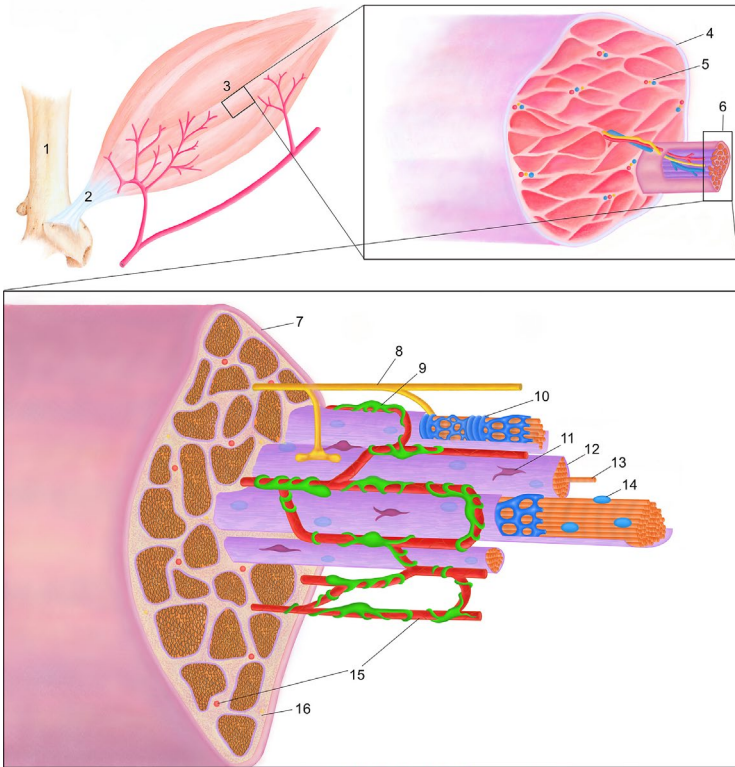


time

mature



Other cel types, organization ?



Connective tissue structure ?

Fat composition, distribution?

Company
name

is raising the steaks with faster manufacturing, culling the time it takes to send a cell-grown piggy to market

has developed the ability to create high-quality cultivated meat in only eight days, a significant reduction in the process, which previously would take three weeks.



Cate Lawrence
23 May 2023



Marketing story

Nutritional value, safety, sustainability

Farm-raised meat also provides essential minerals, creatine, carnosine and vitamins B and D

Post-mortem processes

Perhaps everything can be added to the medium, but then why not consume the medium directly ?

How do we define meat ?

-> Novel foods require novel assessment methods

Fraeye I, Kratka M, Vandeburgh H, Thorrez L (2020). Sensorial and Nutritional Aspects of Cultured Meat in Comparison to Traditional Meat : Much to Be Inferred. *Frontiers in Nutrition* 7: 35.

Chicken nuggets ?



Upscaling



Image credit: Mosa Meat

Mosa Meat opens new facility in Maastricht, sees 'a clear path towards price parity' for cultivated meat

May 8, 2023 Elaine Watson

A decade after cofounder Dr. Mark Post unveiled the world's first beef burger made from animal cells grown outside of an animal, Dutch cultivated meat startup **Mosa Meat** has opened a 30,000sq ft 'scale-up plant' in Maastricht as it edges closer to commercialization.

“the plant will initially have the capacity to make tens of thousands of cultivated burgers a year from 1,000-liter bioreactors.”

- 50000 burgers of 150g/burger
- = 7500 kg output annually
- = amount of meat from 25 cows

What we don't know:

- What inputs go into the facility ?
- What energy consumption ?
- How many highly trained people are needed ?
- What amount and kind of waste streams are generated ?
- Are antibiotics needed ?
- What is the total operational cost ?

"Cellular agriculture": current gaps between facts and claims regarding "cell-based meat"

P. Wood , L. Thorrez , J-F. Hocquette , D. Troy , M. Gagaoua. Anim. Front. 2023. 13(2):68-74.

Policy influence



Food and Agriculture Organization
of the United Nations

Scientific advice on cell-based food products and food safety considerations

Call for experts

Phase I application deadline – 30 April 2022

Phase II application deadline – 20 May 2022

Background

In 1932, Winston Churchill stated: “We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium” (Churchill, 1932). After decades of research and development, the technology has now matured, and Churchill’s idea has become a reality. The production can be done via *in vitro* cultivation of animal cells and then processed into products whose composition can be comparable to conventional animal products without needing the whole animal (Post, 2014; Kadim *et al.*, 2015).

Since the initial studies in the early 2000s, cell-based food production methodologies have been well characterized, meaning they are now ready to move from laboratories to production facilities. In 2013, the first beef burger produced through this technology was presented to the world (Post, 2013). In December 2020, the first cell-based chicken nuggets were approved in Singapore. As of November 2021, there are more than 75 start-ups developing various cell-based products around the world (Byrne, 2021). This commercial landscape is fast expanding with many types of products and commodities such as various types of meat, poultry, fish, aquatic products, dairy and eggs in the pipeline for future commercialization.

Conclusions

Many questions remain



cost?

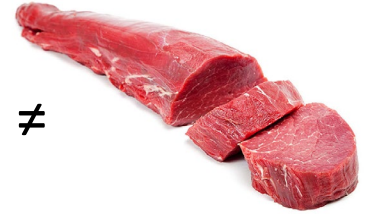
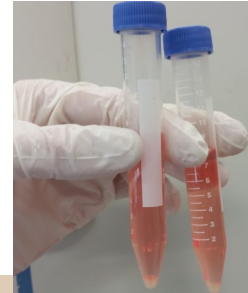


upscaling?



environment?

tissue structure?



≠



healthy?

**Independent academic research is highly needed
to discriminate facts from wishful thinking and to guide policy**

Olenic & Thorrez. Cultured meat production: what we know, what we don't know and what we should know.
Italian journal of animal science 2023.

Acknowledgements

Tissue engineering lab



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<http://kuleuven-kulak.be/tel>

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