

Cell-based food: promises and reality

What we know? and what we should know?

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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

Liu et al., Meat Science, 2023, 200, 109144 <https://doi.org/10.1016/j.meatsci.2023.109144>

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>

“Cultured meat”: an innovation highly promoted



Kinder for you



Kinder for society
worldwide



Kinder to cows
(and other
animals!)



Kinder to the
planet

<https://mosameat.com/>

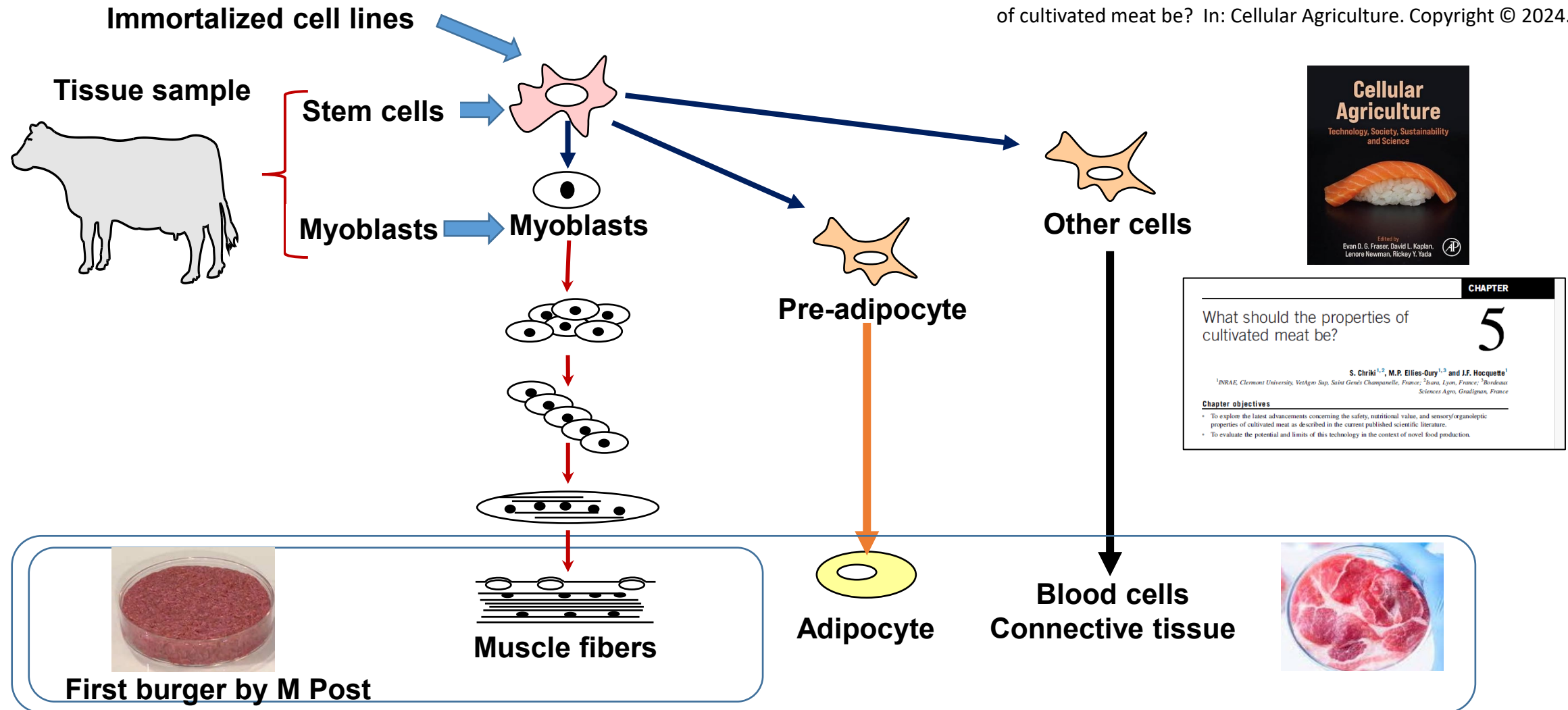
Is it healthy and safe? Is it sustainable? Is it ethical? Is it eco-friendly?

Outline

1. Principles and state of the art of cell-based foods
2. Characteristics of the products
3. Regulatory, social and ethical issues
4. Conclusions

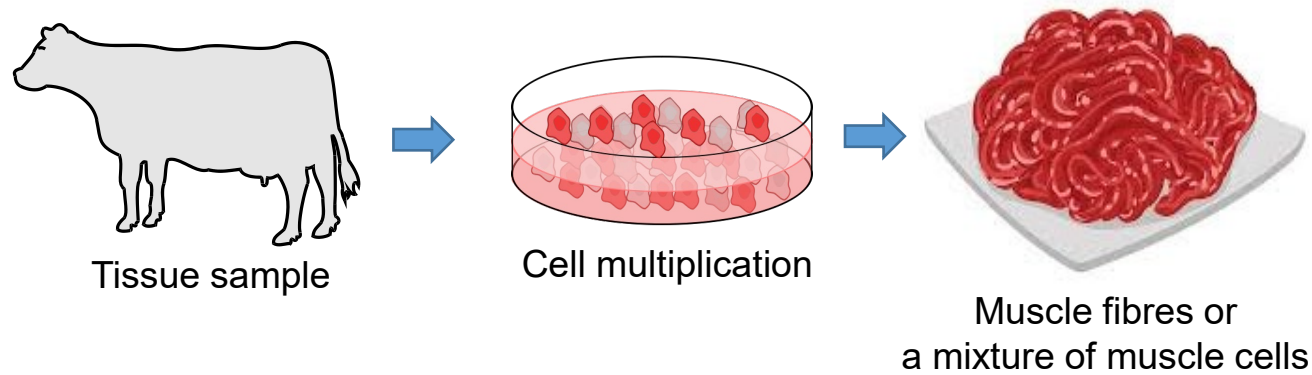
Status of the technology: principles

Chriki, Ellies-Oury, Hocquette (2023). What should the properties of cultivated meat be? In: Cellular Agriculture. Copyright © 2024.



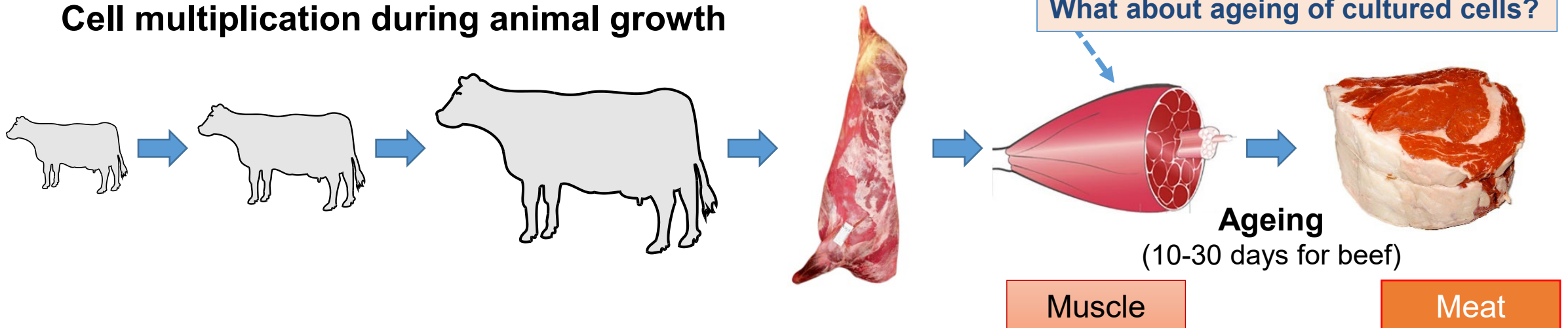
It is not meat on a biological point of view

Cell-based food production



Addition of missing nutrients.
No study on digestibility

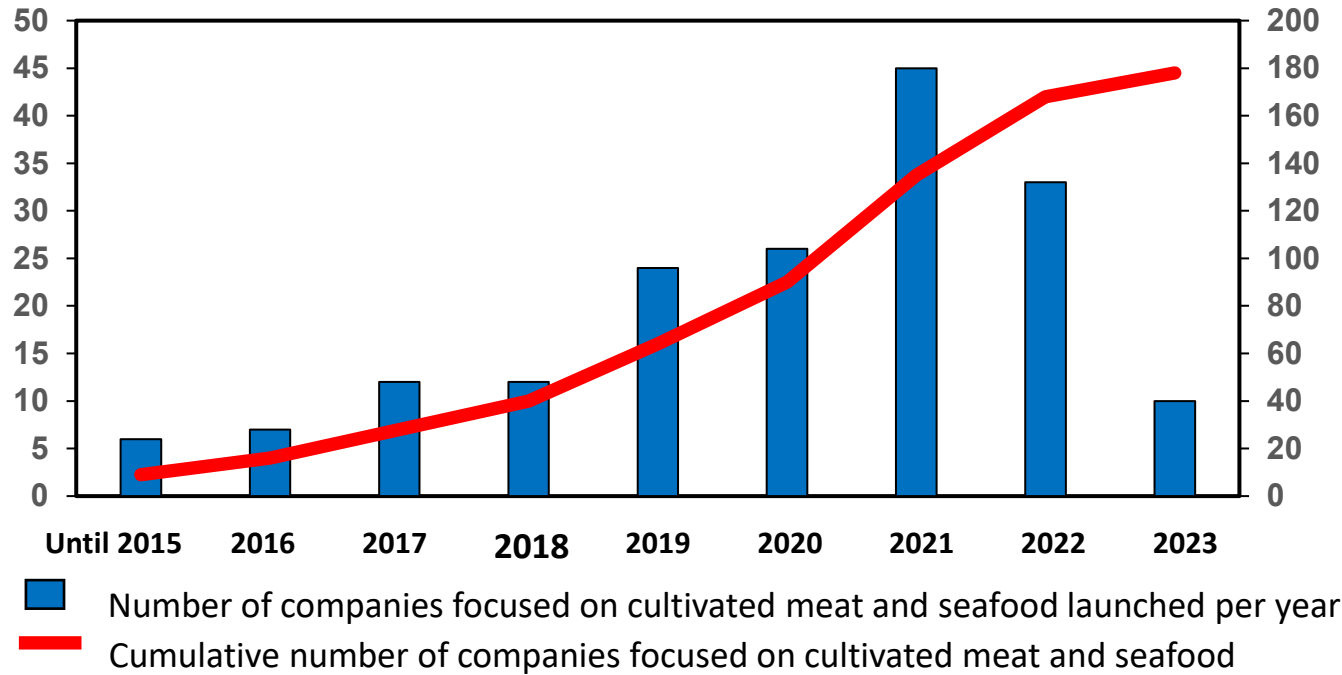
Cell multiplication during animal growth



Brief history

- 1912 Demonstration by the French biologist Alexis Carrel that maintaining muscle tissue outside the body is possible.
- 1932 First patent to produce laboratory meat by Willem van Eelen.
- 2012 Launch of “Modern Meadow”, a company wishing to produce cultured leather and “cultured meat”.
- 2013 Highly-publicised presentation in London of the first artificial meat burger by Mark Post of Maastricht University.
- 2014 Launch of New Harvest (an organisation promoting “cultured meat”),
- 2016 Launch by of the Good Food Institute, an organisation for the promotion of alternatives to animal products.
- 2020 Approval by the state of Singapore of the marketing of “cultured meat”.
- 2021 Launch of the Cellular Agriculture Europe association.
- 2023 Approval for their “cultured meat” labels from the USDA to two “cultured meat” companies (Good Meat and Upside Foods).
- 2023 Approval in the European Union to a Czech start-up Bene Meat Technologies for the commercialisation of its “cultured meat” for pet food.
- 2024 Approval in Israel to Alephs Farm for the commercialisation of its “cultured meat”.
- 2024 A dozen European countries (including Italy, France and Austria) or a few American states (Alabama, Florida) wish to ban “cultured meat”.
- 2024 In a world first, Gourmeyer, a Paris-based food startup, has requested approval for market access in five global markets: the European Union, Switzerland, Singapore, the United States, the United Kingdom.

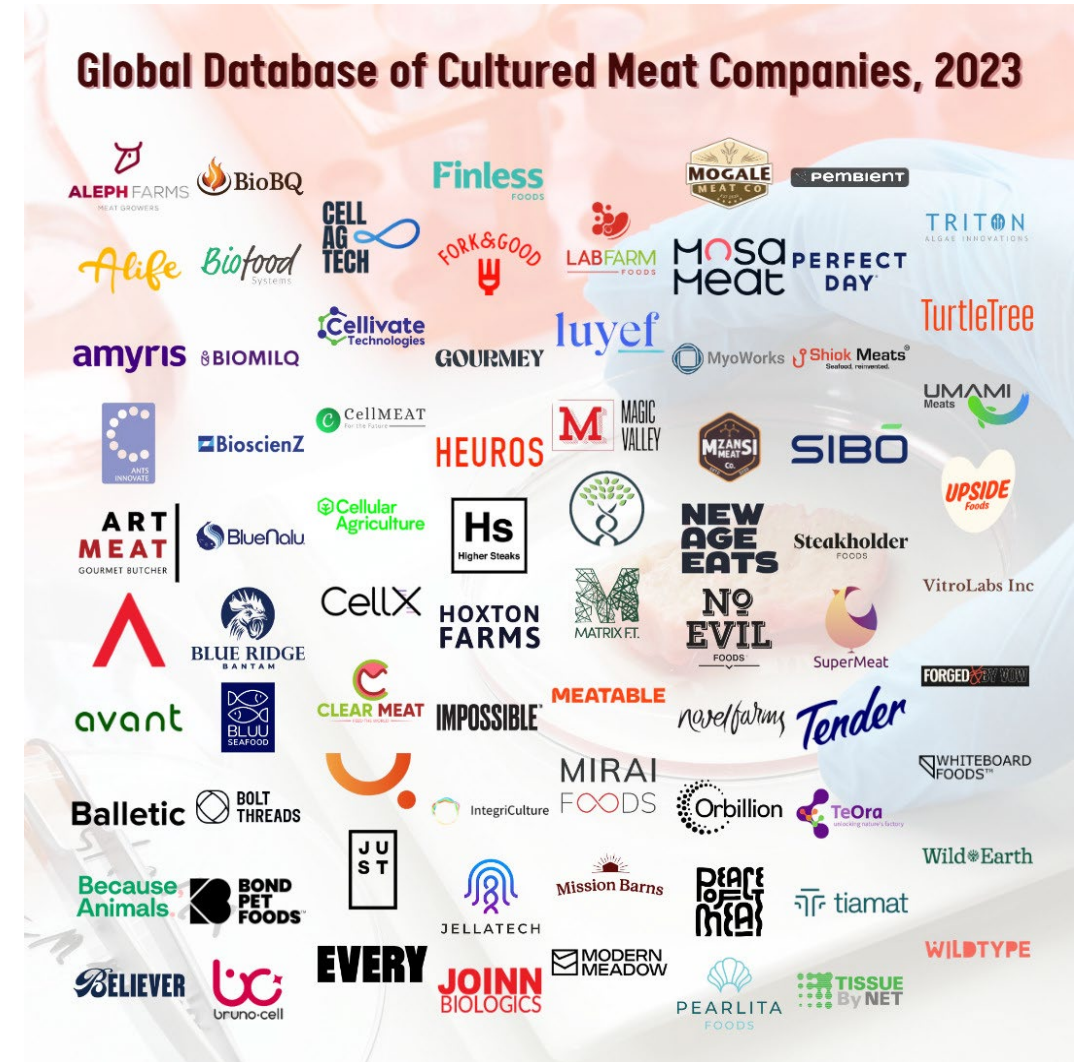
There is an increase in number of private companies



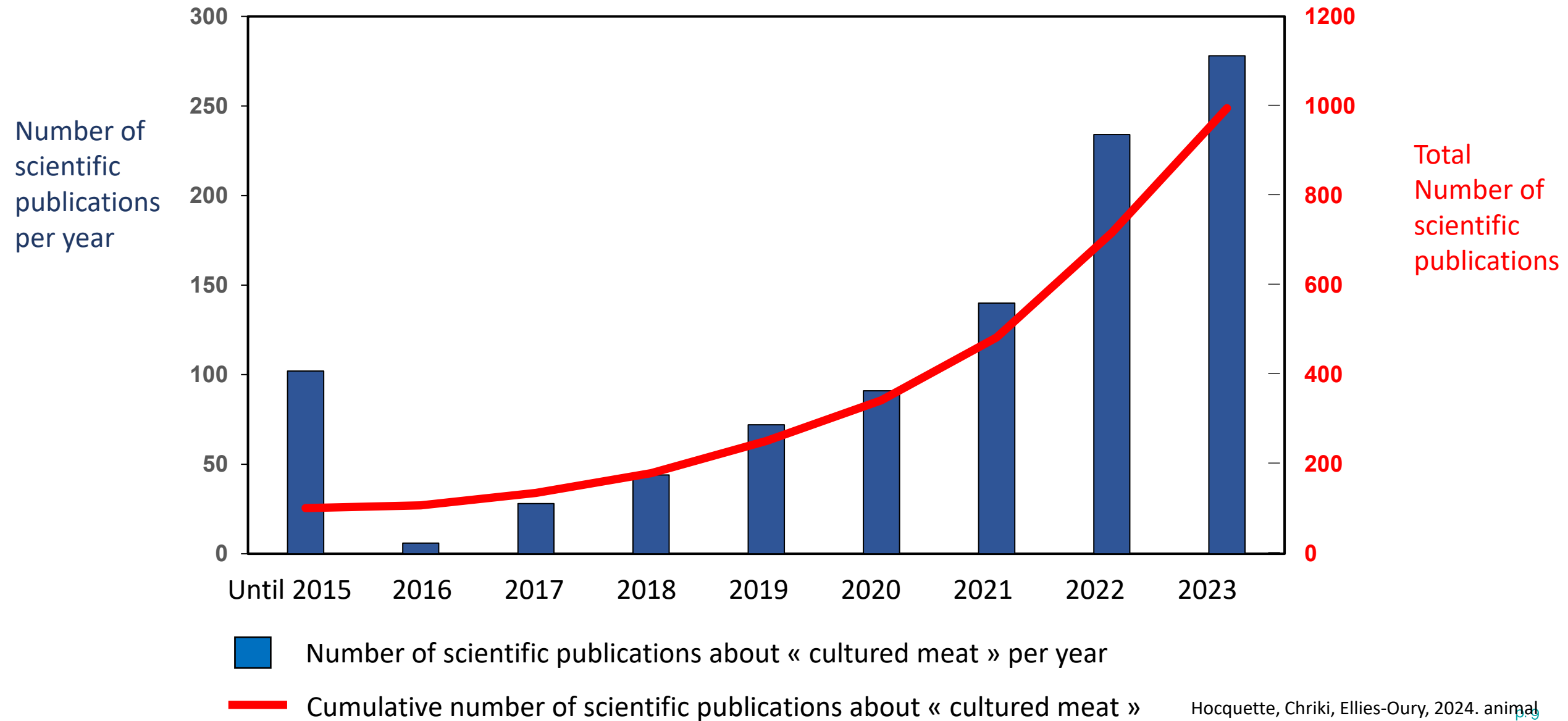
2016



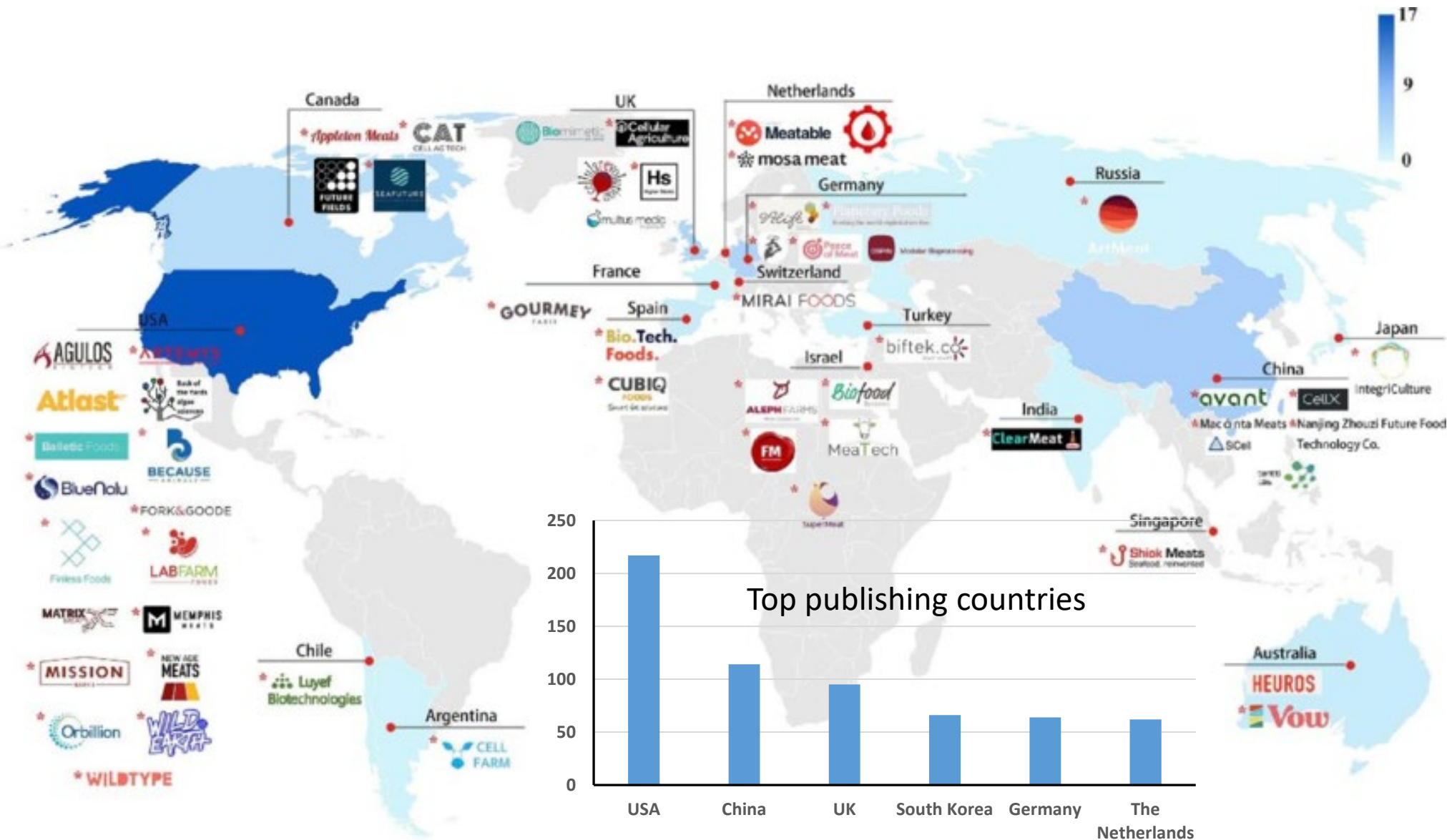
2021



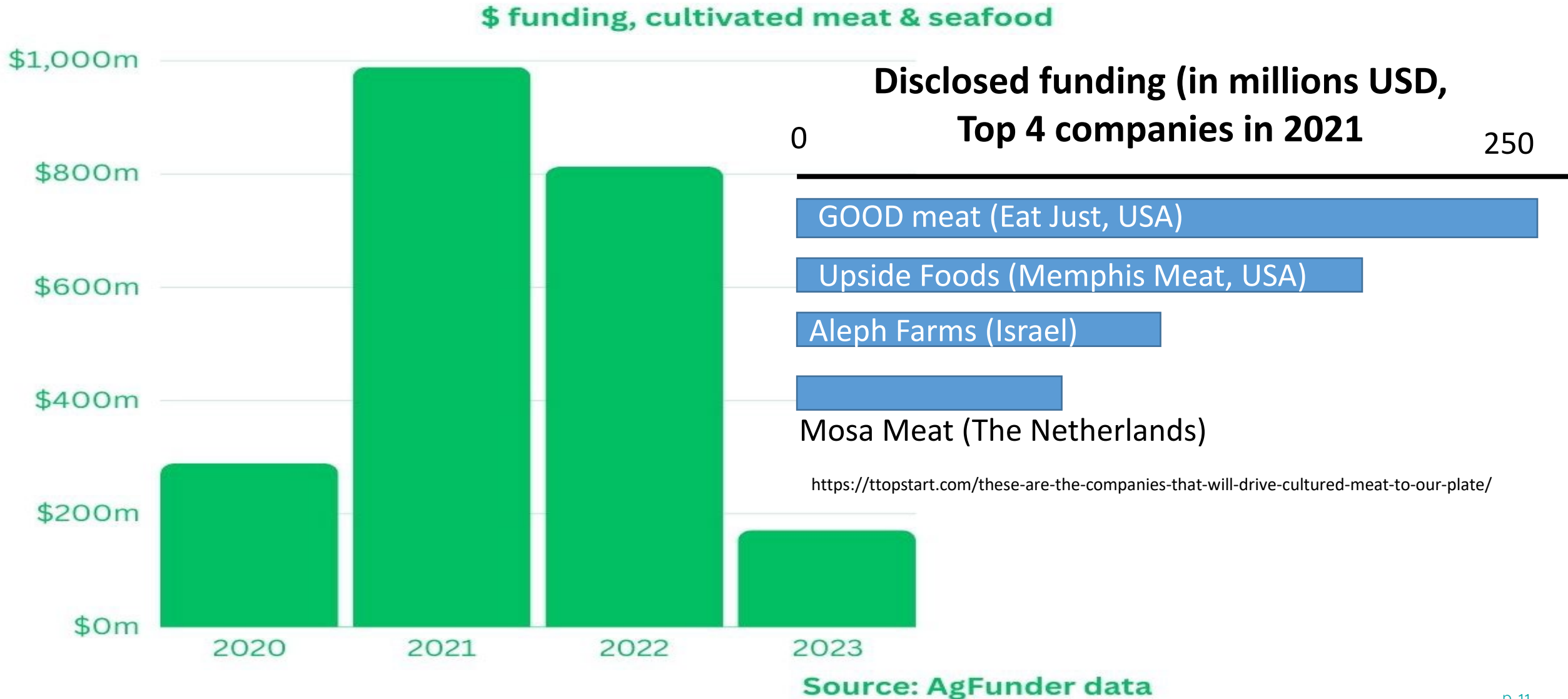
An increasing but a low number of scientific publications



The top prolific countries in research on “cultured meat”



Investments are decreasing



There is a consensus about the technical problems to solve

Current limitations across four domains are:

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

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

Kim et al. (2024). Meat and Muscle Biology 8(1): 17645, 1–25

The great challenge is to efficiently produce cell-based food products at scale, this needs new concepts and bioprocesses that did not exist before

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

Kim et al. (2024). Meat and Muscle Biology 8(1): 17645, 1–25



<https://vegnews.com/2021/11/lab-grown-meat-facility-california>

Cell-based food: revolution, culture clash or hype?

More than 25,000 articles in the press media, but only 826 scientific publications up to on February 13, 2023

SWI swissinfo.ch

Swiss perspectives in 10 languages

Science >

Cultured meat: revolution or hype?



Culture clash? What cultured meat could mean for farmers & sustainable diets

<https://www.swissinfo.ch/eng/business/cultured-meat--revolution-or-hype--/47892954>

Outline

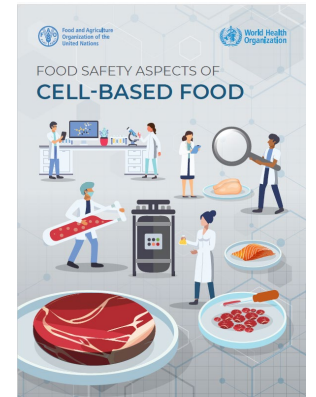
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Cell-based food safety research priorities (FAO)

Hazard identification based on 4 production phases

“If it isn’t safe, it isn’t food.”

	Cell selection Cell sourcing, isolation, preparation and storage	Production Cell proliferation and differentiation	Harvesting Cell/tissue harvesting	Food processing and formulation
Hazard/Concern	• Transmission of zoonotic infectious diseases • Microbial contamination • Chemical residues & by-products	• Microbial contamination • Chemical residues & by-products • Biological residues & by-products	• Microbial contamination • Chemical and biological residues & by-products • Physico-chemical changes	• Microbial contamination • Chemical and biological residues & by-products • Processing contaminants • Physico-chemical changes
Potentially new hazard/concern	• Carry-over of cryoprotectants (used for cell storage)	• Risk of (epi)genetic drift in cell lines due to constant sub-culturing • Potentially allergenic scaffolds or microcarriers	• Culture medium residues	• None



Masami Takeuchi, PhD, Food Safety Officer, FAO, Sept 1st, Lyon
 FAO & WHO. 2023. Food safety aspects of cell-based food. Rome.
<https://doi.org/10.4060/cc4855en>

Is cell-based food healthy?

Cell-based food currently differs significantly from meat in its technological, sensorial and nutritional properties”: it has a pale colour due to the absence of myoglobin” and a low iron content (Fraeye et al., 2020, Frontiers in Nutrition 7:35 and Olenic M, Thorrez L. Cultured meat production: what we know, what we don’t know and what we should know. Ital J Anim Sci 2023;22:749—53, <http://dx.doi.org/10.1080/1828051X.2023.2242702>).

Nutrition Profile	Soy base	Cultured chicken	Chicken breast
Energy (kcal 100 g ⁻¹)	157.0	137.0	106.0
Protein (g 100 g ⁻¹)	22.5	19.1	19.8
Fat by hydrolysis (g 100 g ⁻¹)	4.7	4.5	2.9
Saturated fat (g 100 g ⁻¹)	0.4	0.7	0.9
Cholesterol (mg 100 g ⁻¹)	0.0	56.9	89.8
Carbohydrates (g 100 g ⁻¹)	1.0	0.8	0.1
Sodium (mg 100 g ⁻¹)	399.0	346.2	157.0
Ash for minerals (g 100 g ⁻¹)	1.0	0.9	1.2

Cell-based food has been analysed once

- Same protein content,
- The vitamins, minerals and amino acid profile are comparable.
- Lower in saturated fat and cholesterol
- But higher in sodium

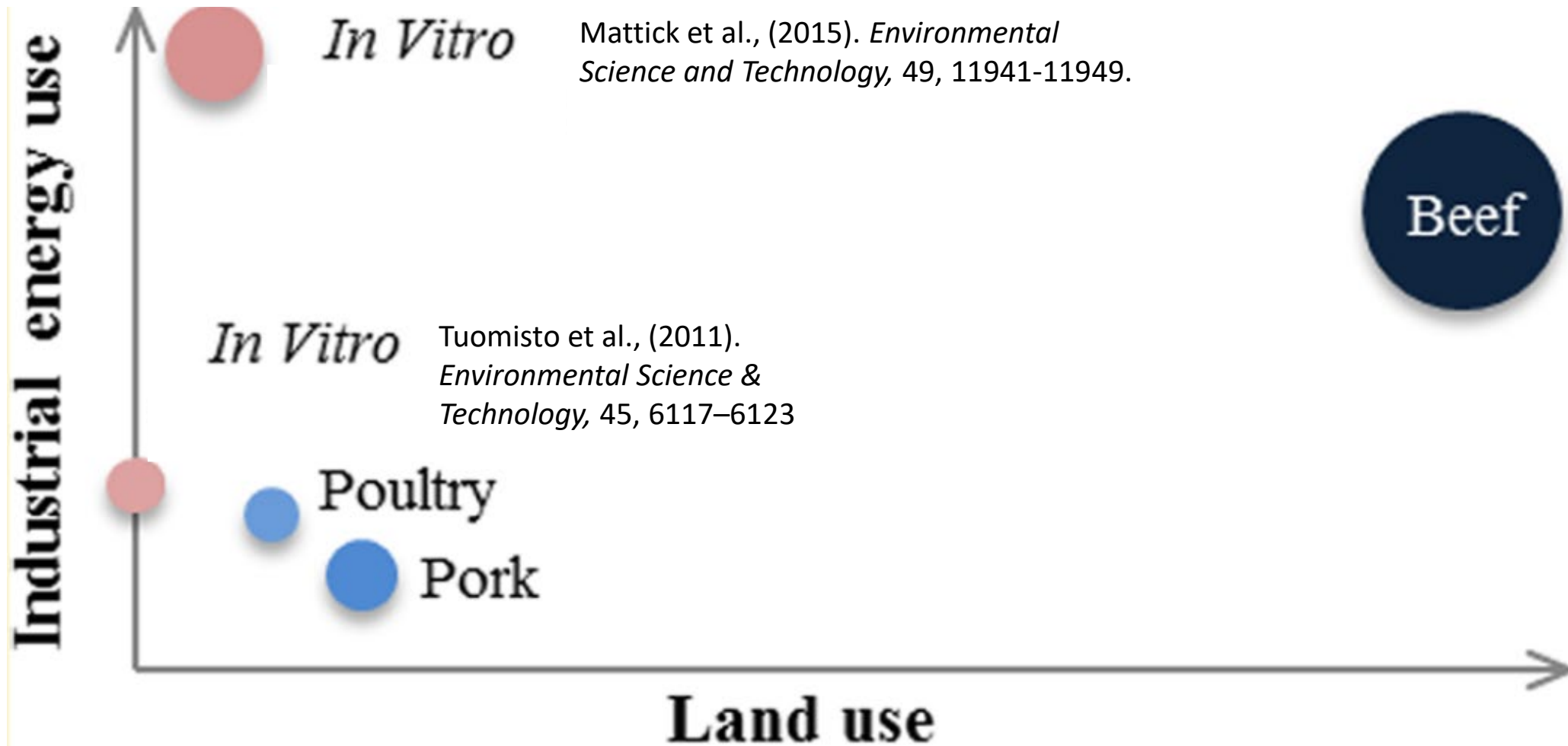
Is cell-based food healthy?

“Compared to conventional chicken meat,

- lower content of protein, and the majority of indispensable amino acid contents, Mg, and vitamin B3,
- but higher levels of total fat, saturated fatty acids, cholesterol, vitamins B5, B6, and A, and minerals Ca, Cu, Fe, K, Mn, Na, P, Se, and Zn.
- Toxic elements (As, Cd, Pb, Hg) did not exceed allowance thresholds,
- But higher levels of Cd and Pb than conventional chicken meat.
- this first assessment generally falls within the European Union requirements,
- but it is crucial to optimize the reproducibility of the production process due to observed variabilities in nutrient levels between tested lots.
- yet it should not be extrapolated to the entire field of cultured meat”.

Dominika Sikora, Piotr Rzymski, 2024. *Journal of Food Composition and Analysis*
<https://doi.org/10.1016/j.jfca.2024.106663>

Contradictory results about energy use



Environmental impacts are not known

Overview of the main gaps identified in each study related to environmental impacts of Cell-based food

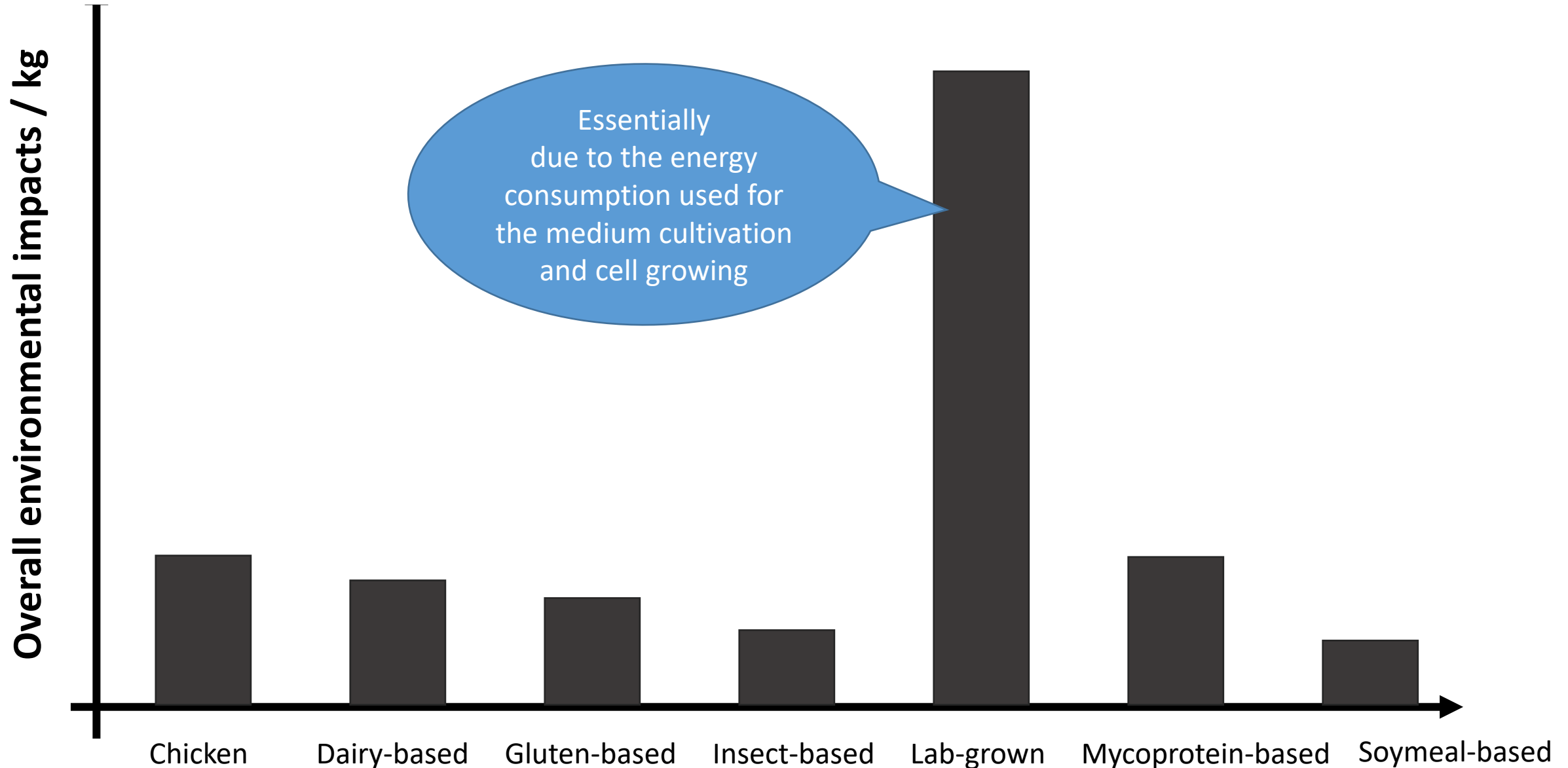
	Tuomisto and Teixeira de Mattos (2011)	Tuomisto et al. (2014)	Smetana et al. (2015)	Mattick et al. (2015)
Cell collection	—	—	—	—
Growth factors production	—	—	—	—
Scaffold production	—	—	—	+
Bioreactor's production	+	+	+	+
Cleaning bioreactor	—	—	—	+
Culture media recycling	—	—	—	—
Scaffold removal/recovery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

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

Cell-based food production is energy-intensive

(Sinke et al., 2023. The International Journal of Life Cycle Assessment volume 28, pages 234–254 <https://doi.org/10.1007/s11367-022-02128-8>)

Life cycle assessment of most known meat substitutes



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Status of regulation worldwide

In addition to Singapore, early 2023,

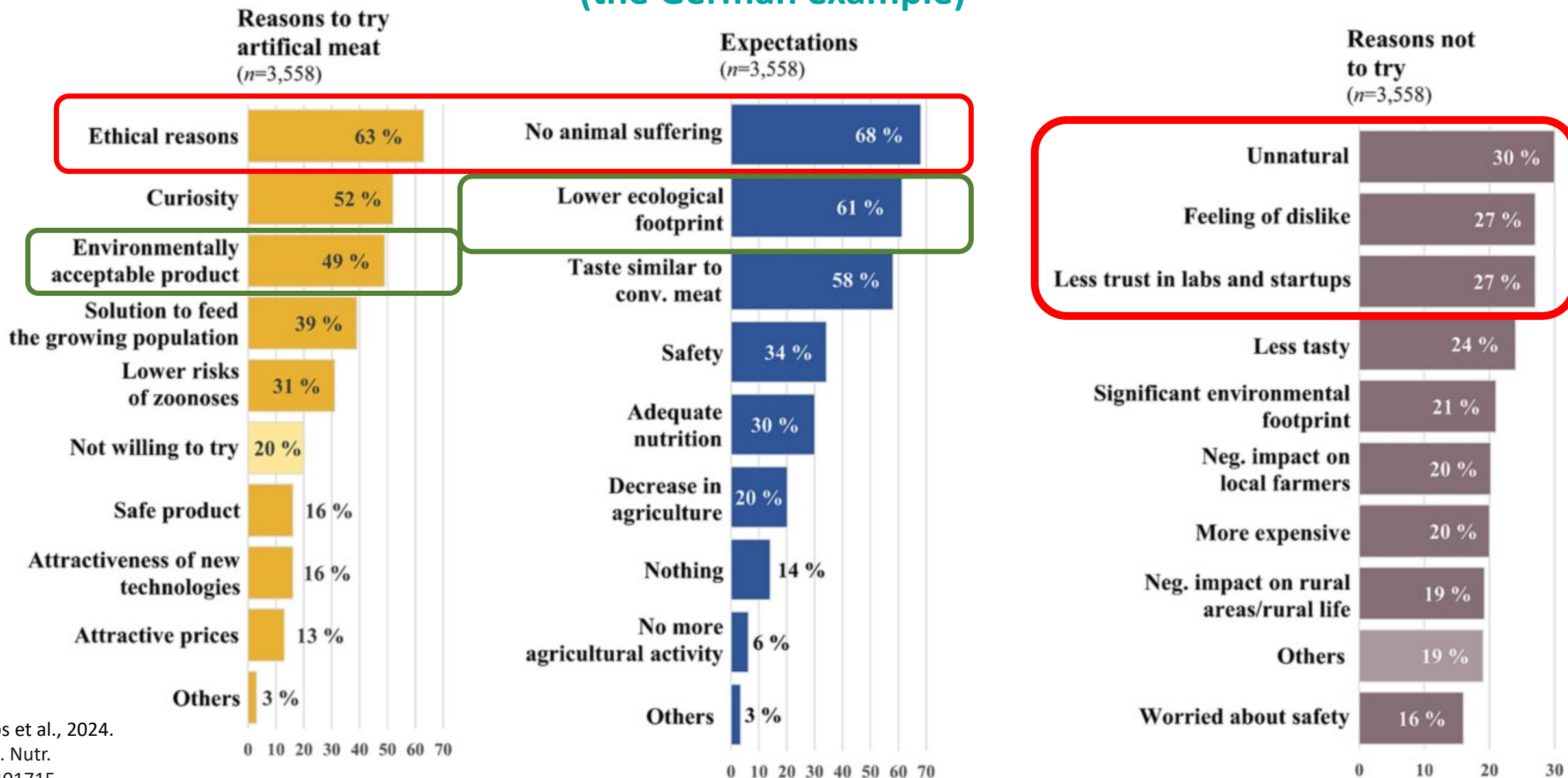
the USDA granted approval for Upside Foods and Good Meat to sell their lab-grown cell-cultivated chicken products in the United States.

Israel also granted approval for Aleph Farms

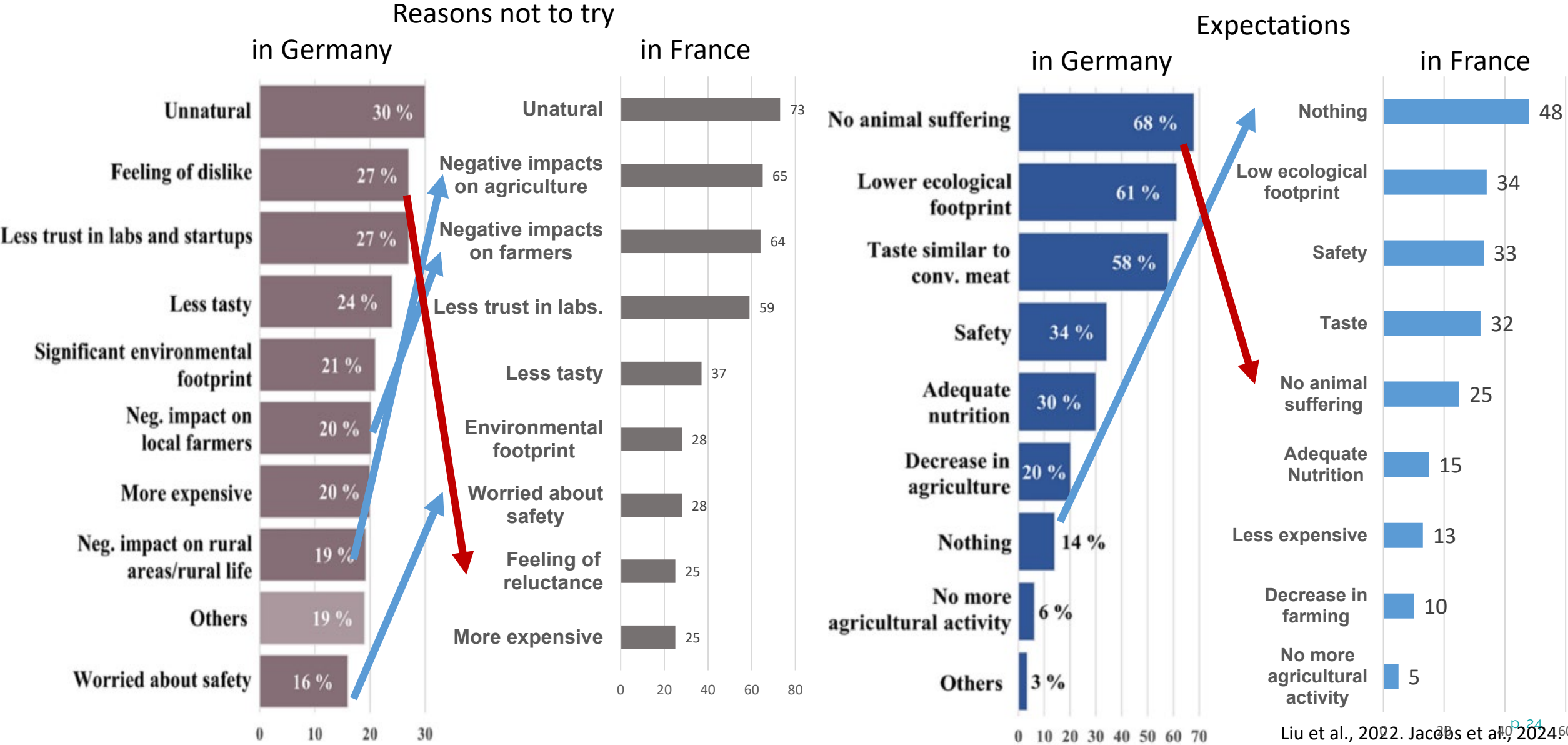
If no genetic modification is involved, the approval by the European Commission on the advice of the European Food Safety Authority (EFSA) under **Novel Foods Regulation** is required before “cultured meat” can be marketed in Europe.

The purpose of this regulation is to ensure that novel foods are safe to eat, and this has not been fully demonstrated at this stage for all cultivated food products [Chriki et al. (2022). *Animal Frontiers*, 12, 35-42]

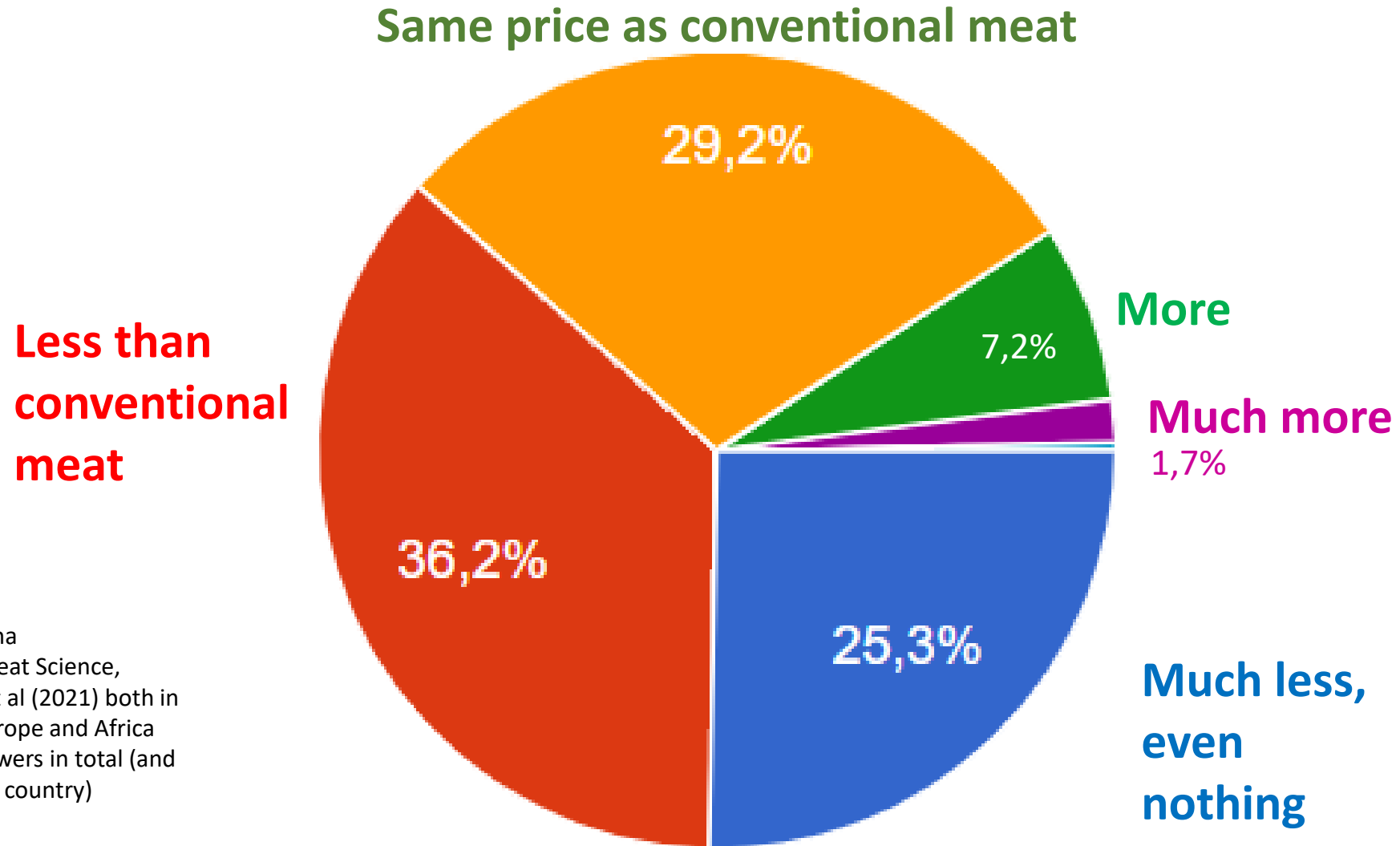
Reasons to taste or not cultured meat and main expectations (the German example)



Reasons not to taste cultured meat and main expectations

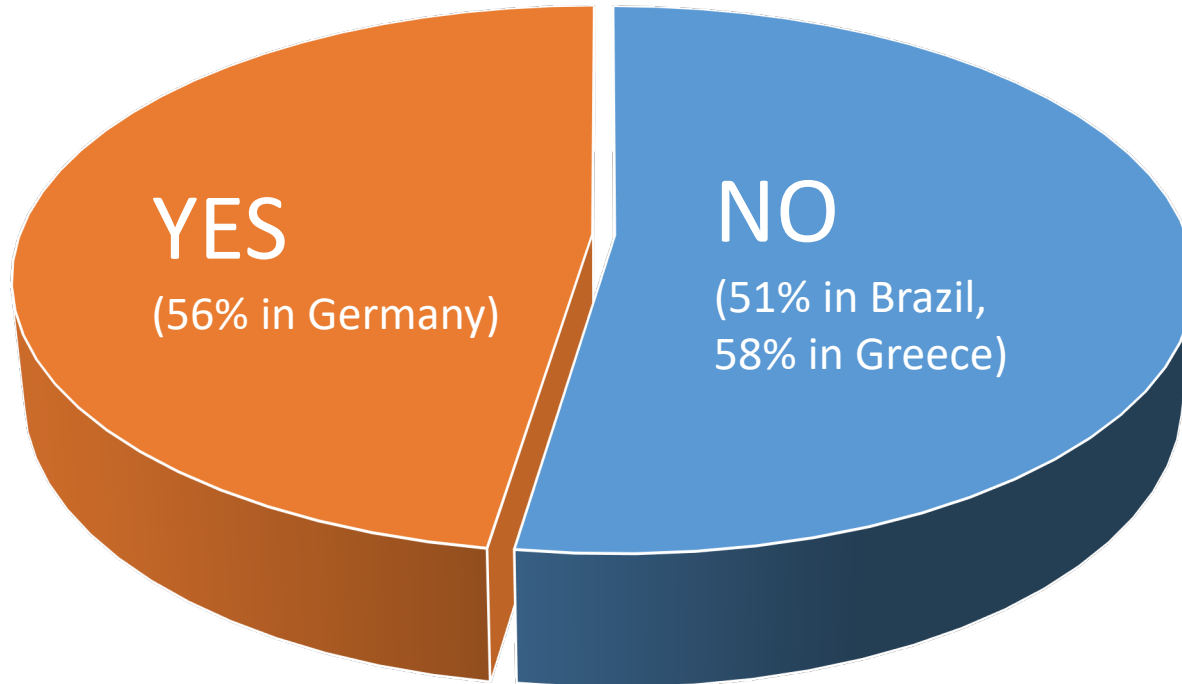


Consumers don't want to pay more for cell-based food



Results in France, Brazil, China
Hocquette et al. (2022) in Meat Science,
Chriki et al. (2021) and Liu et al (2021) both in
Foods. Plus data in South Europe and Africa
Total: more than 15,000 answers in total (and
more than 4,000 answer per country)

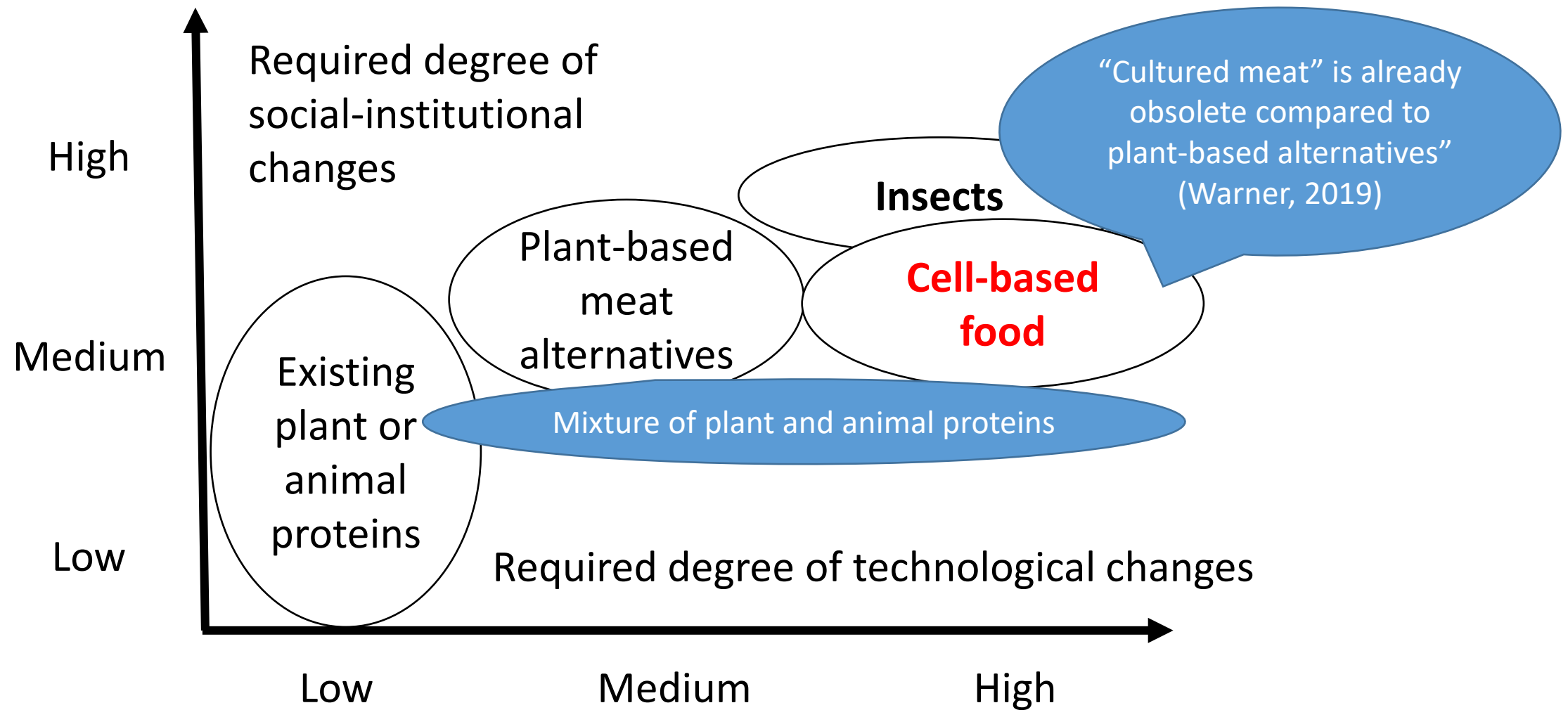
Is it really meat according to consumers?



Average of more than 10,000 answers from Brazil (Chriki et al., 2021. *Foods*, 10,11, 2588 <https://doi.org/10.3390/foods10112588>), European and American countries (unpublished results)

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

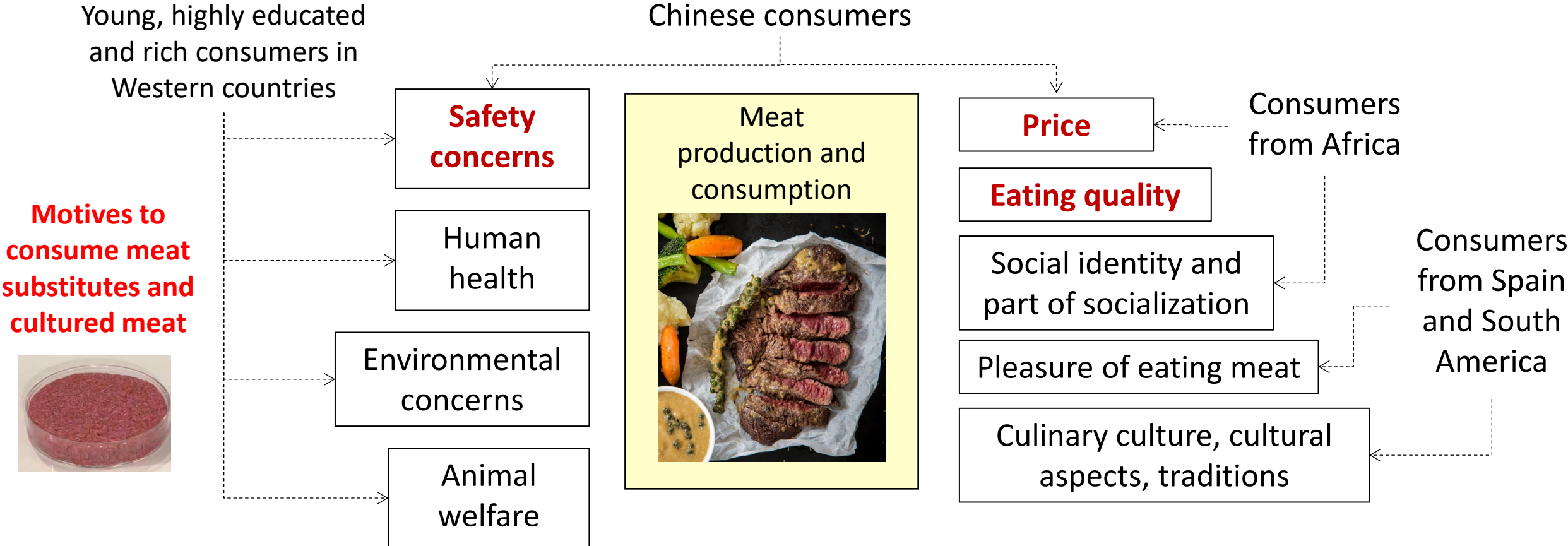
The required degree of changes is a driver of food acceptance



Van der Weele C, Feindt P, Jan van der Goot A, van Mierlo B, van Boekel M. Trends Food Sci Technol. (2019). 88:505–12.

Warner (2019). Animal, 13, 12, 3041-3058. <https://doi.org/10.1017/S1751731119001897>

Motives and barriers of consumption of meat and meat substitutes



Interaction with affective factors, personal compromise between barriers and motives, meat origin, livestock systems, etc

From a special issue of Meat Science (with 24 papers)
Meat Science 200 (2023) 109163

Ethical questions associated related to “cultured meat”

Yes, “cultured meat” is supposed to protect the life of animals, (review from Mancini et Antonioli, 2022).

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

But we need livestock to valorize non-convertible grasslands and co-products that cannot be valorized by human beings (Mottet et al., 2017).

Towards a wide range of alternatives to meat including mixing plant and animal proteins. The competition with other meat alternatives is tough and “cultured meat” is supposed to be rapidly obsolete due to the success of other alternatives (Warner et al., 2019).

Please also consider cultural, symbolic relations with food (meat) and also the rural world (Leroy and Praet, 2017). Toward dehumanization of food.

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?
- “The widespread adoption of such technologies can exacerbate global inequity between affluent and poor individuals and between high- and low-income countries”.

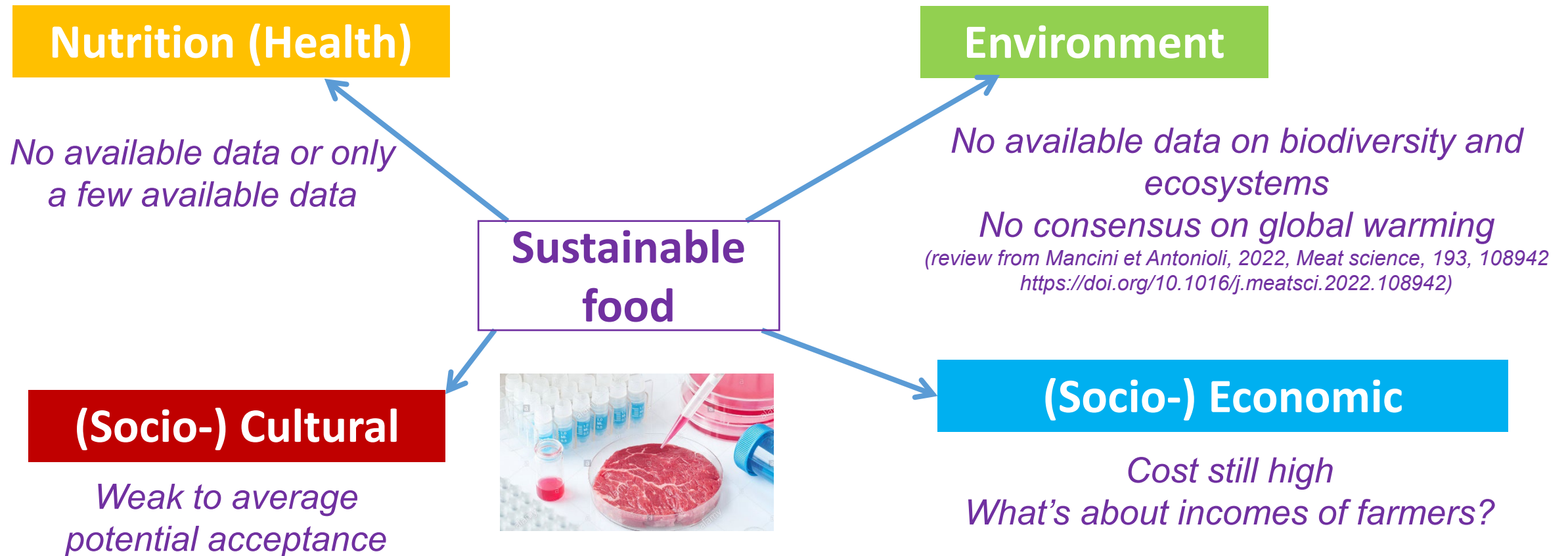
Potential profiles of CM adopters and rejectors

Potential profile of CM adopters	Potential profile of CM rejectors
Young	Old
Higher educated	Less educated
Familiar with CM technology	Not familiar with CM technology
Work outside the meat sector	Work within the meat sector
Scientist	Non-scientist

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“Cultured meat” cannot contribute to a sustainable diet



Definition of sustainable food is from FAO (FAO, WHO, 2019. Sustainable healthy diets -Guiding principles. Rome - Italy)
<http://www.fao.org/3/ca6640en/CA6640EN.pdf>

CONCLUSIONS

Optimistic claims trumpeting the promissory potential of CM are over-simplistic and warrant closer scrutiny (Lee, 2018 ; Hocquette et al., 2024).

We should consider the « precautionary principle » (article in Le Monde signed by more than 60 scientists)

Other solutions are available to provide enough proteins :

- Reducing food losses 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

“Cultured meat” should be compared to these solutions.



Contents lists available at [ScienceDirect](#)

Animal

The international journal of animal biosciences



Review: Will “cultured meat” transform our food system towards more sustainability?

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