“Cultured Meat”: Is it possible? Is it good? Is it acceptable?

Jean-François Hocquette, Marie-Pierre Ellies-Oury, Sghaier Chriki

“Cultured Meat”: Is it possible? Is it good? Is it acceptable?

Report of the workshop organized by the French Academy of Agriculture, the French Association for Animal Production, the French Veterinary Academy and the French Society for Human Nutrition

Jean-François Hocquette, Marie-Pierre Ellies-Oury, Sghaier Chriki,
And Michel Duclos, Hervé This, Beatrice Morio, Claude allo

1) Is it possible?
   a) History
   b) Principles
   c) Is it really meat?
2) Is it good?
   a) For the society
   b) For our planet
   c) For animals
   d) For health
3) Is it acceptable?
   a) By consumers
   b) By the society









1) IS IT POSSIBLE? 1a) History

There is consensus about the problem to solve

Nowadays, the livestock and meat sectors are facing new and important challenges:

- balancing the need for increased production of animal products (to satisfy the increasing human population)
- coupled with a lower footprint



- addressing societal needs in terms of animal welfare and product quality for the consumer

➔ Consequently, we should be innovative

Scollan (UK), Greenwood (Australia), Newbold (UK), Yáñez Ruiz (Spain), Shingfield (Finland), Wallace (UK) and Hocquette (France), Animal Production Science, 2011, 51, 1–5. https://doi.org/10.1071/AN10051

Promises of “cultured meat” companies



Kinder for you



Kinder for society worldwide



Kinder to cows (and other animals!)



Kinder to the planet

REIMAGINING MEAT FOR AN UNCOMPROMISING AND CONSCIOUS GENERATION

“It tasted of a future free of any feelings of guilt for cruelty to animals and pollution of Mother Earth. But really, it tasted just like a good steak.”

Sources: websites of private companies aiming to commercialize « cultured meat ».

History of cultured meat

- In 1931, Winston Churchill wrote: "We shall escape the absurdity of growing a whole chicken to eat the breast or wing, by growing these parts separately under a suitable medium."
- In the 1950s, Dutch researcher Willem van Eelen independently came up with the idea for cultured meat.
- In vitro cultivation of muscle fibers was first performed successfully in 1971 by professor Russel Ross.
- In 1991, Jon F. Vein (USA) secured patent US 6835390 for the production of tissue-engineered meat for humans.
- In 2001, several scientists announced that they had filed for a worldwide patent on a process to produce cultured meat. That same year, NASA began conducting experiments on cultured meat.
- In 2004, Matheny founded New Harvest, which aims to encourage development of cultured meat.
- In 2008, PETA offered a $1 million prize to the first company to bring cultured chicken meat to consumers by 2012. It was later extended until 4 March 2014. The deadline eventually expired without a winner.
- In 2008, the Dutch government invested $4 million into cultured meat. The In Vitro Meat Consortium held the first international conference on the matter, hosted by the Food Research Institute of Norway in April 2008.

https://en.wikipedia.org/wiki/Cultured_meat

The First In Vitro Meat workshop, June 15, 2007

First international symposium April 9-11, 2008



The symposium was held at the Norwegian Food Research Institute (Matforsk), Aas, Norway, hosted by the Norwegian University of Life Sciences (UMB) and the Norwegian Food Research Institute (Matforsk).

http://invitromeat.org/

The first “cultured steak”

Mark Post (2013): « In seven years, you’ll eat *in vitro* meat. »







On August 5, 2013, Prof Mark Post of Maastricht University presented a burger made from Cultured Beef in front of an invited audience in London.
This was acknowledged by the World Technology Network when M Post received the World Technology Award for Environment on 15 Nov 2013.
This burger costed €250,000.

Bill Gates and Richard Branson Embark on the Business with Artificial Meat (August 30, 2017). They chose to invest capital in the new Memphis Meat Company.

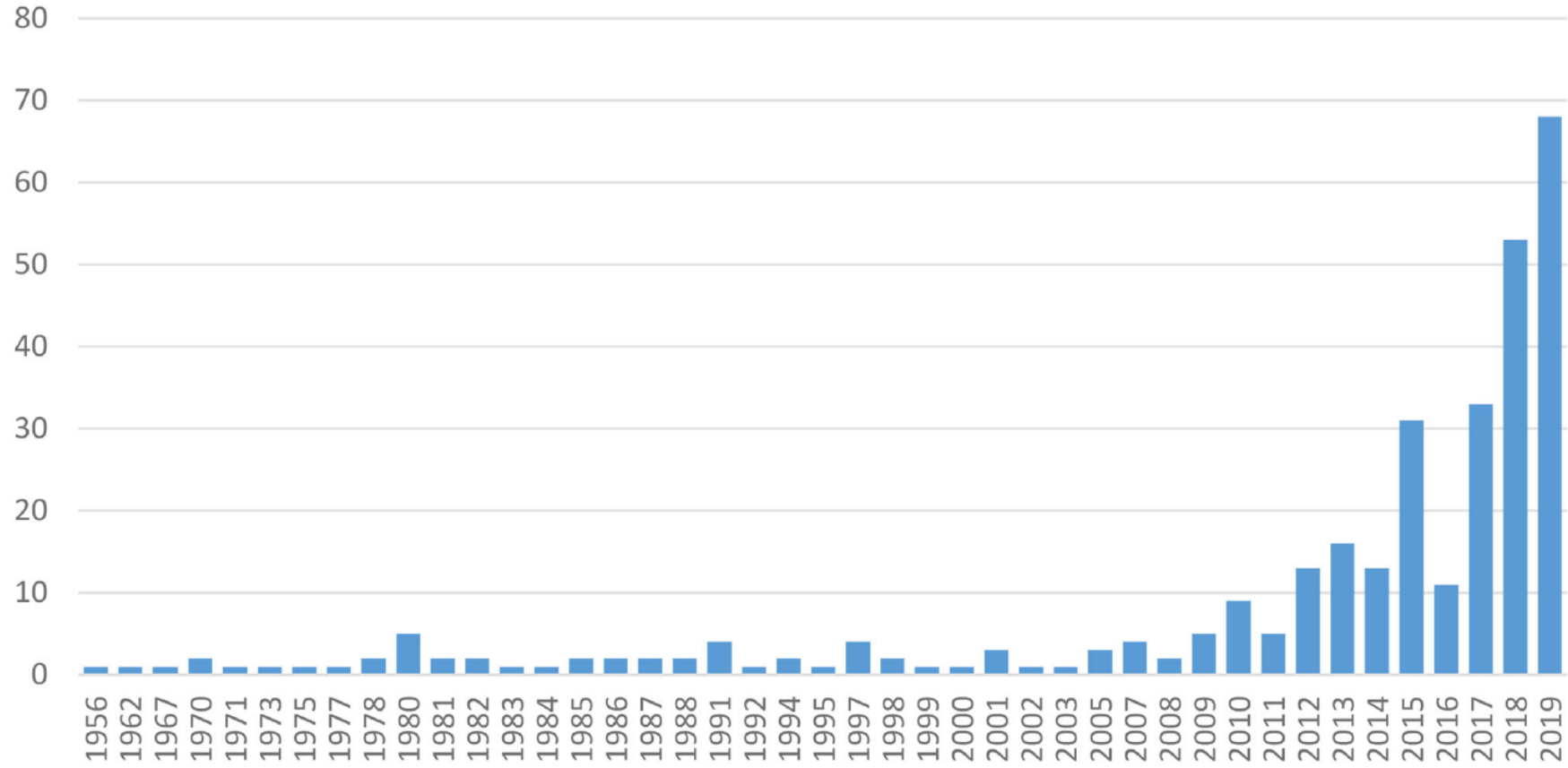
1) IS IT POSSIBLE?

Theoretically yes, because cell culture is well known in a great number of research labs and can be used to produce “meat” as some start-ups claim

In décembre, 2020

Singapore Approves a Lab-Grown Meat Product, a Global First

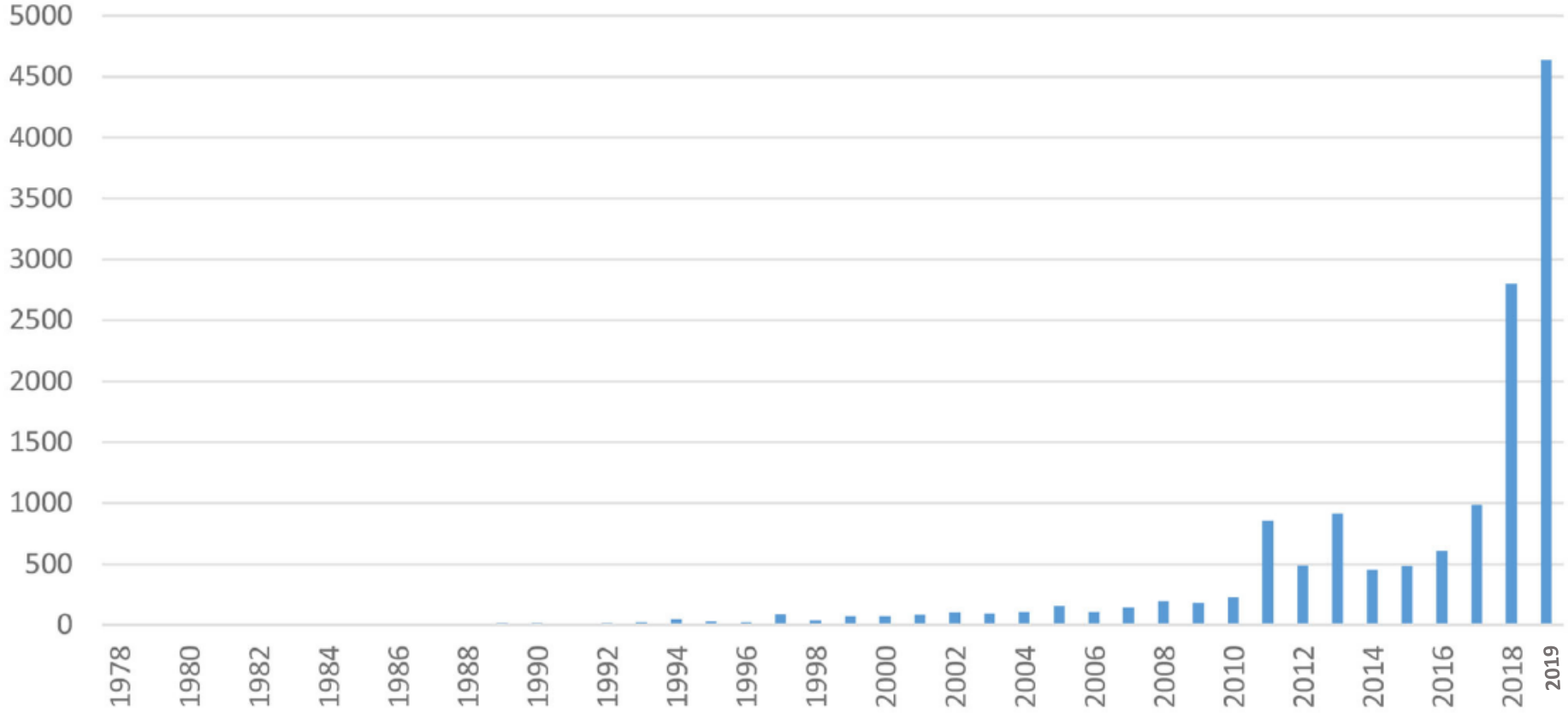
Number of scientific papers dealing with cultured meat



INRAE

Chriki et al., (2020). Frontiers in Psychology
vol 11 | Article 1845, doi: 10.3389/fpsyg.2020.01845

Number of articles in the press media dealing with cultured meat

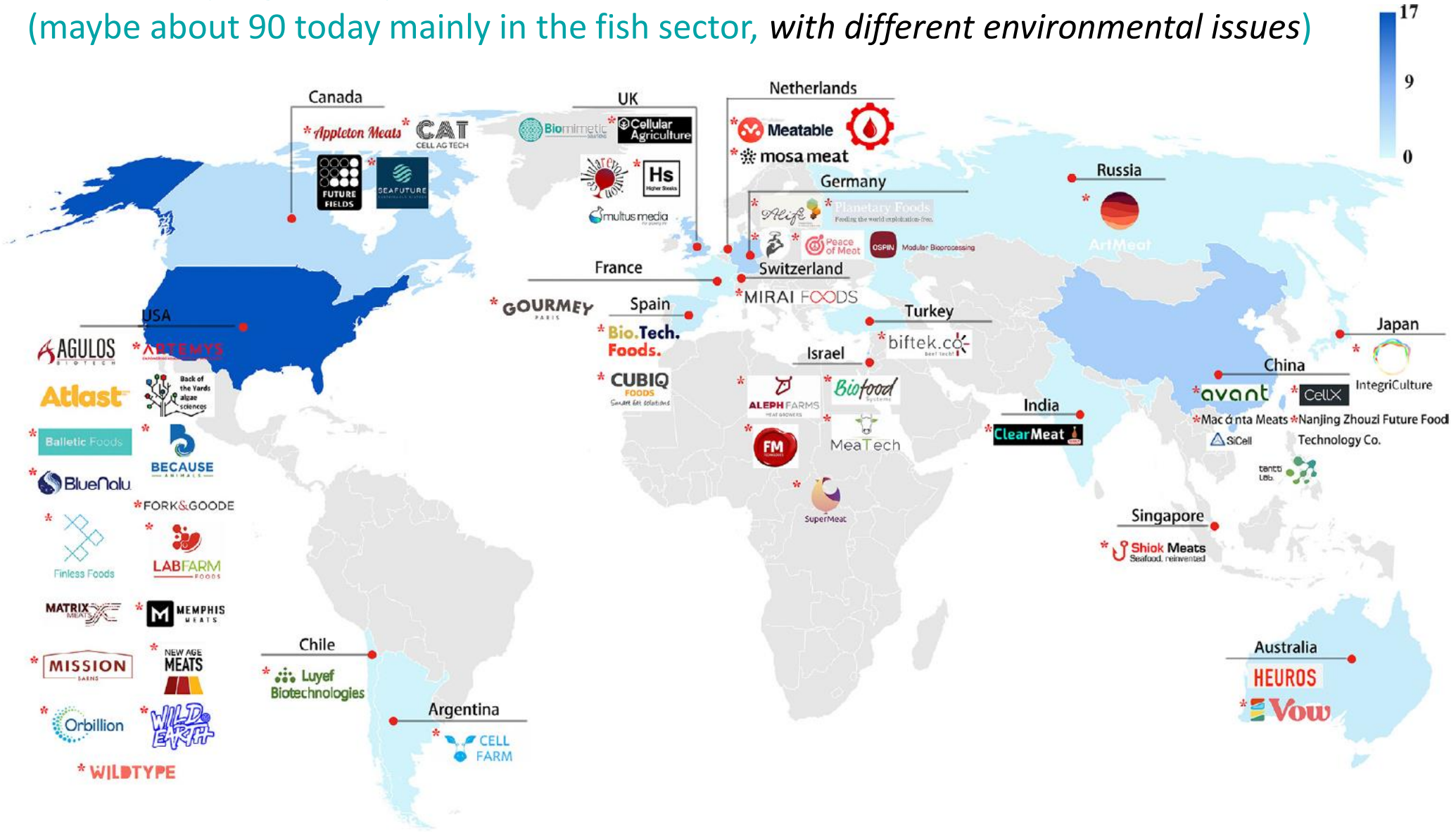


INRAE

Chriki et al., (2020). Frontiers in Psychology
vol 11 | Article 1845, doi: 10.3389/fpsyg.2020.01845

Geographic distribution of “cultured meat” companies.

Fifty-eight companies in the field of cultured meat/fish are included
(maybe about 90 today mainly in the fish sector, *with different environmental issues*)



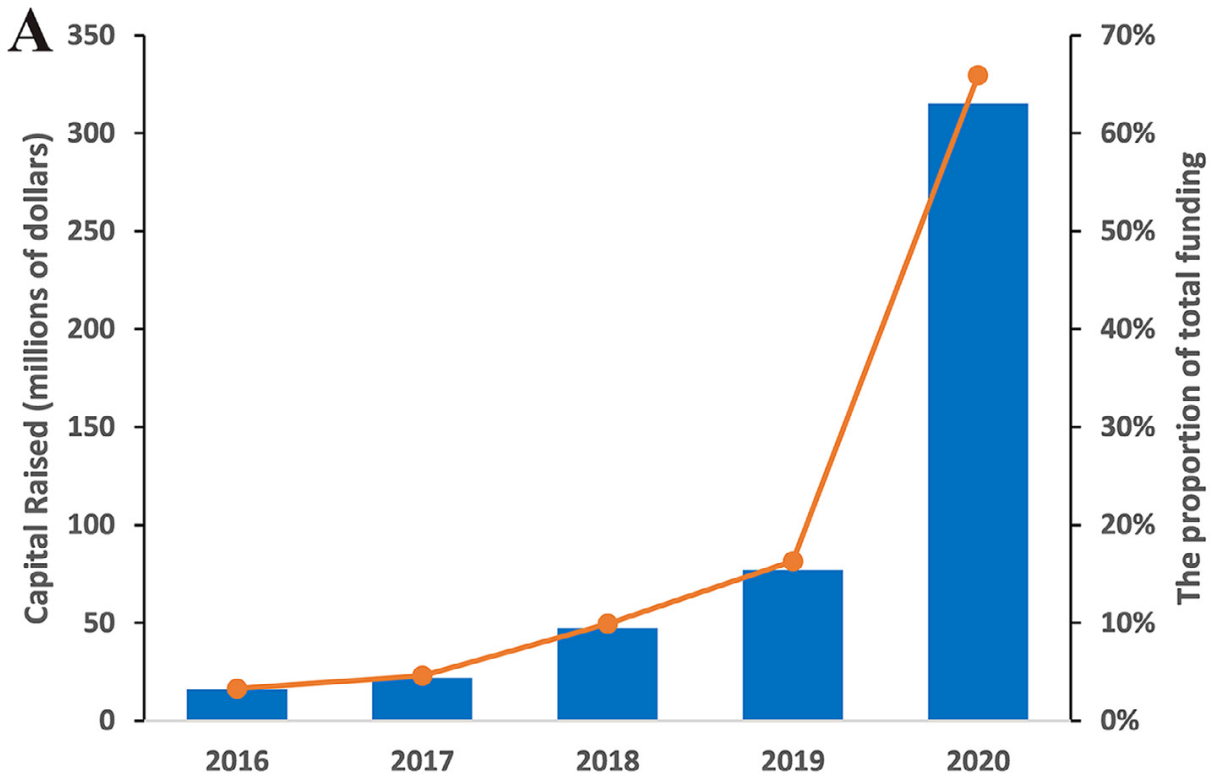
Guan, Lei, Yan et al. Future Foods 3 (2021) 100032

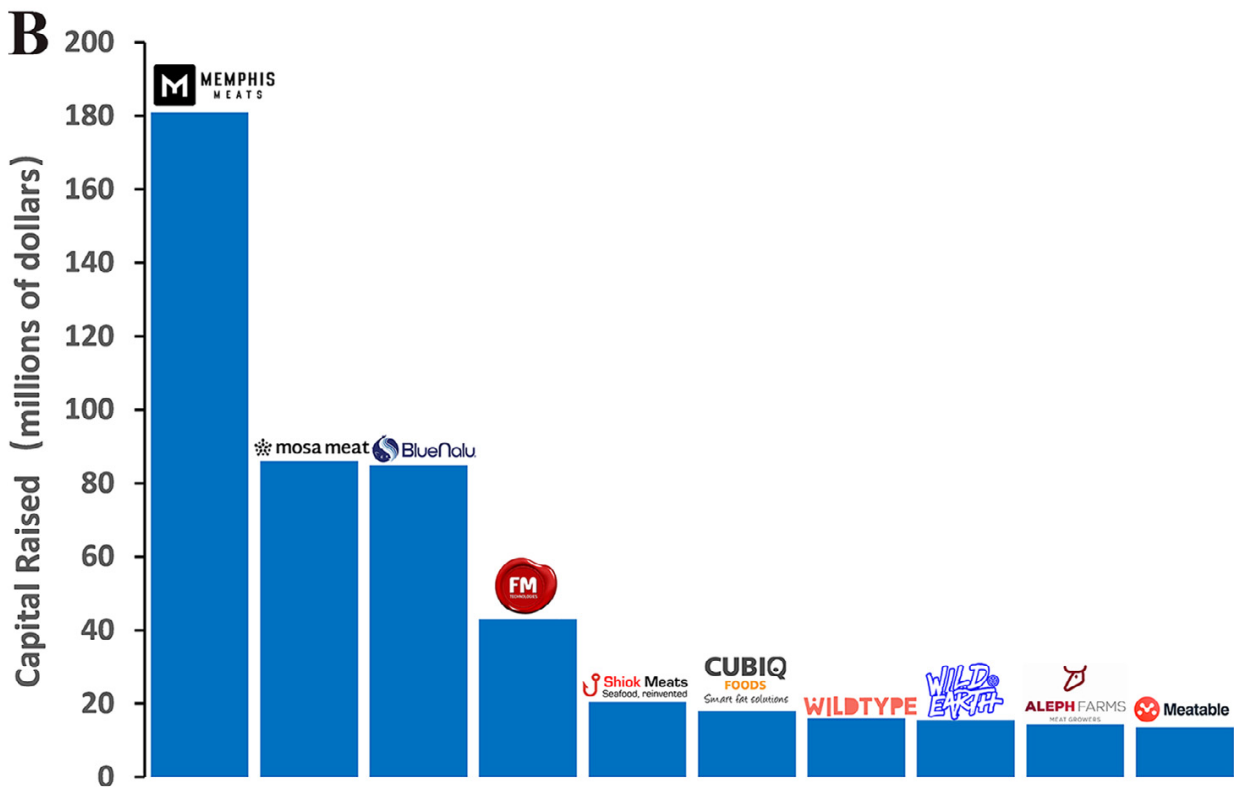
Capital investment of cultured meat industry.

A) Total capital invested in cultured meat companies over the years.

B) Top ten companies regarding the capital investment.

Funding data are collect ed from publicly available resources by Dec 31, 2020.





Guan, Lei, Yan et al. Future Foods 3 (2021) 100032

BIG MEAT COMPANIES ARE MOVING INTO PLANT-BASED SUBSTITUTES

Cargill™

Meat giant



- Invested in lab grown meat company — ALEPH FARMS MEAT GROWERS
- Joint venture with pea protein firm — PURIS
- Contracting to source insects for animal feed — INNOVA FEED
- Introducing its own plant-based meat substitute

JBS FOODS

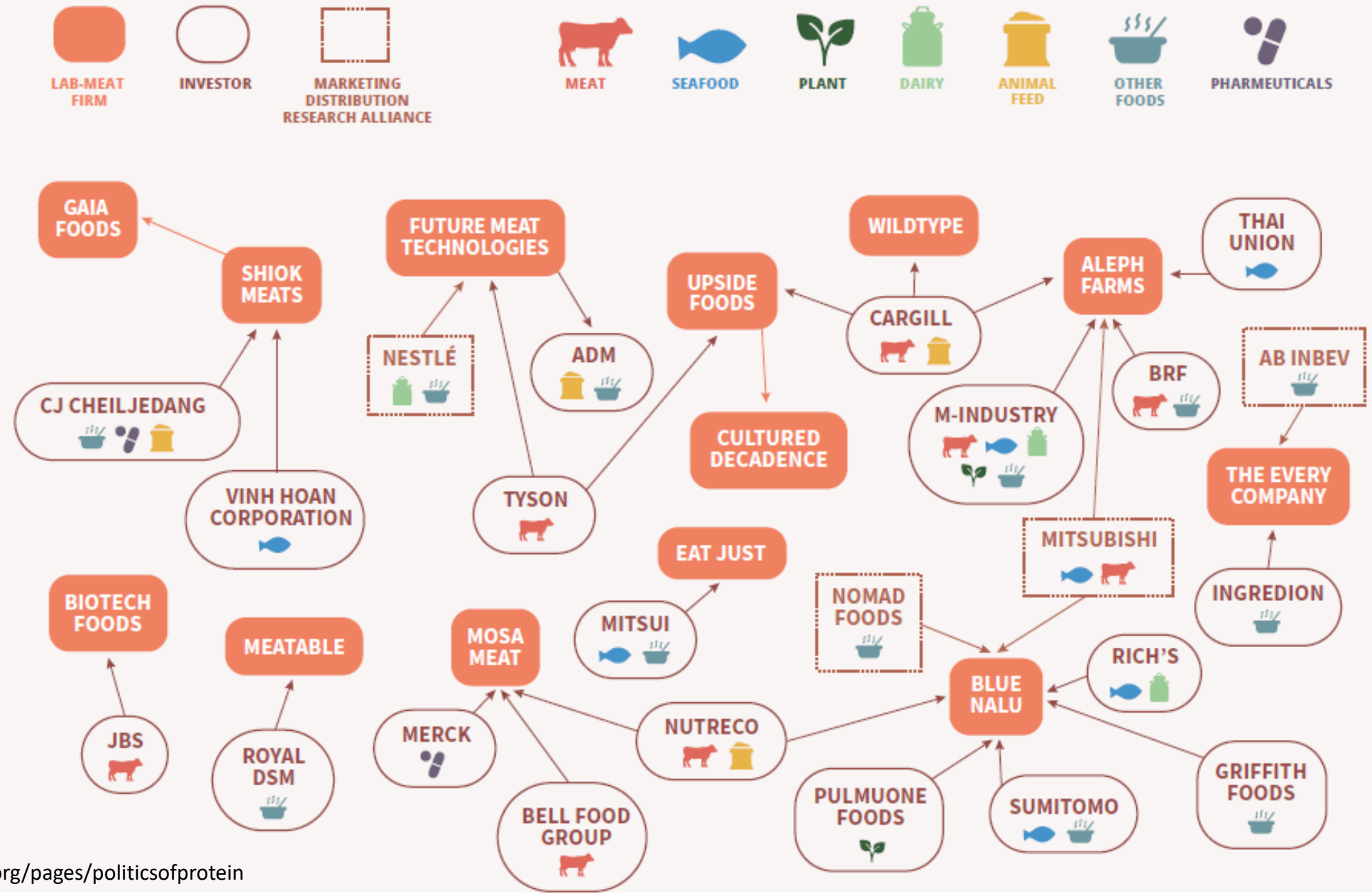
The largest meat company in the world



- Purchased Bio.Tech. Foods. (A Spanish lab grown meat firm)
- Investing $100M in developing lab grown meat

www.ipes-food.org/pages/politicsofprotein

LARGEST LAB GROWN MEAT FIRMS AND KEY INVESTORS



www.ipes-food.org/pages/politicsofprotein

1) IS IT POSSIBLE?

CALIFORNIA'S NEW LAB-GROWN MEAT FACILITY IS THE MOST ADVANCED IN THE WORLD - 2020



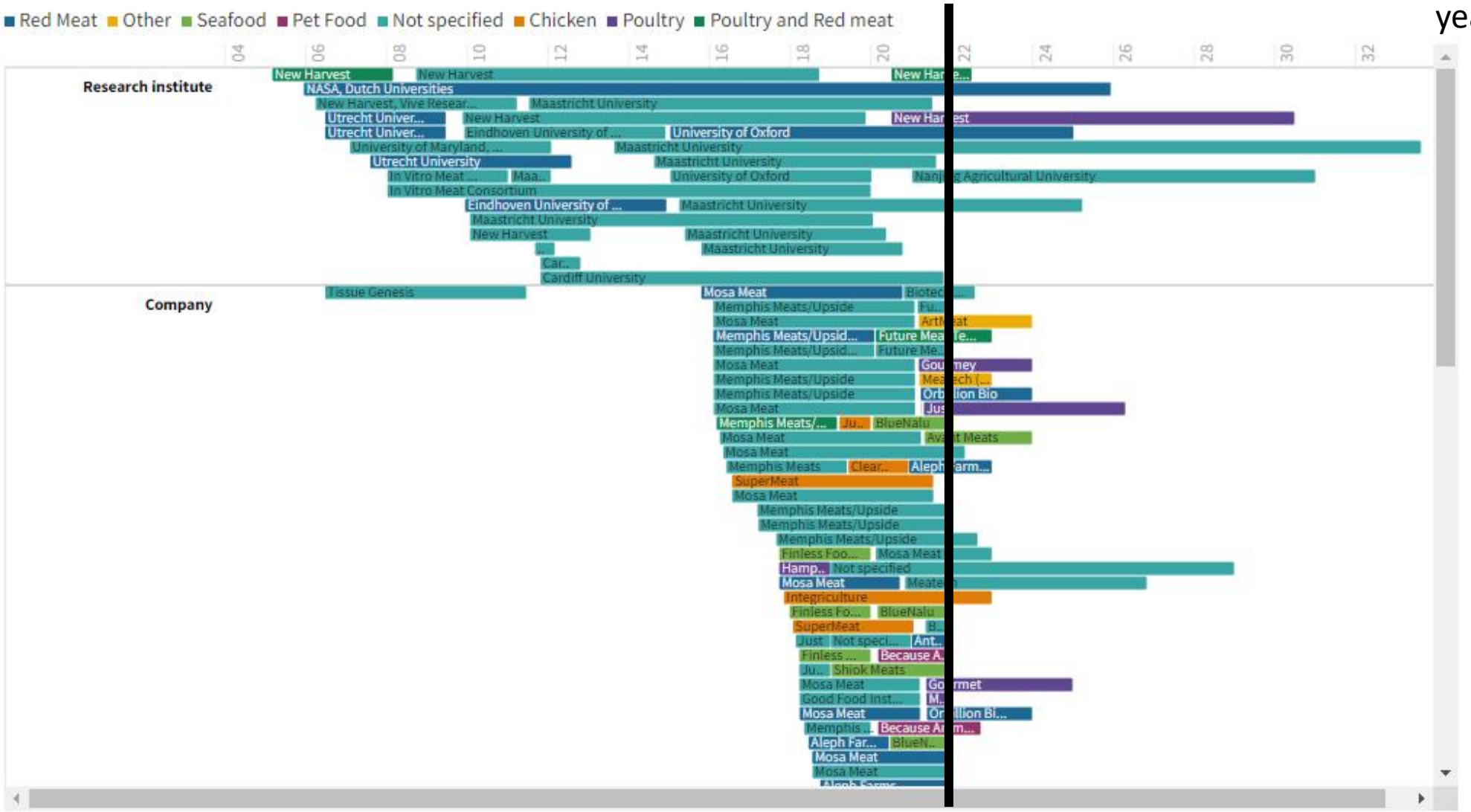


June 2021

Growing Burgers

Israeli biotech company Future Meat has opened what it claims to be the "world's first industrial cultured meat facility," a watershed moment in the development of futuristic meat alternative products.

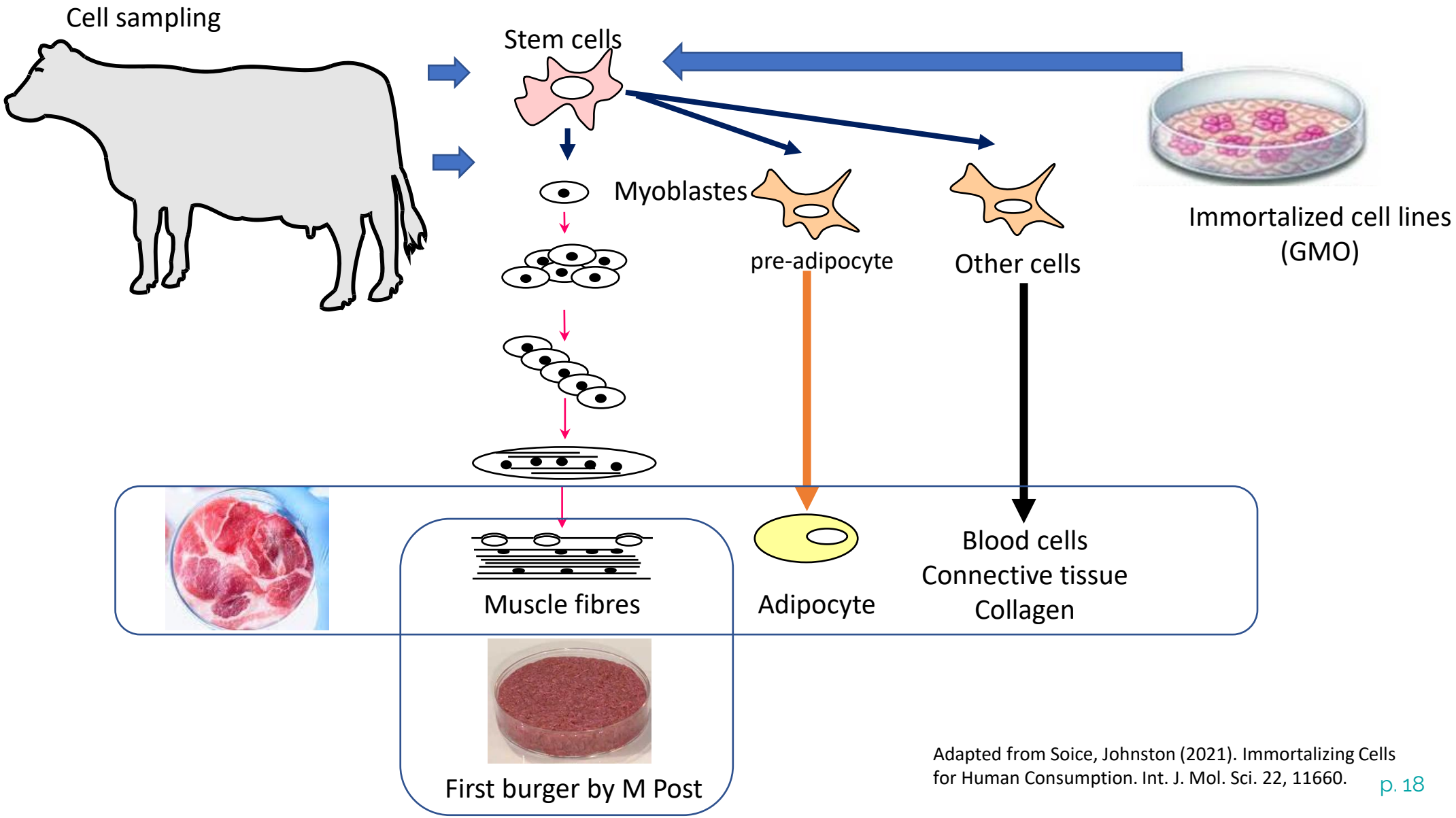
Cultivated meat companies have repeatedly missed product launch deadlines



Source: Data visuals by Sinduja Rangarajan. Data compiled by Tom Philpott, Allison Esperanza, and Alexis Madrigal

https://thecounter.org/lab-grown-cultivated-meat-cost-at-scale/

1) IS IT POSSIBLE? 1b) Principles



Adapted from Soice, Johnston (2021). Immortalizing Cells for Human Consumption. Int. J. Mol. Sci. 22, 11660.

There is a consensus about the technical problems to solve

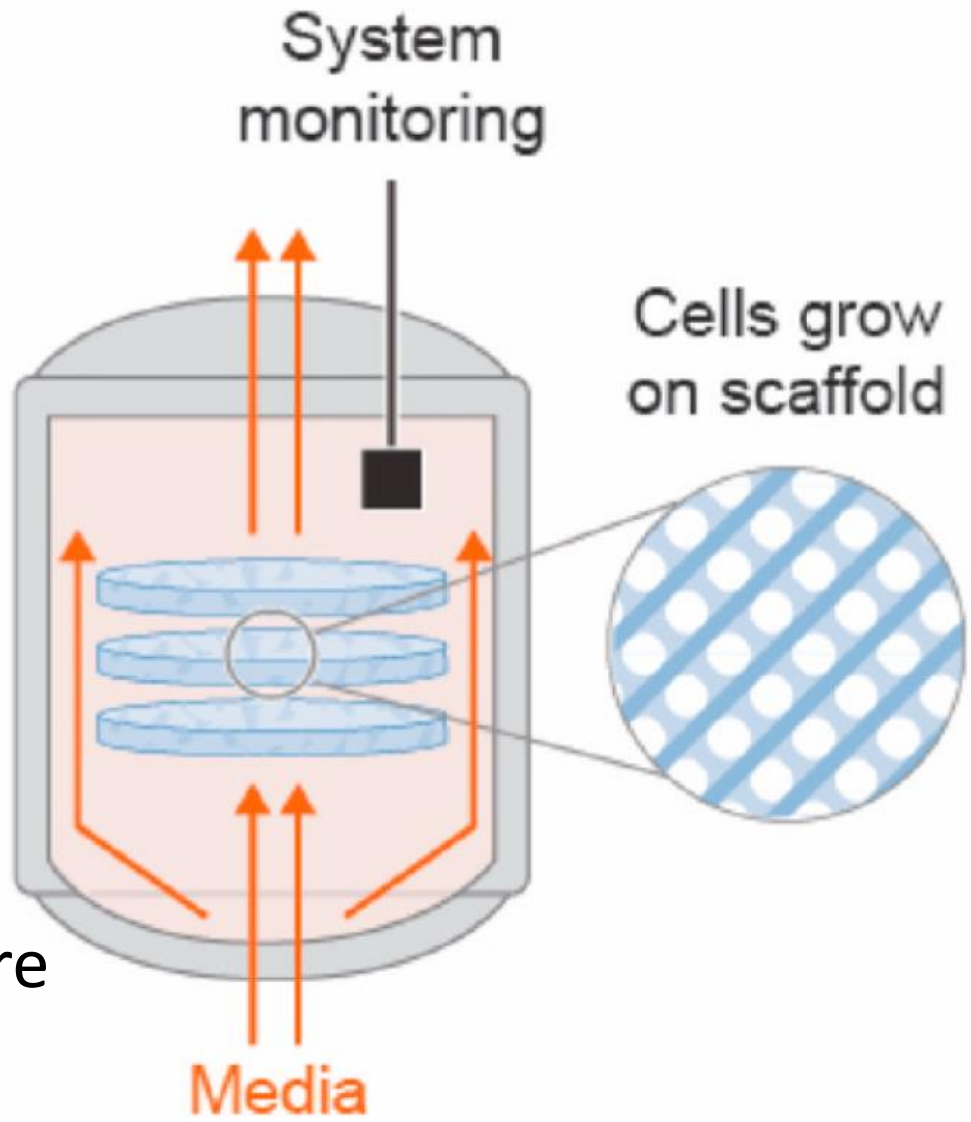
Current limitations across four domains are described by Chen et al. (2020):

- cell line development,
- cell culture media (fetal bovine serum),
- scaffolding, and
- bioreactors.

Chen et al. (2022). Biomaterials 280, 121274

The great challenge is to efficiently produce "cultured meat" products at scale, this needs new concepts and bioprocesses that did not exist before

Bellani et al (2020) Front. Nutr. 7:575146.



Issues with culture conditions



Numerous nutrients (carbohydrates, amino acids, lipids, vitamins…), growth factors (TGFβ, FGF, IGF) **and hormones** (insulin, thyroid hormones and/or growth hormone) **are necessary** for cell culture.

Currently, in most research labs, stem cells are often cultured in a medium containing antibiotics and fungicides for safety as well as fetal bovine serum. An animal component-free medium for cell culture is needed. **The precise nature of the composition of this serum is unknown.**

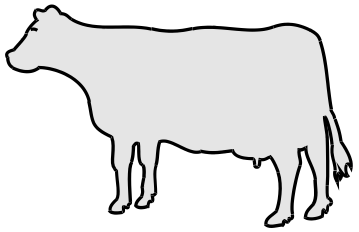
Scaffold material must be food-safe, edible, or biodegradable and derived from animal-free sources.

A challenge is to produce, in **large quantities and in an edible way**, new media necessary for the culture of muscle cells. Compounds will have to be prepared by the chemical industry or genetic engineering, and our environment is likely to be polluted by waste generated by this process

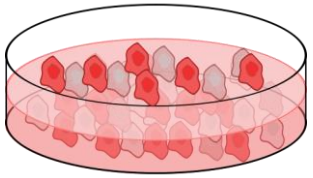
The efficiency of the whole process (outputs / inputs) is still unknown

1) IS IT POSSIBLE? 1c) Is it really meat?

Tissue sample



Cell multiplication

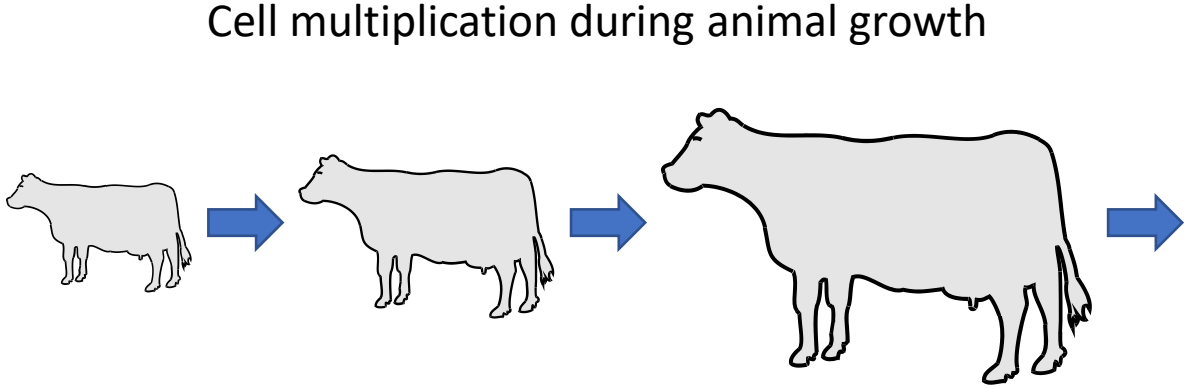




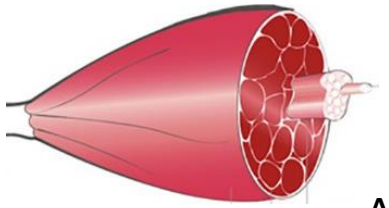
Muscle fibres or
a mixture of muscle cells

Addition of missing
compounds

Cell multiplication during animal growth









Ageing
(10-30 days for beef)

Muscle

Meat

Chriki et al. (2022). Animal Frontiers, 12, 35-42

Grape and wine are two different concepts, but also muscle and meat



Vinification





Ageing



It is not (yet) meat according to the American Meat Science Association (AMSA)

AMSA: *"To be considered meat, in vitro meat must … be inspected and considered safe for consumption, and be comparable in composition and sensory characteristics to meat derived naturally from animals"* [essential amino acids, fatty acid composition, macro- and micronutrient]

- Meat is the edible tissues from an animal consumed as food.
- Meat analogs (plant, fungal, and bacterial) used to make imitation meat products are not considered meat.
- In vitro meats that originate from animal cells may be considered meat in the future.

Boler, D.D., and D.R. Woerner. 2017. What is meat? A perspective from the American Meat Science Association. Anim. Front. 7:8–11. doi:10.2527/af.2017.0436

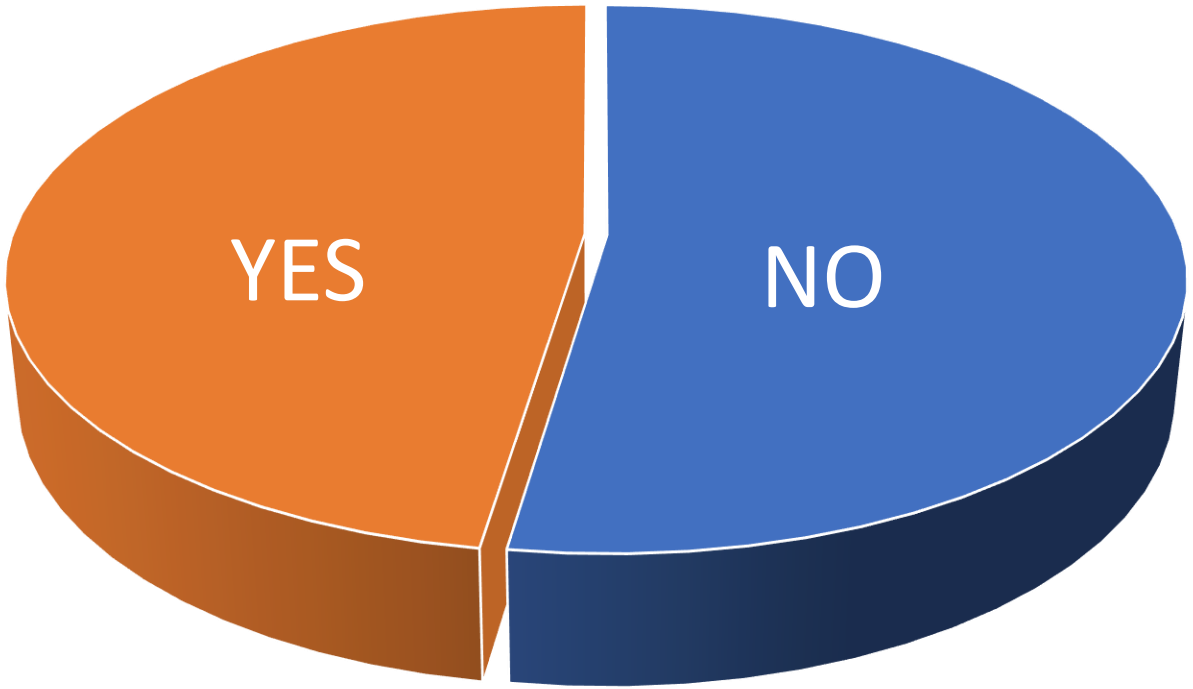
It is not meat according to EU regulation

"Cultured meat" **is considered a novel food**, and before it can be placed on the market, it should fulfil conditions related to nutritional value and scientific requirements that are listed in Regulation (EU) No 2015/2283, also known as the Novel Food Regulation (NFR)

The underlying principles underpinning Novel Food in the European Union are that Novel Foods must be:

- Safe for consumers
- Properly labelled, so as not to mislead consumers
- If novel food is intended to replace another food, it must not differ in a way that the consumption of the Novel Food would be nutritionally disadvantageous for the consumer.

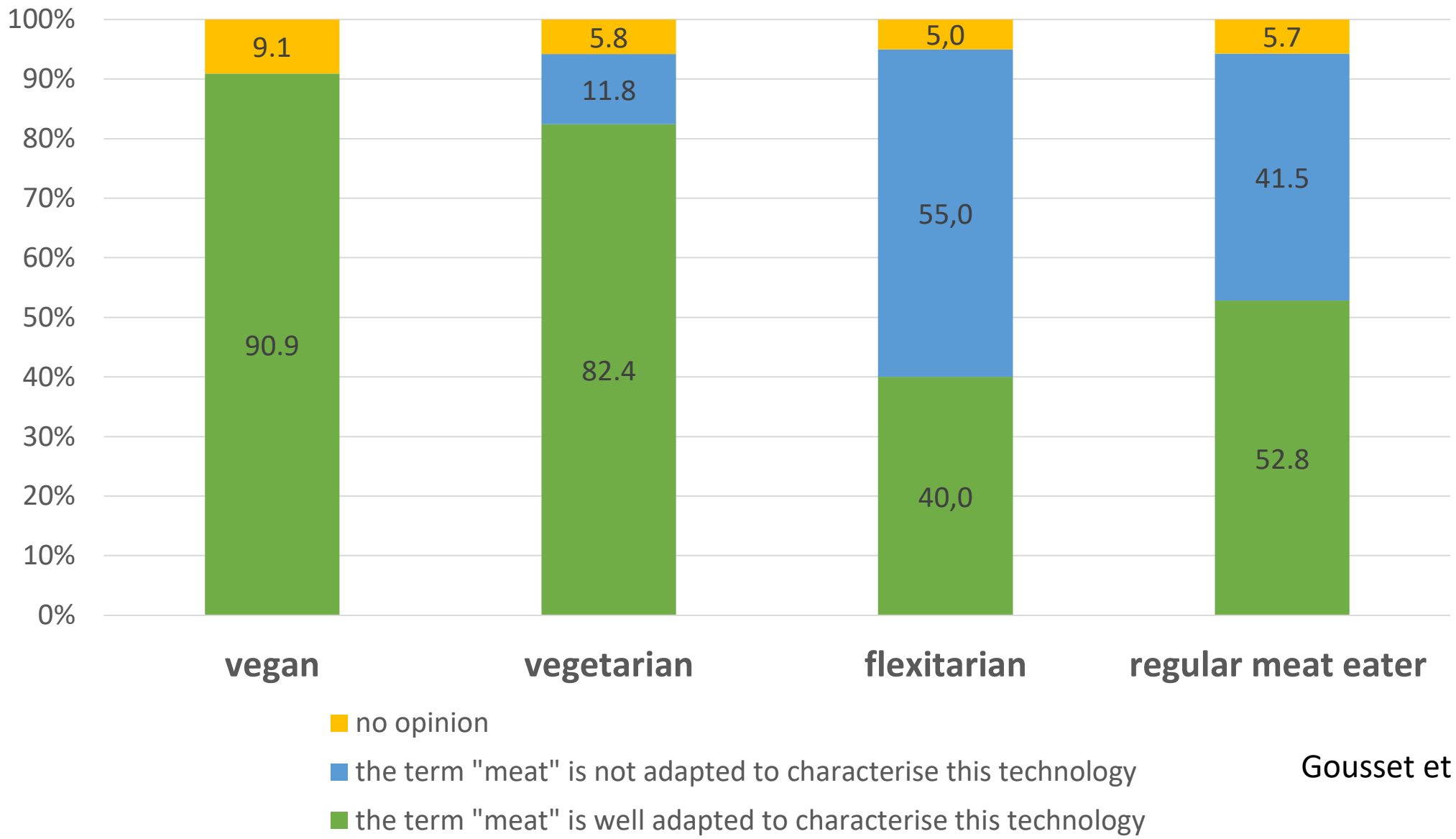
Is it really meat according to consumers?



Average of more than 10,000 answers from Brazil (Chriki *et al.,* 2021), European and American countries (unpublished results)

Reminder: the product should be properly labelled, so as not to mislead consumers (EU regulation)

In France, it is meat for vegans, but not for flexitarians



Gousset et al. (2022)

2a) IS IT GOOD *for the society*?

It is often claimed that “cultured meat” will bring proteins.

We are producing 4-fold more proteins than we need, but distribution of these proteins is not fair.

Consumption of proteins is often too high especially in developed countries.

Meat does not bring only proteins, but also iron, vitamins and pleasure!

Laisney, 2021, FAO reports, and collective expertise from INRAE

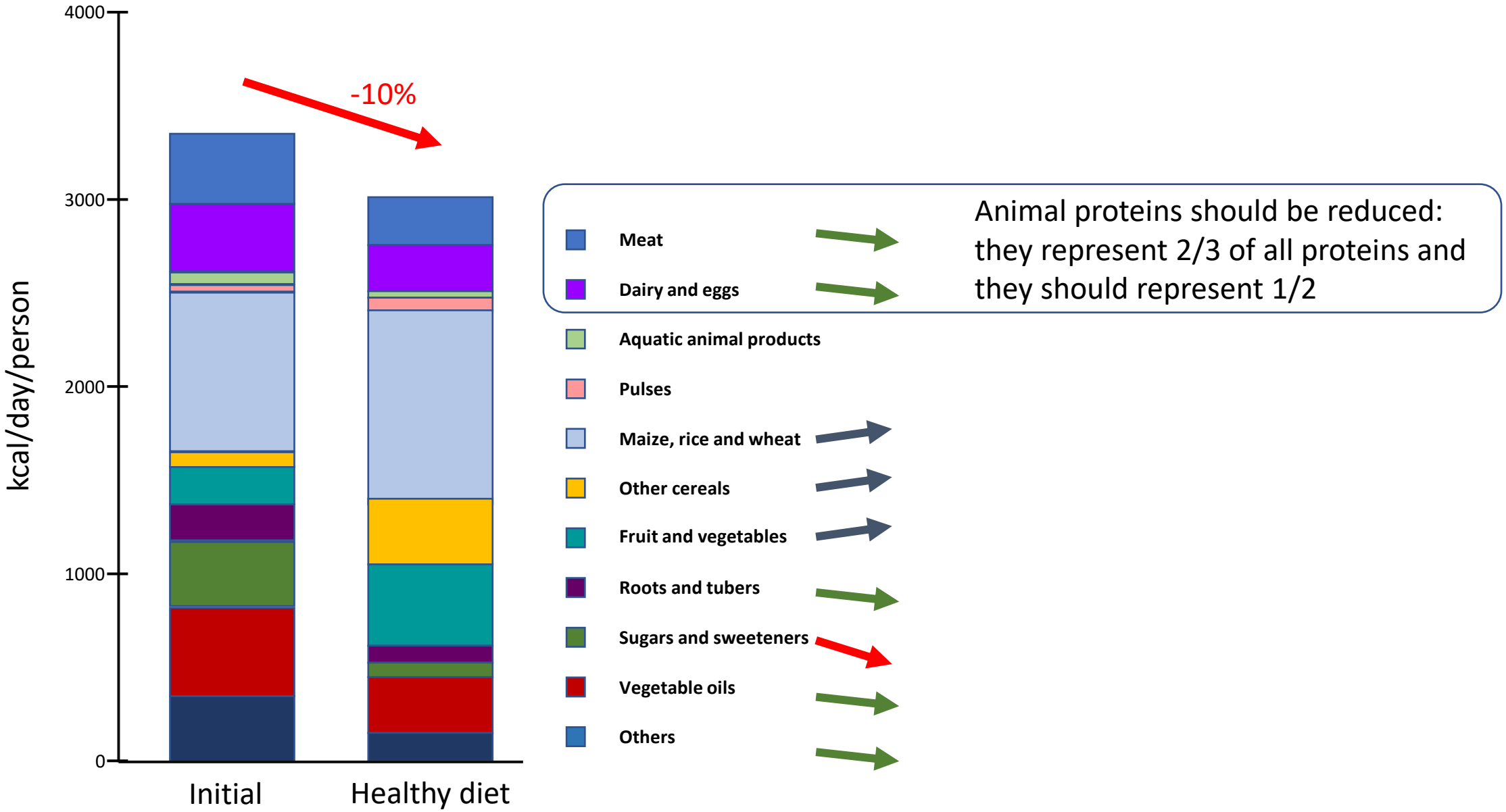
2a) IS IT GOOD *for the society*?

Other solutions are available to provide enough proteins to human beings and the “cultured meat” solution should be compared to these alternatives:

- Reducing food loses and waste (1/3 of our food production)
- Revisiting our livestock farming systems with more agroecology
- Change our consumption habits by eating less calories and less animal proteins in developed countries

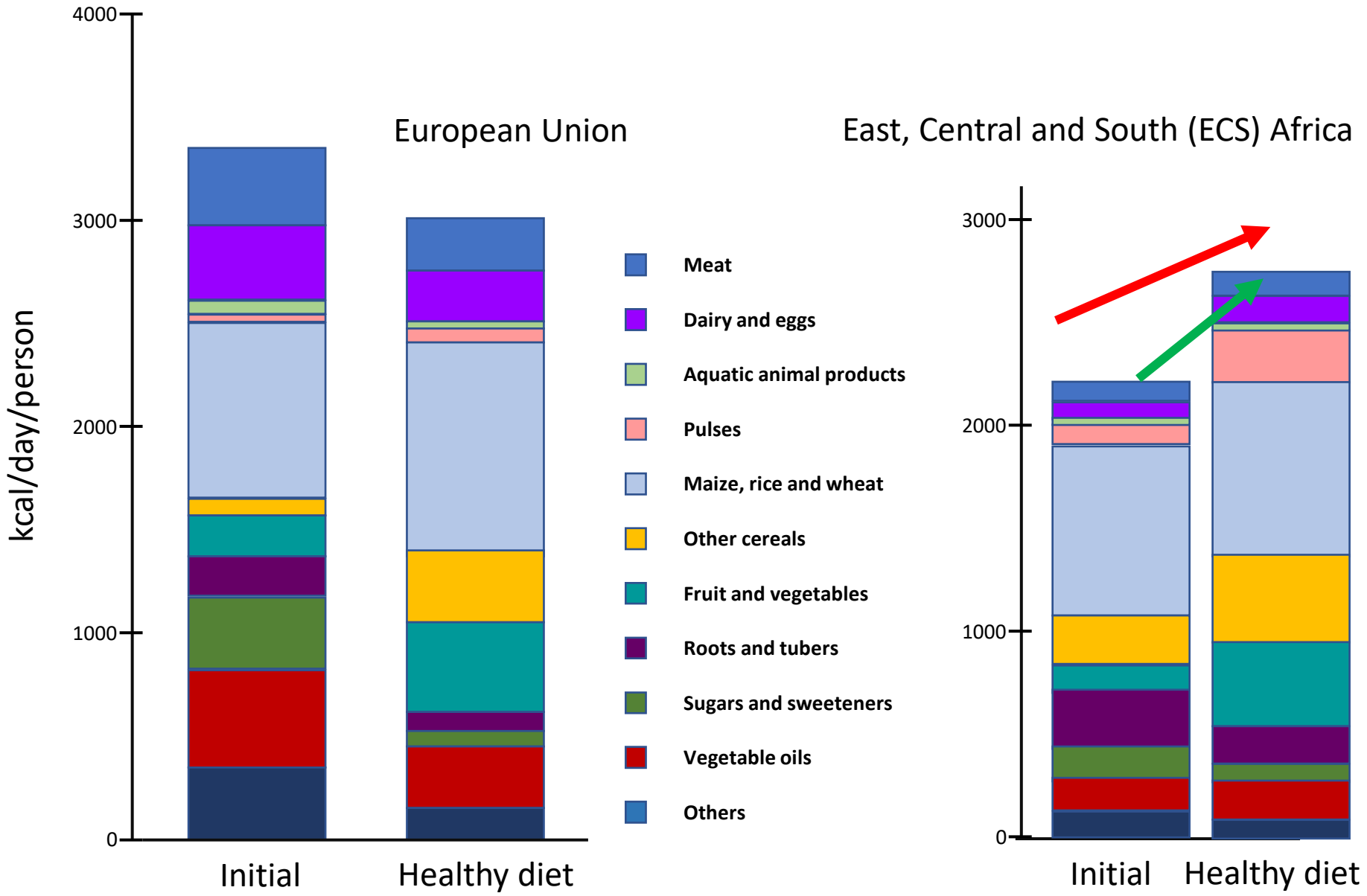
Laisney, 2021, FAO reports, and collective expertise from INRAE

The recommended healthy diet in Europe



Agrimonde-Terra foresight: Land use and food security in 2050. Hypotheses about the future of the drivers of the "land use and food security" system and their translation into quantitative hypotheses. By Le Mouël C., Marajo-Petitzon E. (Inra, SMART, Rennes), Mora O. (Inra, DEPE, Paris), de Lattre-Gasquet M. (Cirad, Paris)

The recommendations vary across the World



Agrimonde-Terra foresight: Land use and food security in 2050. Hypotheses about the future of the drivers of the "land use and food security" system and their translation into quantitative hypotheses. By Le Mouël C., Marajo-Petitzon E. (Inra, SMART, Rennes), Mora O. (Inra, DEPE, Paris), de Lattre-Gasquet M. (Cirad, Paris)

2b) IS IT GOOD *for our planet*?

There is a high demand for more environmental-friendly food.

“Climate and livestock” is a political topic, with focus on deforestation and greenhouse gas emissions only.

Many discussions about the real impacts of livestock on the environment with negative impacts (well known) and positive impacts (not well known).

2b) IS IT GOOD *for our planet*?

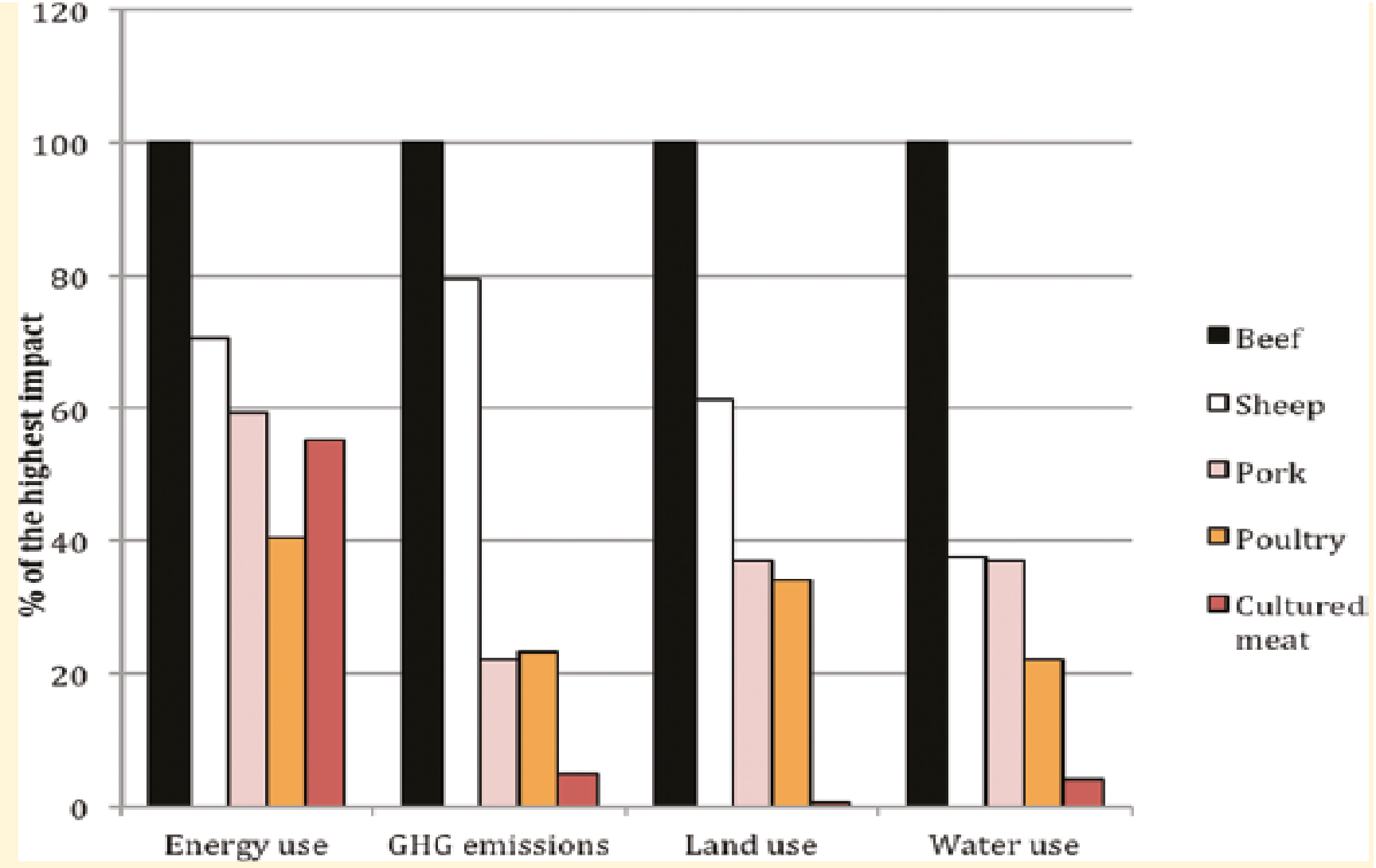
Only 4 scientific publications on impacts of “cultured meat” on the environment,

“due to the limited data, the studies … are scarce and based on hypothetical production processes” (Rodriguez Escobar et al., 2021).

The private report by CE Delft is also highlighting uncertainties and limitations.

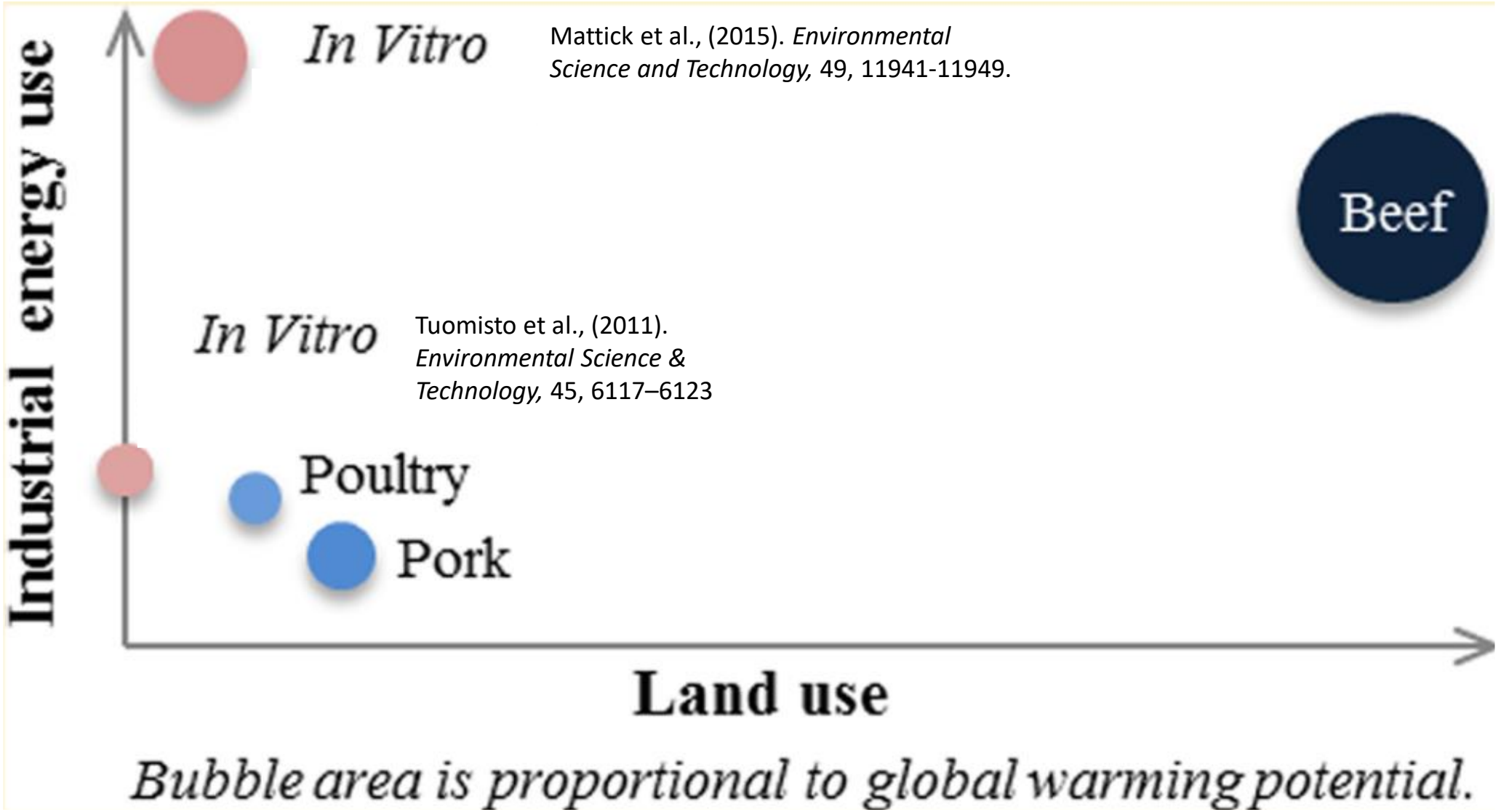
Four publications is very low and there is no scientific consensus despite claims by private companies producing “cultured meat”.

The first highly advertised scientific paper



Tuomisto H.L., Teixeira de Mattos M.J., 2011. Environmental impacts of cultured meat production. Environ. Sci. Technol., 45, 6117-6123.

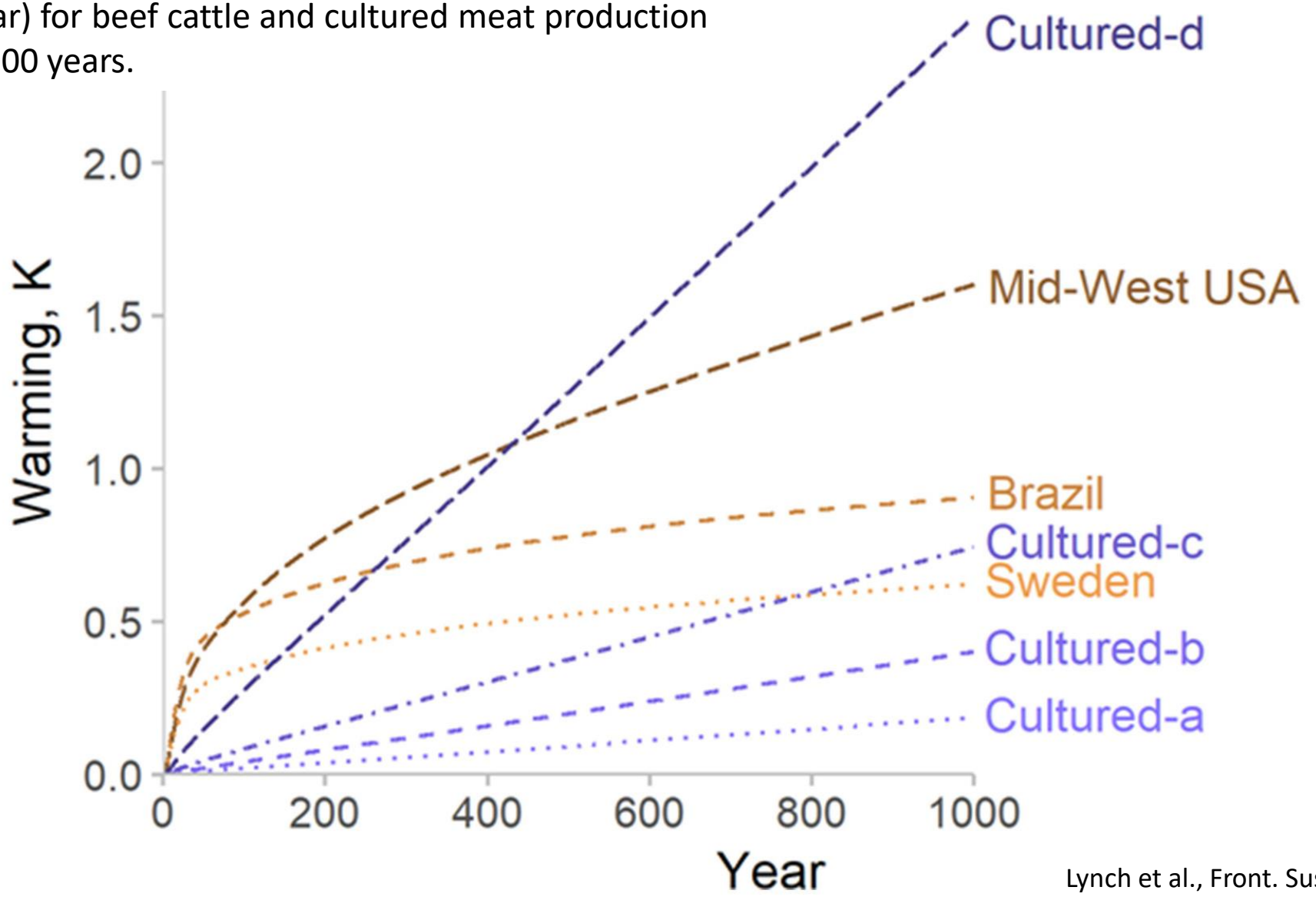
2b) IS IT GOOD *for the planet*?



Mattick et al., (2015). *Environmental Science and Technology,* 49, 11941-11949.

2b) IS IT GOOD *for the planet*?

Warming impact for perpetual consumption at very high rates (250Mt per year) for beef cattle and cultured meat production systems for 1,000 years.



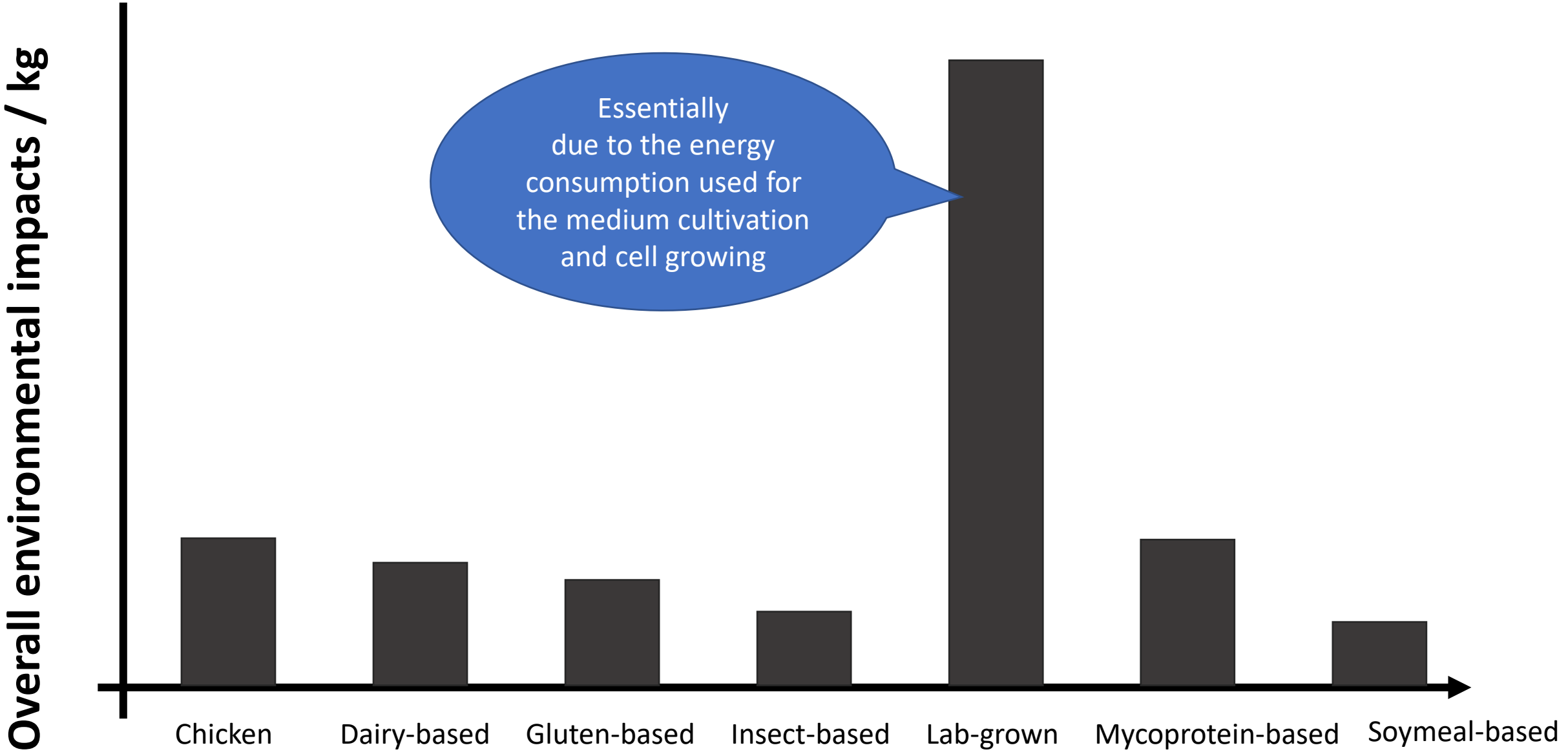
Lynch et al., Front. Sustain. Food Syst., 19, 2019

Overview of the main gaps identified in each study related to environmental impacts of cultured meat

	Tuomisto and Teixeira de Mattos (2011)	Tuomisto et al. (2014)	Smetana et al. (2015)	Mattick et al. (2015)
Cell collection	–	–	–	–
Growth factors production	–	–	–	–
Scaffold production	–	–	–	+
Bioreactor's production	+	+	+	–
Cleaning bioreactor	–	–	–	+
Culture media recycling	–	–	–	–
Scaffold removal/recovery	–	–	–	–
Wastewater treatment	–	–	–	–

Rodríguez Escobar et al. (2021). Foods 2021, 10, 2941. https://doi.org/10.3390/foods10122941

Life cycle assessment of most known meat substitutes

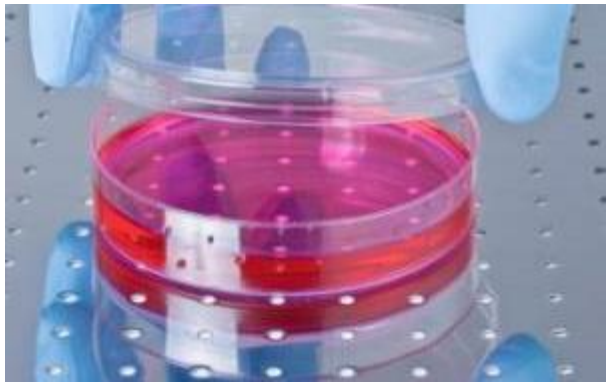


Smetana et al. (2015). Int J Life Cycle Assess (2015) 20:1254–1267. DOI 10.1007/s11367-015-0931-6

2c) IS IT GOOD *for animals*?

There is a high demand from consumers for more animal-friendly food.

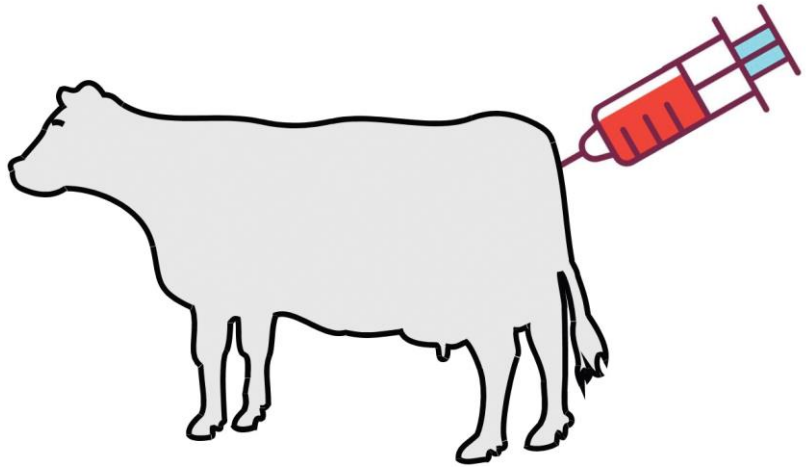
"Cultured meat" has the potential to avoid slaughtering many animals (discussed by Chriki et al., 2022) ... if fetal bovine serum is not used anymore in the culture medium (it is in progress: Messmer at al., 2022).



"Cultured meat" commercialized in Singapore is produced with fetal bovine serum.

2c) IS IT GOOD *for animals*?

These animals will be biopsied regularly and this raises new welfare issues.



Alternatively, if cell lines are used, farm animals will no longer be needed. At least for a transition period, the number of farm animals should be decreased by slaughtering them and/or limiting their reproduction.

Animal biodiversity will be reduced with fewer farm animals.

Chriki et al. (2022). Animal Frontiers, 12, 35-42

2c) IS IT GOOD *for animals*?

Which consequences if the number of farm animals needed for meat production is dramatically decreased?

- What will be the future of those animals? How will they be treated?
- What about positive impacts of livestock farming (on biodiversity, ecosystems, landscape)?
- These fields are rarely discussed

Chriki et al. (2022). Animal Frontiers, 12, 35-42

We have to revise the relationships between animals and humans (Francis Wolf)



Human beings have a diversity of relationships with the diversity of living organisms in the animal kingdom (from flea to dog).
Thus, man's duties toward animals depend on the nature of these relations.
The status of the animal cannot be unique.



"Modern animalism", which assigns a unique value to all animals, considered as a unique being (called), contains several contradictions:
first, man is sometimes included, sometimes excluded from animal kingdom;
then, dogs and their fleas cannot be handle in the same way.

The main cause of the complex relationships between humans and animals is the man consciousness loss of his human specificity

2d) IS IT GOOD *for health*?

"Due to technological challenges ….., cultured meat prototypes are currently not available for independent technological, sensorial and nutritional assessment" (Fraeye et al., 2020, Frontiers in Nutrition 7:35.).

"Based on the available state of the art regarding production processes, it can be inferred that cultured meat currently differs significantly from traditional meat in its technological, sensorial and nutritional properties" (Fraeye et al., 2020).

"Cultured muscle tissues generally have a pale color due to the absence of myoglobin" (Fraeye et al., 2020). → low iron content.

2d) IS IT GOOD *for health*?

Some fears (to be confirmed):

"High-rate cell proliferation of industrial-scale production is likely to accumulate genetic alterations … There is also concern around developing cancerous and other undesirable cells from genomic alterations. As a result, regular monitoring of genetic stability is necessary for quality assurance" (Ong et al., 2021. Comprehensive Reviews in Food Science and Food Safety 20:5421–5448. Chen et al., 2022. Biomaterials, 280, 121274).

What is the composition of the culture medium? Of scaffolds?

Globally, there is a lack of transparency, and many unverified claims.

It is likely to be a highly-processed food product.

3a) IS IT ACCEPTABLE *for consumers*?

A good option for consumers who still want to eat meat without compromise while protecting animals.

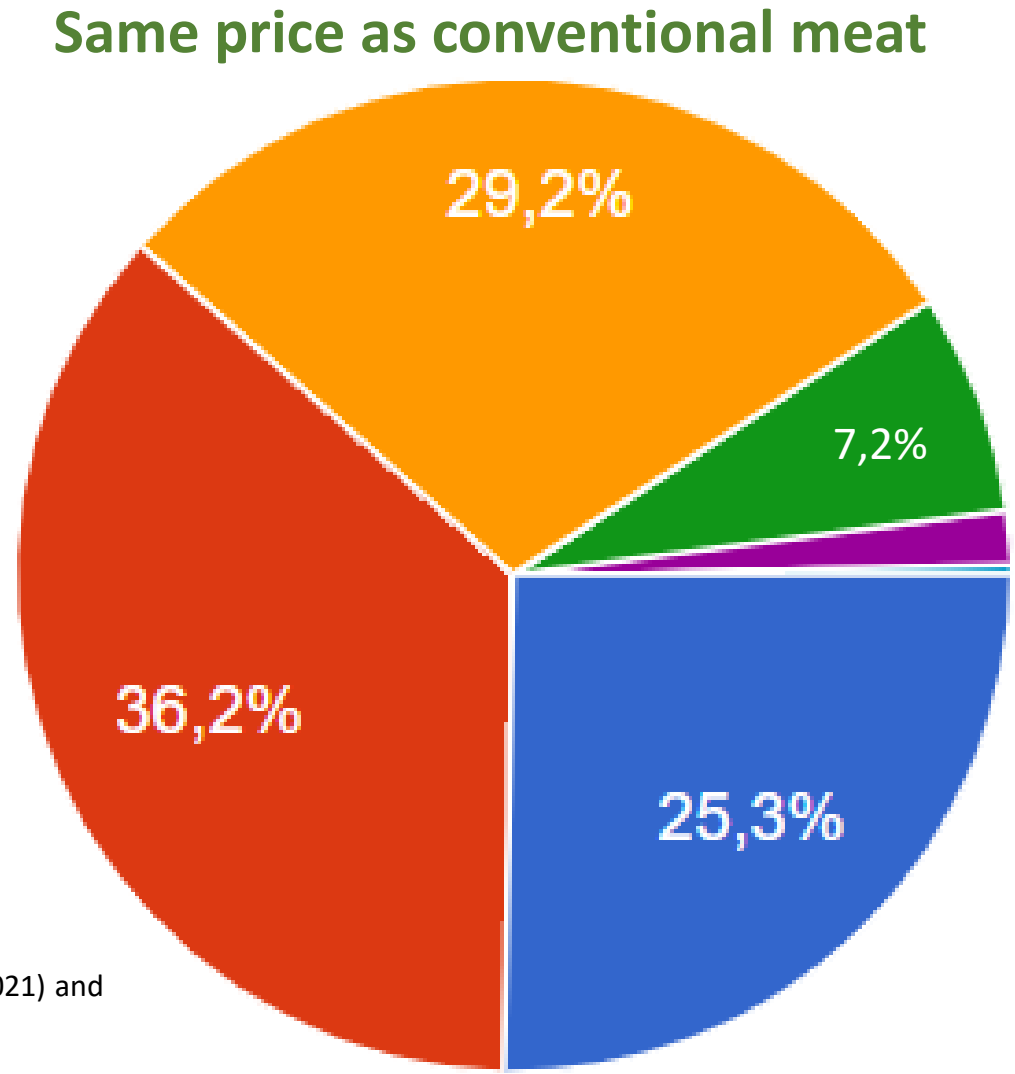
Consumers' surveys are often conducted by proponents of "cultured meat" (ex: Bryant, van Nek, Rolland, Foods 2020, 9, 1152).

Conclusions are fragile because consumers' opinions about a product which does not exist yet can lack of robustness.

Sometimes, expression of disgust which induces emotional resistance.

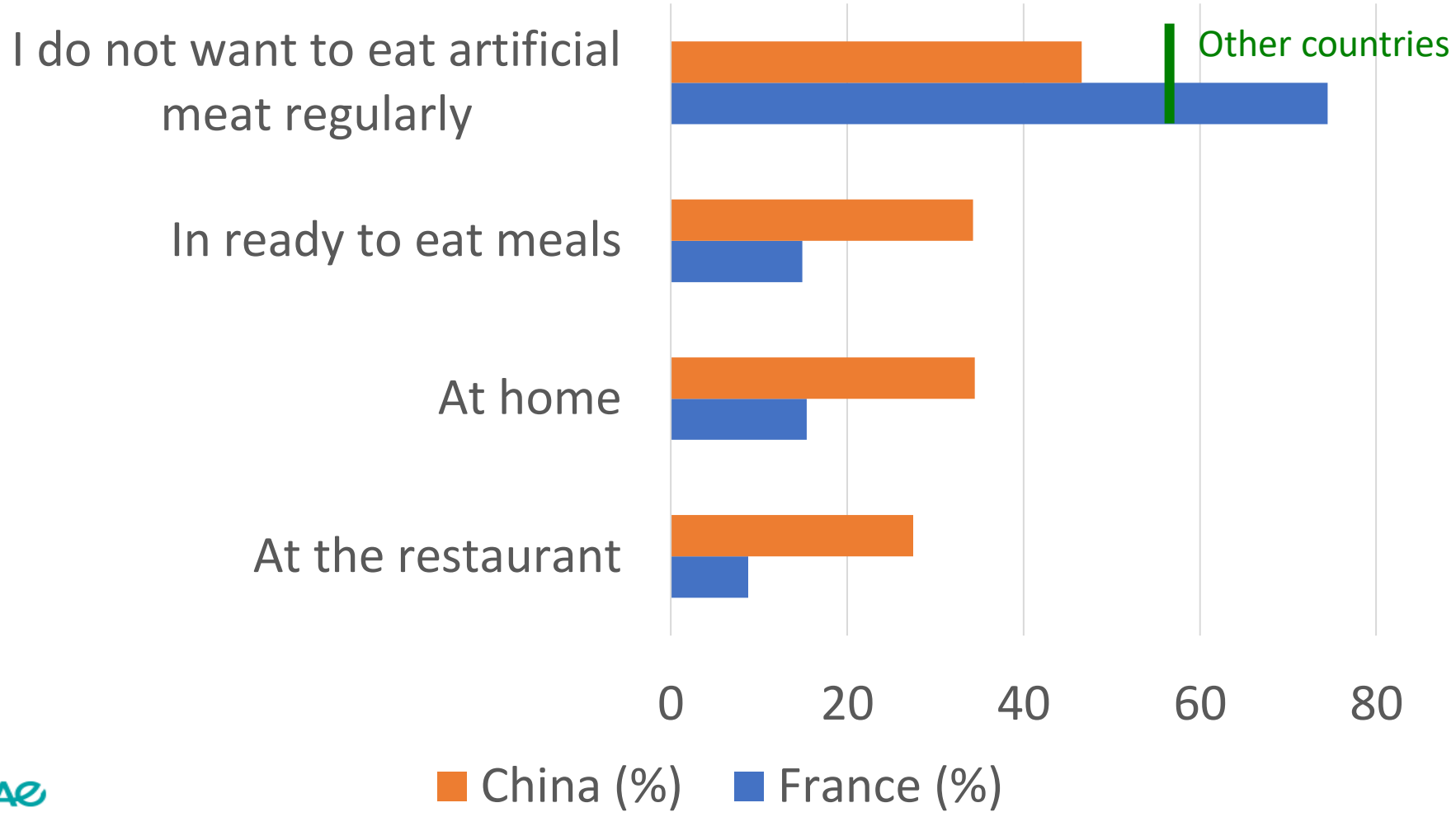
Due to curiosity, willingness to try is always higher than willingness to eat. Globally, a low willingness to eat and to pay.

Most of the consumers don’t want to pay more for “cultured meat”



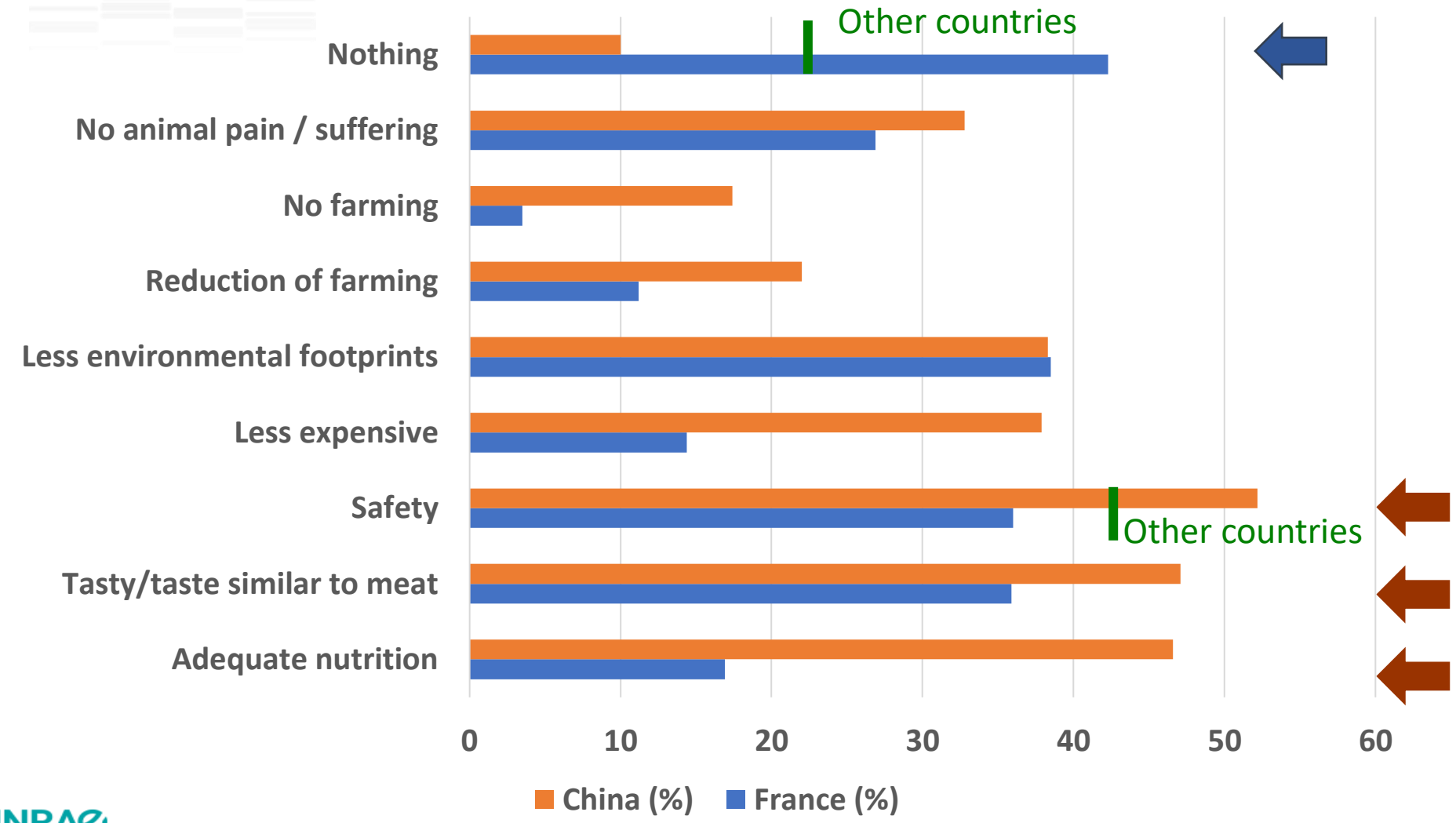
Similar results in France, Brazil, China
Hocquette et al. (2022) in Meat Science, Chriki et al. (2021) and Liu et al (2021) both in Foods
Total: more than 15,000 answers

Would consumers be willing to eat cultured meat regularly in 2020?



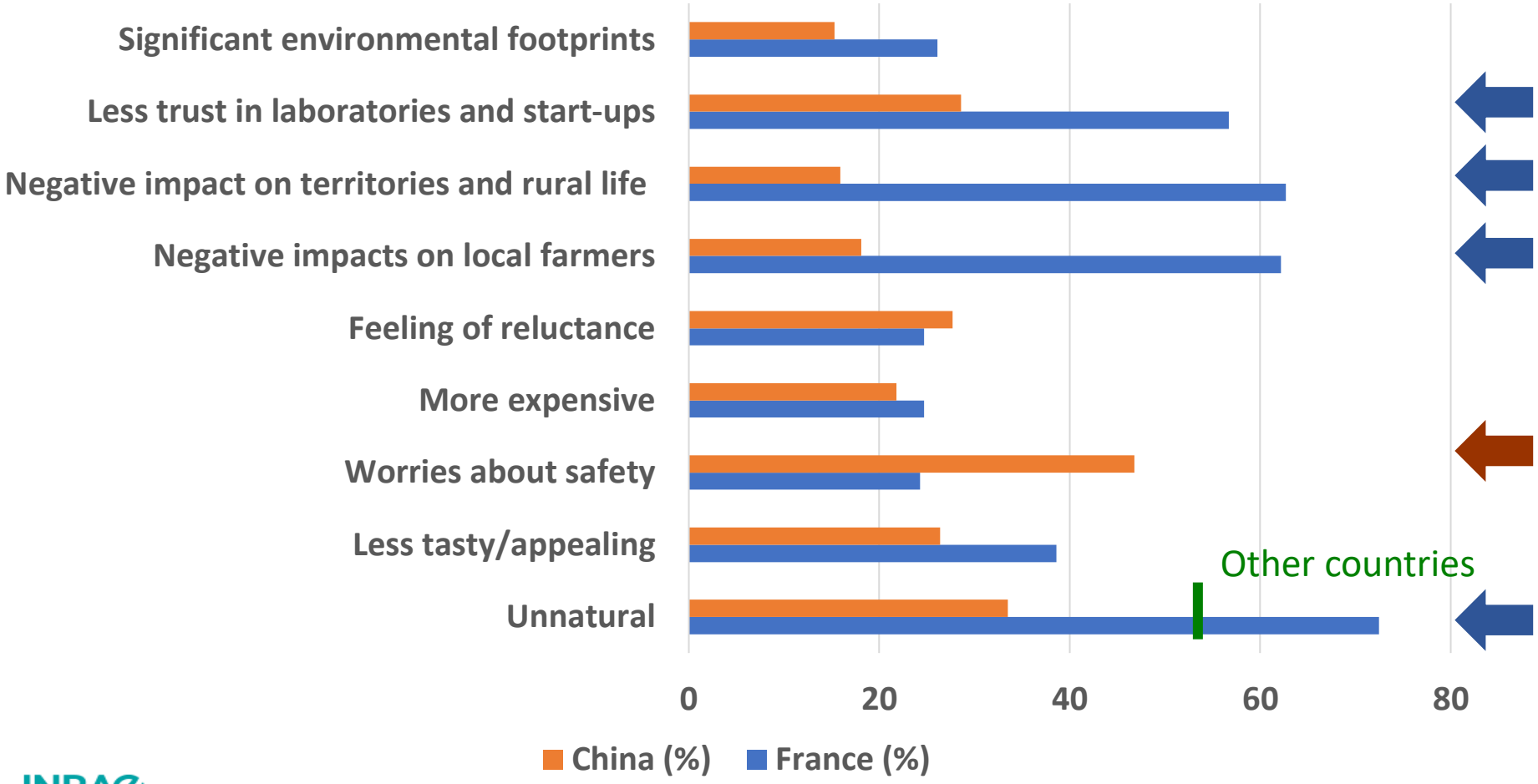
Liu et al., 2021 ; Chriki et al., 2021 about 4,000 answers in each country

What consumers would expect from cultured meat?



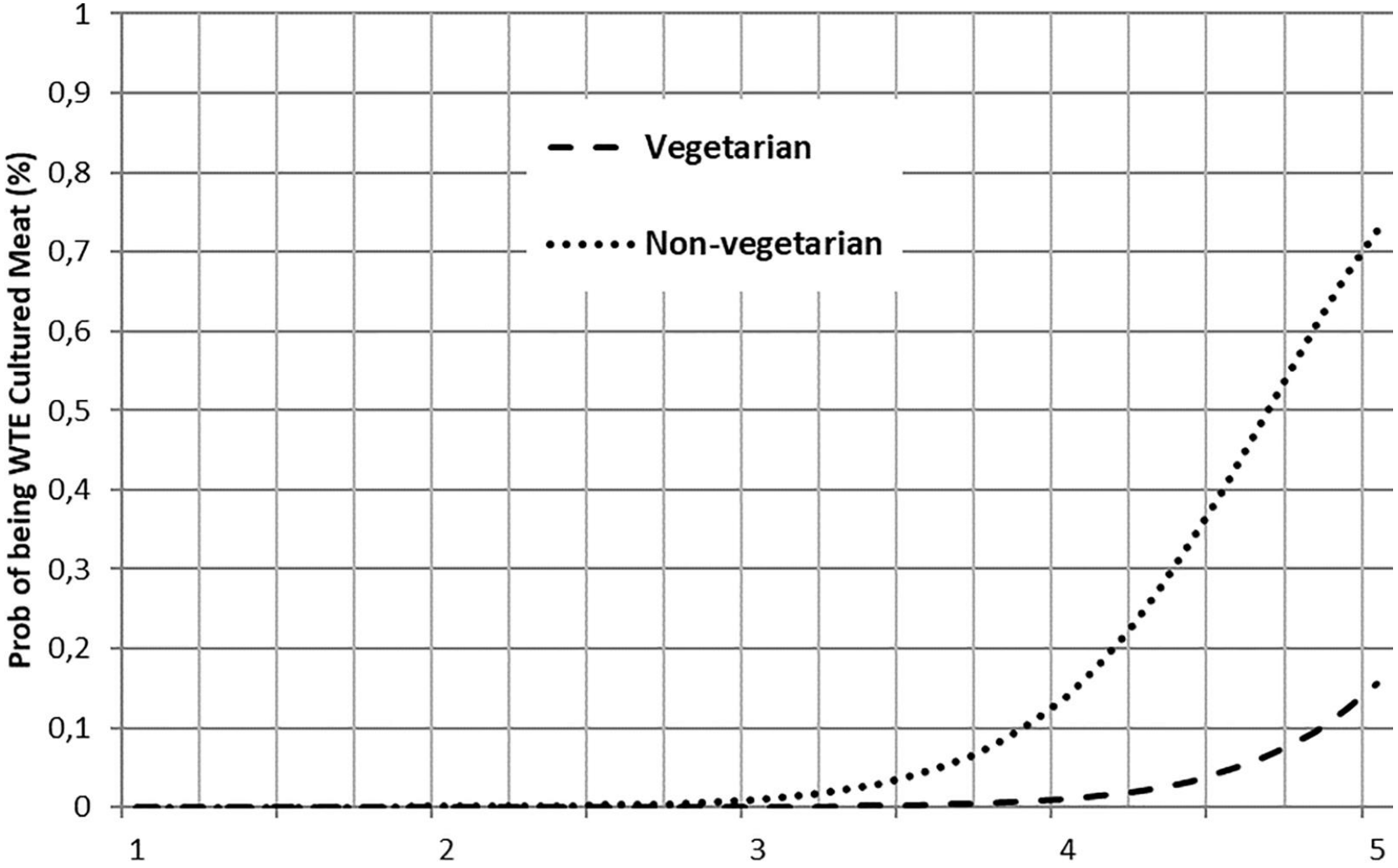
Liu et al., 2021 ; Chriki et al., 2021 about 4,000 answers in each country

Why consumers would not be willing to try cultured meat



Liu et al. (2021) and Hocquette et al. (2022).

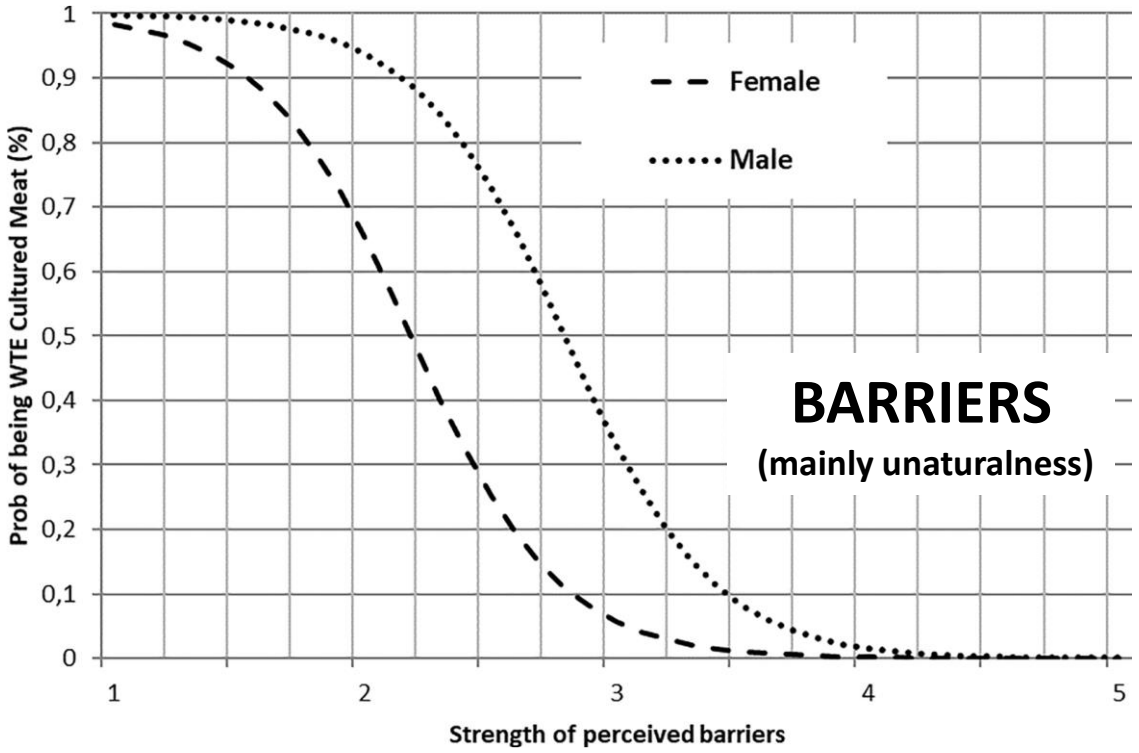
Perceived motives are 14 times higher among non-vegetarians compared to vegetarians

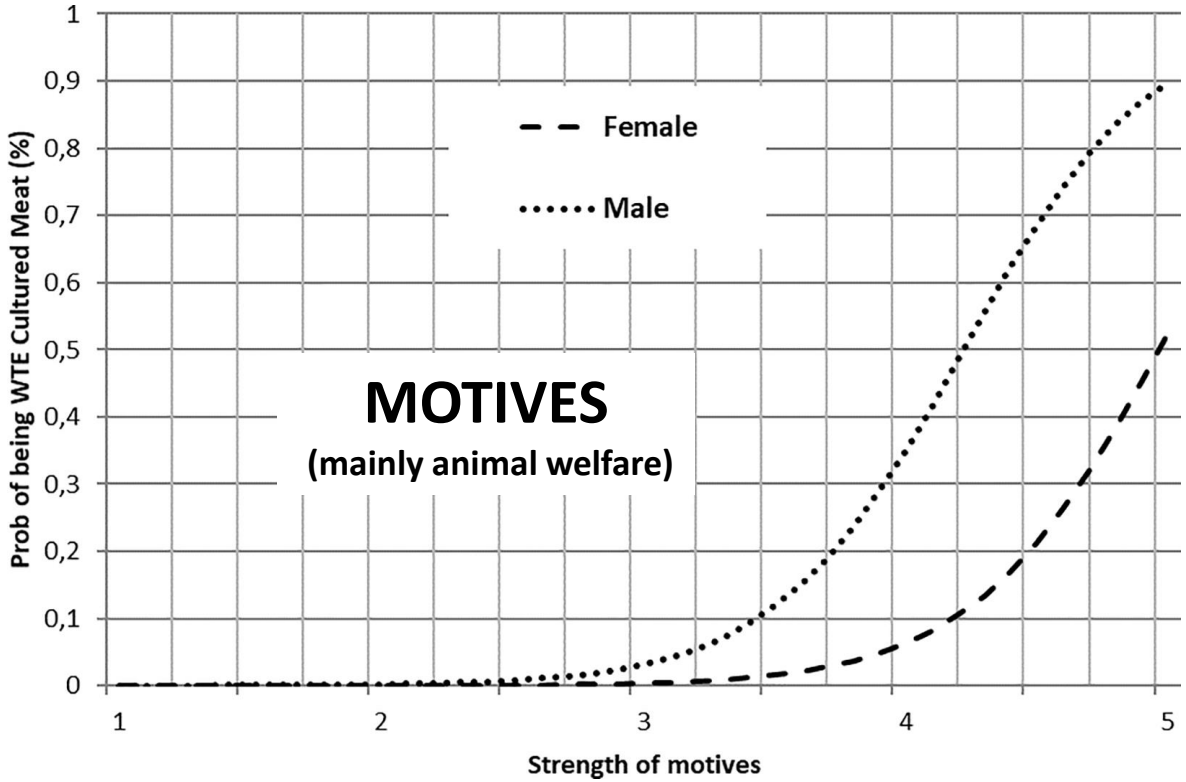


MOTIVES
(mainly animal welfare)

Verbeke et al. (2021). Livestock Science 253, 104705

Perceived barriers emerged as being twice as powerful in shaping consumers' willingness to eat as compared to motives





The likelihood of being willing to eat cultured meat was eight times larger among males compared to females and decreased by 50% per increase of 10 years in age.

Verbeke et al. (2021). Livestock Science 253, 104705

But younger people are more open to eat cultured meat

In a survey of 2,100 Americans, people under 40 were more likely to say that they would try cultured meat -- meats that don't come directly from animals, but instead from cell cultures.

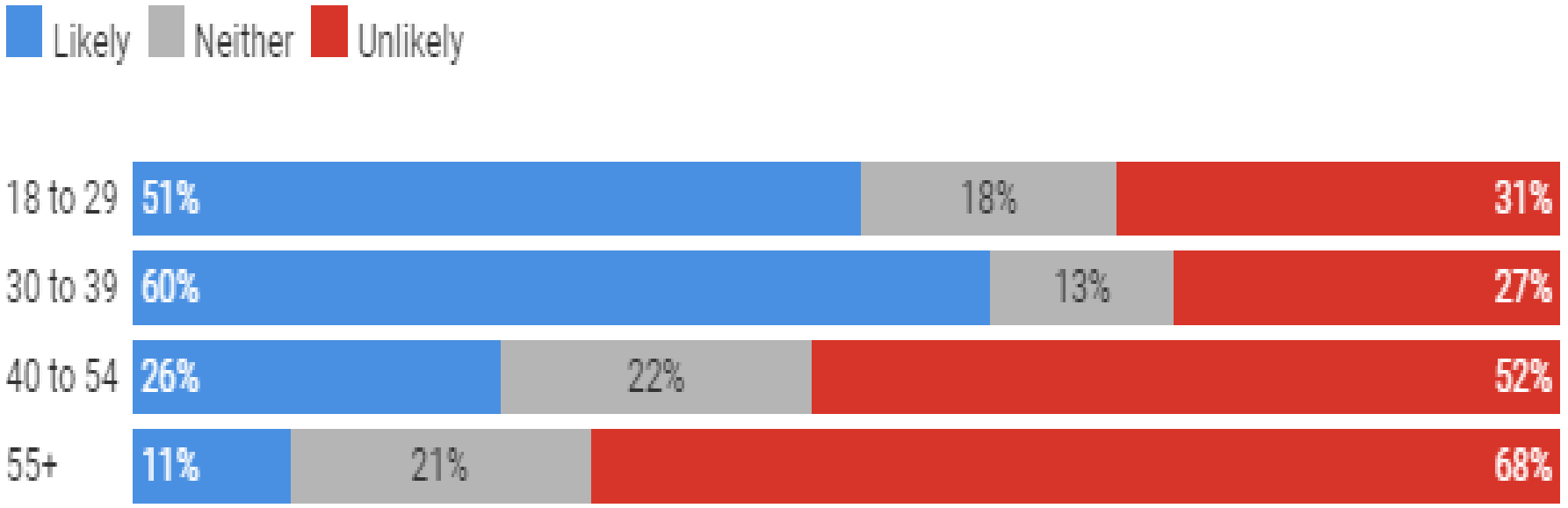
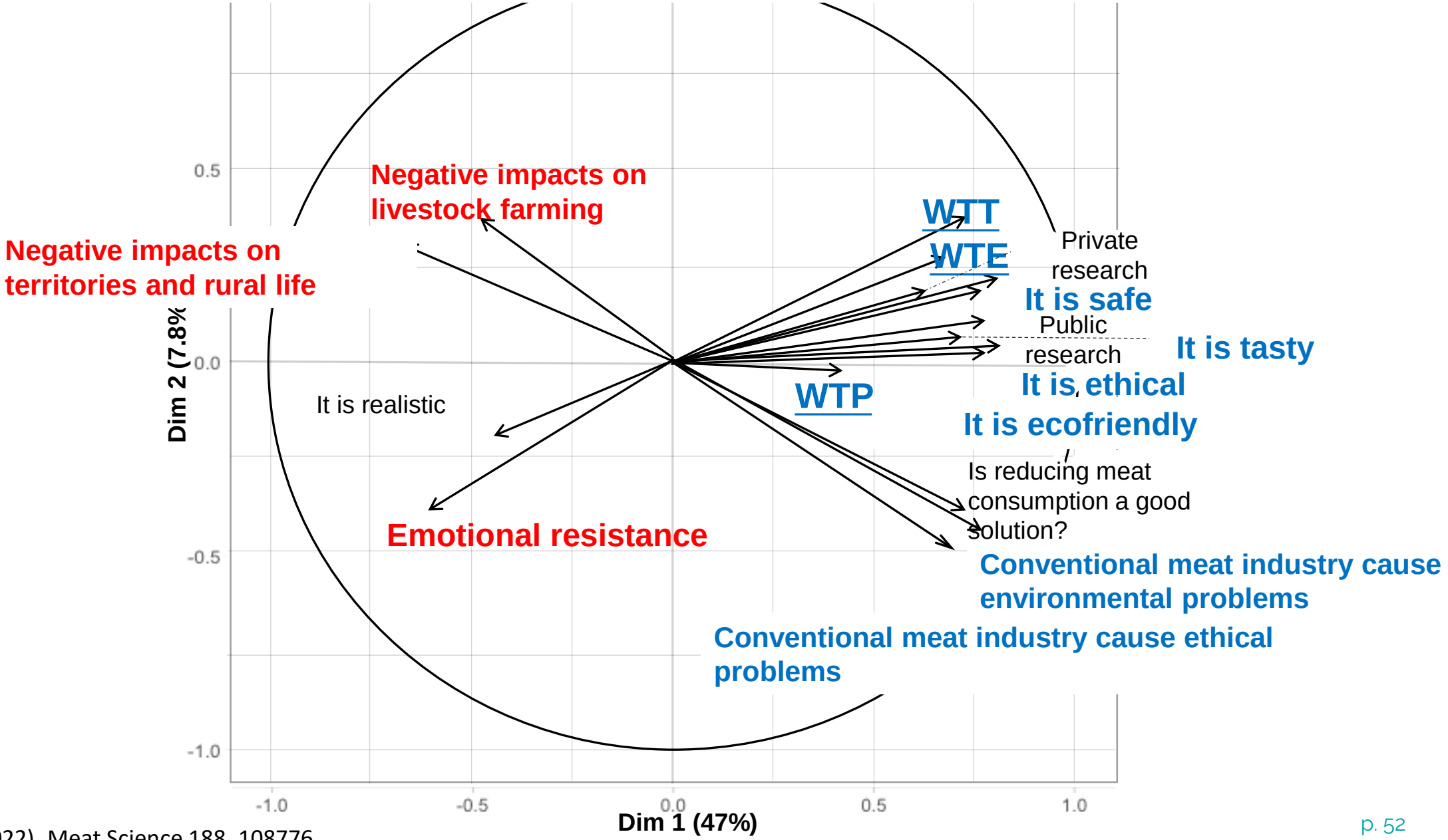


Chart: The Conversation, CC-BY-ND • Source: Michigan State University Food Literary and Engagement Poll • Get the data

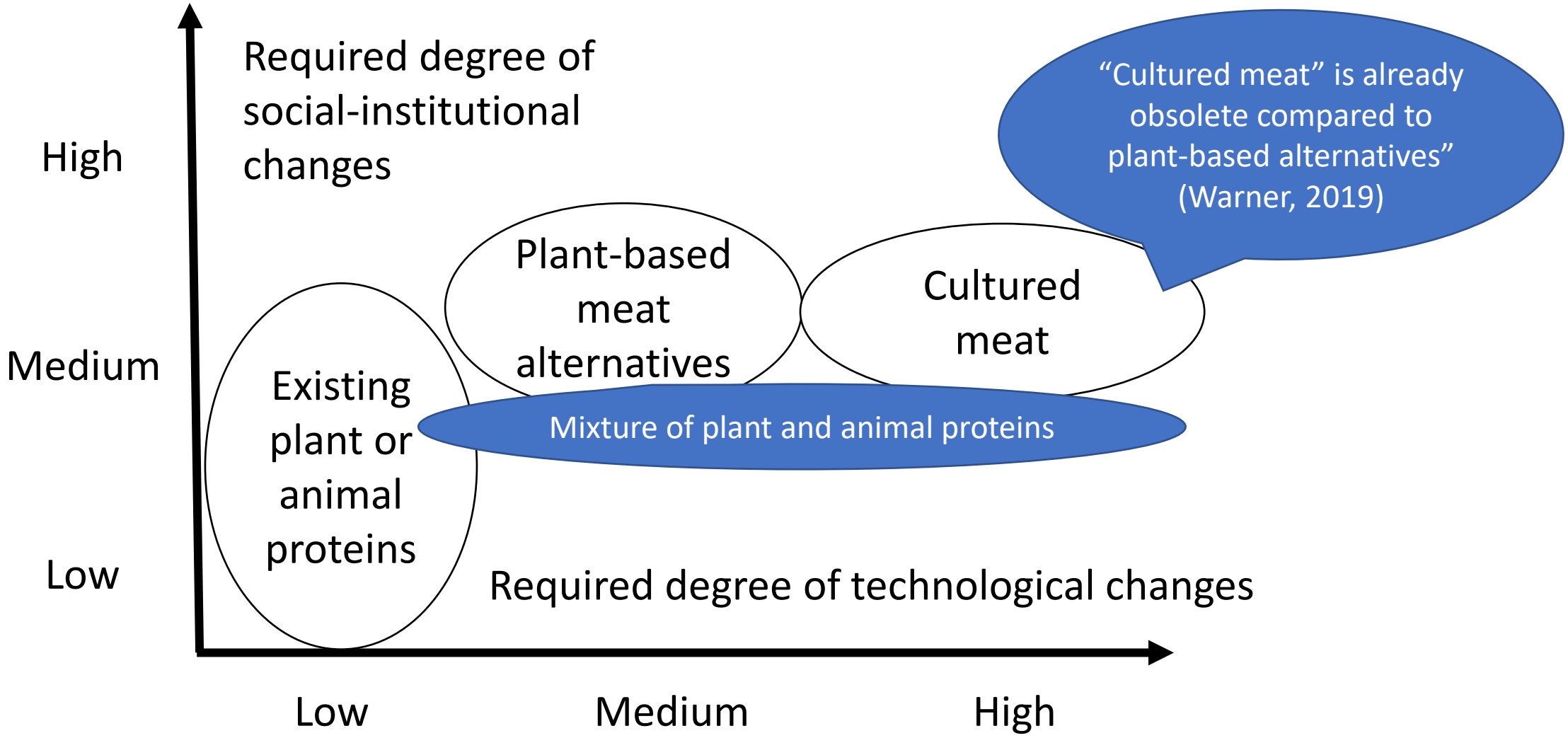
https://theconversation.com/would-you-eat-meat-from-a-lab-consumers-arent-necessarily-sold-on-cultured-meat-100933, 2018

Perceived barriers and motives for French consumers



Hocquette et al. (2022). Meat Science 188, 108776

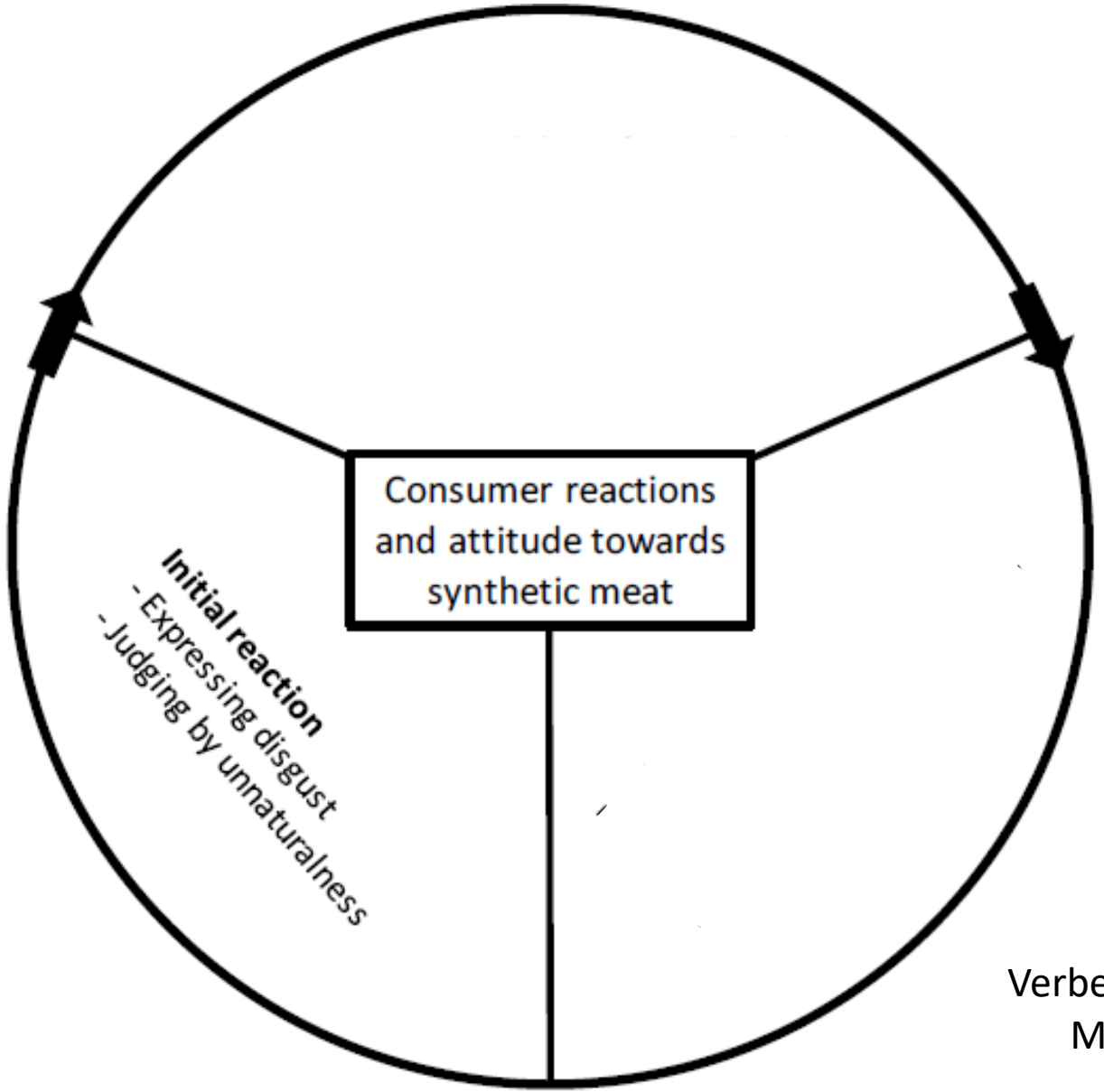
The required degree of changes is a driver of food acceptance



Van der Weele C, Feindt P, Jan van der Goot A, van Mierlo B, van Boekel M. Meat alternatives: an integrative comparison. Trends Food Sci Technol. (2019). 88:505–12. https://doi.org/10.1016/j.tifs.2019.04.018

Warner (2019). Review: Analysis of the process and drivers for cellular meat production Animal, 13, 3041-3058. DOI: https://doi.org/10.1017/S1751731119001897

Consumers' reactions and attitude formation



Verbeke et al., 2015.
Meat Science

3b) IS IT ACCEPTABLE *for the society*?

Towards a wide range of alternatives to meat (including mixing plant and animal proteins). Different models depending on the country. The competition with other meat alternatives is tough.

An alternative to intensive farming. Towards the end of livestock?

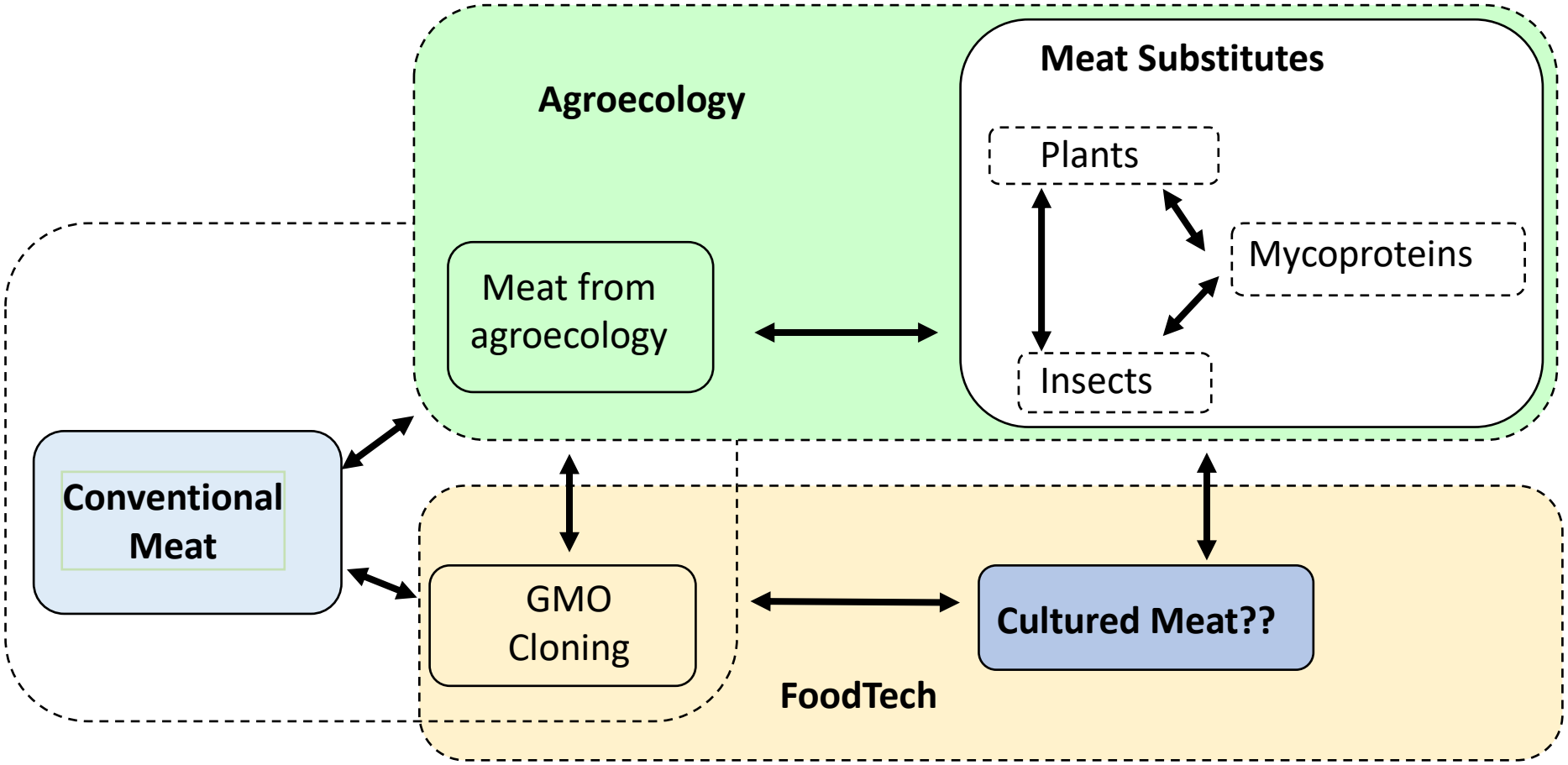
But we need for livestock to valorize non-convertible grasslands and co-products that cannot be valorized by human beings.

Cultural, symbolic relations with the rural world

Disembodiment and dehumanization of food

Control of our food by huge FoodTech companies of the private actor?

Future of the meat market



Bonny et al. (2015). What is artificial meat and what does it mean for the future of the meat industry? Journal of Integrative Agriculture, 14(2): 255–263

Ethical questions associated to the FoodTech

- What will be the future of pastures, agriculture, landscapes, and the countryside with fewer farm animals?
- This will be associated with a decline in plant biodiversity, rural life, etc...
- What will be the future of farmers, especially in poor and developed countries if there are fewer farm animals?
- How and by whom will our food production be managed and controlled?
- Do we want FoodTech companies to manage the production and quality of our food instead of local farmers?

Consumers do not know what we can do

Do you have any favourite singer?
Do you have any favourite sportsman?
Do you have any favourite politician?

Now, you can eat meat from muscle samples taken from your celebrity



INRAE

IN CONCLUSION:

Not sure yet that « cultured meat » could contribute to a sustainable diet

Nutrition (Health)

No available data

Environment

No available data on biodiversity and ecosystems
No consensus on global warming

Sustainable food



(Socio-) Cultural

Weak to average potential acceptance

(Socio-) Economic

Cost still high.
What's about incomes of farmers?

Definition of sustainable food is from FAO (2010)

WORLD ASSOCIATION for ANIMAL PRODUCTION



WORLD and EUROPEAN CONGRESS ON ANIMAL PRODUCTION (on-site, on-line)

LYON

27-31 August 2023

EAAP
European Federation of Animal Science

ONLYLYON TOURISM AND CONVENTIONS

INTERBULL



Please answer to our survey about artificial meat available in English for any country

https://forms.gle/VzUp2sK6H3TbSHxV9

The results for China have been published:
Liu J, Hocquette É, Ellies-Oury M-P, Chriki S, Hocquette J-F. Chinese Consumers' Attitudes and Potential Acceptance toward Artificial Meat. Foods. 2021; 10(2):353. https://doi.org/10.3390/foods10020353