Food and Agriculture Organization
of the United Nations

Food safety aspects of cell-based food

Background document **one – Terminologies**

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Contents

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Abbreviations and acronyms

AMPS	Alliance for Meat, Poultry and Seafood Innovation
ANPR	Advance Notice of Proposed Rulemaking
FAO	Food and Agriculture Organization of the United Nations
FDA	United States Food and Drug Administration
FSIS	Food Safety and Inspection Service of the United States Department of Agriculture
SD	Standard deviation
USDA	United States Department of Agriculture

Executive summary

Cell-based food technologies allow for the production of animal proteins from *in vitro* grown animal or microbial cells. These technologies are developing rapidly and could play a role in safeguarding access to animal proteins for a growing world population, while further analyses are necessary to evaluate their sustainability and impact on human health and environmental health. There are currently a wide range of different terminologies in relation to the technologies, production processes and the final products, which might hamper clear communication to audiences from varying backgrounds and sectors. Moreover, the terminologies can influence both consumer perceptions and national regulatory frameworks, including the possible labelling requirements of cell-based food products to provide consumers with information regarding food safety, allergens, and nutrition. It is therefore important to analyse the existing cell-based food terminologies and how they can be used and perceived by different stakeholders. An overview of the literature was conducted on the use of cell-based food terminologies to serve as a basis to initiate a global discussion on the possible need to support policymakers worldwide in making informed decisions on selecting cell-based food terminologies that could be used in communications or in the relevant legislation on cell-based food products.

Keywords: cultured meat, cultivated meat, cell-based food, alternative proteins, emerging technology, novel food, terminology, nomenclature, definition, harmonization, food safety, standards

1. Introduction

1.1. Background

The increasing global demand for animal-sourced protein adds to the existing pressure on ecosystems and biodiversity (FAO, 2018). Intensifying animal production may also threaten broader sustainability objectives, such as climate change and public health, resulting in trade-offs in various aspects of environmental protection, food security and animal welfare (FAO, 2019, Henchion *et al.*, 2021, OECD, 2021). These factors have triggered research efforts for developing more sustainable ways of producing animal meat as well as a research focus on a "protein transition" wherein consumption of animal protein will be at least partially replaced by alternative protein sources, such as from plants and micro-organisms but also *in vitro* produced animal protein (Aiking and de Boer, 2020), in order to accommodate the increased demand for protein and assure global food security.

One of the technological developments that could produce analogues of animal proteins without slaughtering animals is via *in vitro* cultivation of animal cells on a large scale, which could then be processed into products that are substantially equivalent to conventional meat. Such products are often called "cell-based", "cultured" or "cultivated" meat, and currently there are several terms in use to define this type of products around the globe.

While research in this area has been ongoing since the early 2000s, the development of the products was presented to the general public in 2013, when researchers from the Netherlands demonstrated the first product describing it as a "lab-grown" beef burger at a press conference in London (BBC News, 2013). In December 2020, so-called "cultured" chicken nuggets became the first commercialized product of its kind, after market approval in Singapore; these particular nuggets are a blend of cultured chicken and plant-based ingredients (Carrington, 2020). On a broader scale, the production of analogues of animal products, such as meat, poultry, seafood, dairy, and eggs produced through cell-based culture techniques has been advancing quickly in the past few years and at least 76 companies have been developing similar products in 22 different countries since 2013 (Byrne, 2021).

Because of the novelty of the cell-based food production process and products, assurance of food safety is one of the main concerns of nutritionists, food technologists, the competent authorities and consumers. In addition, the national competent authorities will have to consider various socio-economic issues relating to these products, including consumer preference, acceptance, ethical issues, production costs, trade issues and market prices. When there is a need for clear labelling of such products and/or special authorization processes are to be conducted by competent authorities, then appropriate regulatory frameworks need to be adjusted or newly employed, as these products may enter their jurisdictions or appear at the border at any time, via e-commerce for example.

In order to discuss the relevant technical issues about cell-based food production, it is important to use clear and consistent terminologies that can be accepted by all the stakeholders. Terminologies and labels are also an important and direct means of communicating information to consumers (FAO, 2021). However, currently many different terms and labels exist for these types of products in both the scientific literature and public communications, thereby potentially creating confusion. It is therefore important to make an inventory of these terms and their current usage, framing and legal consequences, in order to achieve a consensus on the terminology to use at the global level. This will also contribute to a better understanding of the topic as well as encourage further discussions on cell-based food products in different parts of the world.

This document provides a synthesis of the available literature on the existing terminologies in the area of cell-based food production and their associated positive and negative attributes, and recommends options for the terms to use at the global level.

1.2. Scope

To aid the scientific advice activities provided by the Food and Agriculture Organization of the United Nations (FAO), it is essential to use clear terminologies to describe the relevant processes, associated technologies, techniques and products in animal cell-based food production. The document focuses on the terminologies used in different sectors and describes the associated issues, by making a systematic inventory of the available scientific literature as well as non-scientific reports and public communications. This overview employed the systematic-review methodology, and it does not include any political nor opinion-based views. The aim of the document is not to define the relevant terminologies but to simply collect the existing ones with the attributed analyses, so that subject-matter experts and/or policymakers at the national level can use this overview as a reference to make informed decisions. In this document, and without setting a precedent, the term "cell-based" is generally used to indicate the products and production in this field. It is being published as one of the background document series for the expert consultation in November 2022, thus the contents will be further added to, modified and refined in the final publication in 2023. Therefore, the present document can be considered as valid until that time.

2. Methodology

A systematic literature search strategy was defined for the collection of data, using search strings relating to "cell-based" meat and seafood terminology for the technologies, products, regulations, food safety and production processes. The strategy covers the collection of data from both English language scientific literature from the period 2013–2021 and from English language "grey" information sources with no time limit. The latter include national/supernational/regional competent authorities, international organizations, private sector entities, academia, research institutions, civil society and non-governmental organizations. Information from these grey sources was collected from publicly available websites, white papers, reports, reviews and guidelines. Data from the scientific literature was collected from the Web of Science and Scopus databases and from the abstracts of the Centre for Agriculture and Bioscience International (CAB) and the records retrieved from these databases were searched through and screened for relevance before the retrieval of full references and in-depth screening. Analysis of the frequency of use of cell-based modifier terms by the media was done using the corpus of News on the Web (Davies, 2016), which is a highly searchable collection of texts.

3. Results

3.1. Product modifier terminologies

A list of the synonyms used for cell-based food products, such as cell-based meat and seafood products, and their use by different professional sectors is provided in Table 1 based on the outcomes of several consumer and industry studies on the perception, acceptance and preference for terminologies for the modifier part (e.g. "cultured") of the terminologies.

Table 1: Synonyms of modifier terms for animal "cell-based" food products and their common use in professional sectors

	Sector			
Modifier term (1)	**Authorities**	**Industry and developers**	**Academia**	**Media**
animal-free			X	X
artificial			X	X
cell-based	X	X	X	X
cell-cultivated (2)			X	
cell-cultured	X	X	X	X
cellular			X	X
clean		X		X
cruelty-free				X
cultivated	X	X	X	X
cultured	X	X	X	X
fake			X	X
Frankenmeat				X
healthy		X		X
imitation				X
in vitro			X	X
lab-grown			X	X
made				X
Meat 2.0 (3)				X
Shmeat				X
slaughter-free				X
synthetic			X	X
test tube				X
vat-grown				X

Source: Authors' own elaboration.

(1) Based on scientific articles collected from the literature search, grey literature and media; (2) Hallman, W. K., Hallman, W. K. II, & Hallman E. E. (2021). Cell-Based, Cell-Cultured, Cell-Cultivated, Cultured, or Cultivated. What is the best name for meat, poultry, and seafood made from the cells of animals? https://www.biorxiv.org; (3) Meat 2.0 is a term that is used to cover "cell-based" meat, but also plant-based and microbe-based meat replacers.

3.2. Modifier terminologies used by authorities

The use of terminologies by authorities such as governmental institutions and regulatory bodies is often expected to be guided by legally accepted terms. Besides, for example, Singapore and the European Union, regulatory bodies in most countries have not yet ruled as to what existing legislation cell-based food products fall under, or which specific terms for labelling of cell-based food products are to be used. As of February 2022, the Singapore Food Agency (SFA) is the only regulatory body that has implemented a specific section for cell-based food products in their "Requirements for the Safety Assessment of Novel Foods" document (SFA, 2021a). This document uses the term "cultured" meat, but this is not the only term allowed, as the SFA has indicated that product package labelling will require qualifying terms that clearly communicate the nature of "cultured" meat food products to consumers so that they can make informed choices. These terms may also include, for example, "cultured", "cultivated" and "cell-based" (SFA, 2021b). Singapore has also published general food labelling guidelines that advise against the use of claims that would cast doubt on the safety of other foods or imply that a particular food is safer than other similar food, and these would also apply to cell-based food (SFA, 2021a).

In the United States, the Food Safety and Inspection Service (FSIS) of the United States Department of Agriculture (USDA) published in September 2021 an ANPR (Advance Notice of Proposed Rulemaking) in which it requests comments for "the labelling of meat and poultry products comprised of or containing cultured cells derived from animals" (USDA, 2021). Similarly, the United States Food and Drug Administration (FDA), which has labelling authority for cultured fish and seafood cell products, published in October 2020 a "Request for Information" in which it calls for comments for "the labelling of foods comprised of or containing cultured seafood cells." (FDA, 2020). The FDA intends to use the information and data resulting from this notice to determine what type(s) of actions, if any, the agency should take to ensure that these foods are properly labelled. The FSIS and the FDA have agreed to develop joint principles for product labelling and claims to ensure that products are labelled consistently and transparently. Although the FSIS's ANPR makes use of the term "cultured" meat, the US authorities are still in the process of defining the actual food labels that will be allowed in the future, which will impact the terms to be used by these authorities in the future. It is also worth considering that the authorities' labelling regulations may have preference for terms that describe the process the food has undergone.

3.3. Modifier terminologies used by industry and developers

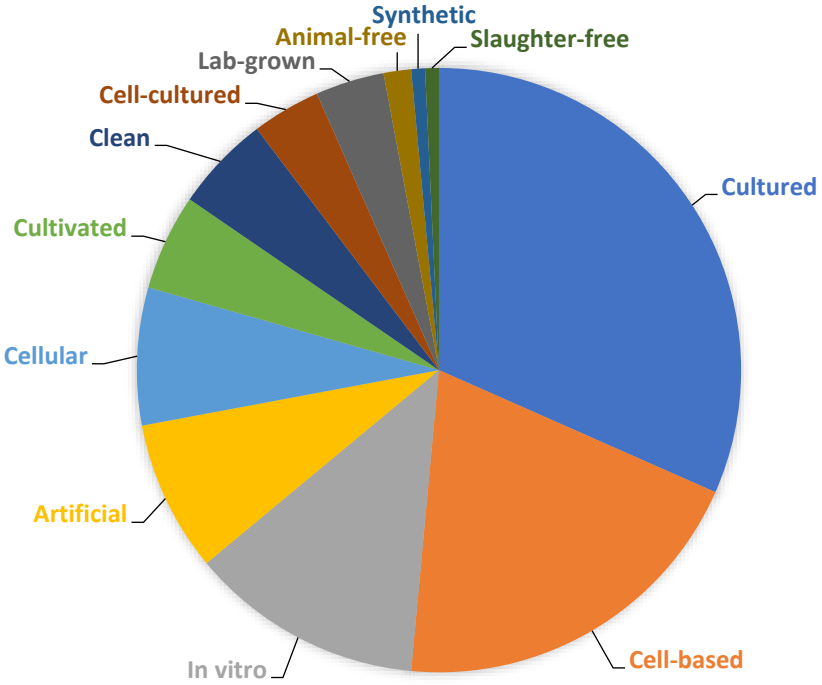
In September 2021, a focus group surveyed the Chief Executive Officers (CEOs) of 44 cell-based food companies globally about their preferred nomenclature for their products. Seventy five percent of the companies were found to use the modifier "cultivated", 20 percent the concept "cultured" meat, and one company (~2 percent) "cell-based". Several quotes from the interviewed CEOs appear to point to a shared view that the use of "cultivated" allows us to differentiate from other products and at the same time appeal to consumers and be amenable to consumer education. The use of "cultivated" might therefore align the industry viewpoint for the modifier term (Byrne, 2021). This survey indicates an increase in adoption of the term "cultivated" since a study in 2020, where this term was found to be used in 45 percent of relevant websites and promotional material from the cell-based food industry. This is partially in line with the recommendation from the American "cultured" meat industry trade group Alliance for Meat, Poultry and Seafood Innovation (AMPS) to use either "cultured", "cultivated" or "cell-based" and in line with the recommendation by the cell-based meat industries based on the outcomes of the consumer study by Szejda *et al.* (2019). Following various post-hoc stakeholder meetings, the study executor and stakeholders chose the term "cultivated" meat to go forward with. Towards this end, a communication strategy was devised, where an analogy was drawn between cultivating meat and growing plants in a greenhouse.

In addition, the use of cultivation-related language, such as "cultivator" for the reaction vessel in which cells are grown, was considered to expand the narrative to engage people with the concept of meat cultivation (Szejda *et al.*, 2019). It is important to note that the terminologies used or preferred by industry are subject to change and indicates the need to harmonize terminologies in the industrial sector, which might come from legal approval of specific terms by the authorities.

3.4. Modifier terminologies used in academic research

The scientific community uses a wide variety of terminologies (Table 1). However, no studies have been performed to analyse the preferred modifier terminologies among scientists and, therefore, a consensus on accepted terminologies does not exist. Based on the scientific articles (N[1]=144) collected from the literature search on this topic for the period 2013–2022, the most used terms are "cultured" (N=43) and "cell-based" (N=27), followed by "*in vitro*" (N=17), "artificial" (N=11) and "cellular"(N=10), while other modifier terms appear to be less commonly used (Figure 1).

Figure 1: Relative share of the synonyms of "cell-based" meat modifiers



Source: Authors' own elaboration.

Terms used in the titles of scientific articles collected from the literature search for the years 2013-2021 (as mentioned in Table 1).

3.5. Modifier terminologies used by the media and others

Using the News on the Web corpus (Davies, 2016) via the website English-Corpora.org, a large collection of texts was searched through to verify the frequency that "cell-based" meat terms were mentioned in the media between 2010 and 2021 (Figure 2). This showed that media coverage of "cell-based" meat developments has markedly increased in the last 10 years (Figure 2.a) and uses a wide variety of synonyms (Figure 2B and Table 1). The most frequently used terms since 2010 were, among others, "cultured" (30 percent), "lab-grown" (19 percent) and "fake" (14 percent) and "clean" (9 percent). It has to be noted that the preferentially used terms in the media have shifted in the last

[1] N=144 means that the number (N) of scientific articles was 144.

years: while in the initial years, terms such as "*in vitro*", "cultured" or "clean" meat were often used alongside "cultured" meat, currently other terms are more frequently encountered, such as "cultivated" or "cell-based" meat (Southey, 2021).

Figure 2.a: The number of mentions of various terms for the period 2010–2021

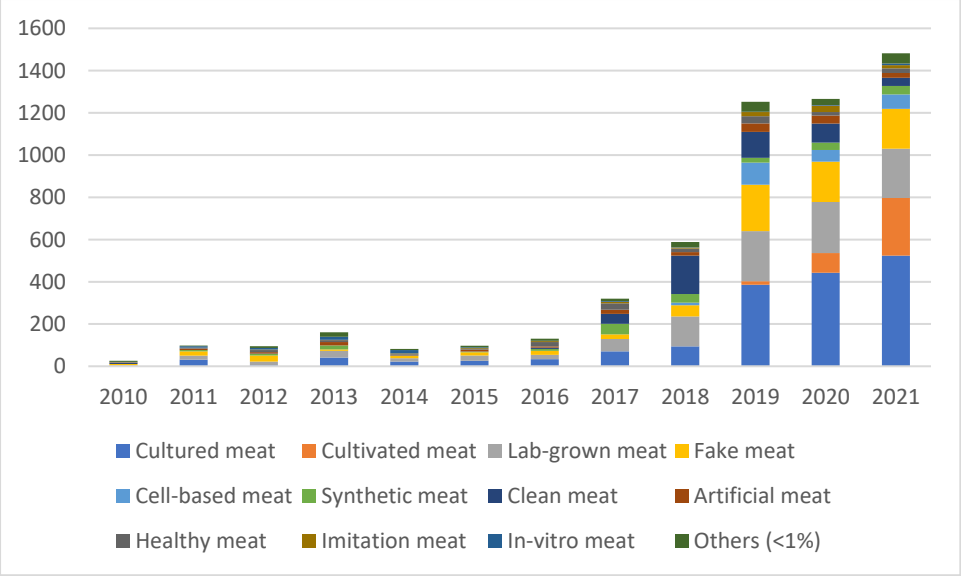
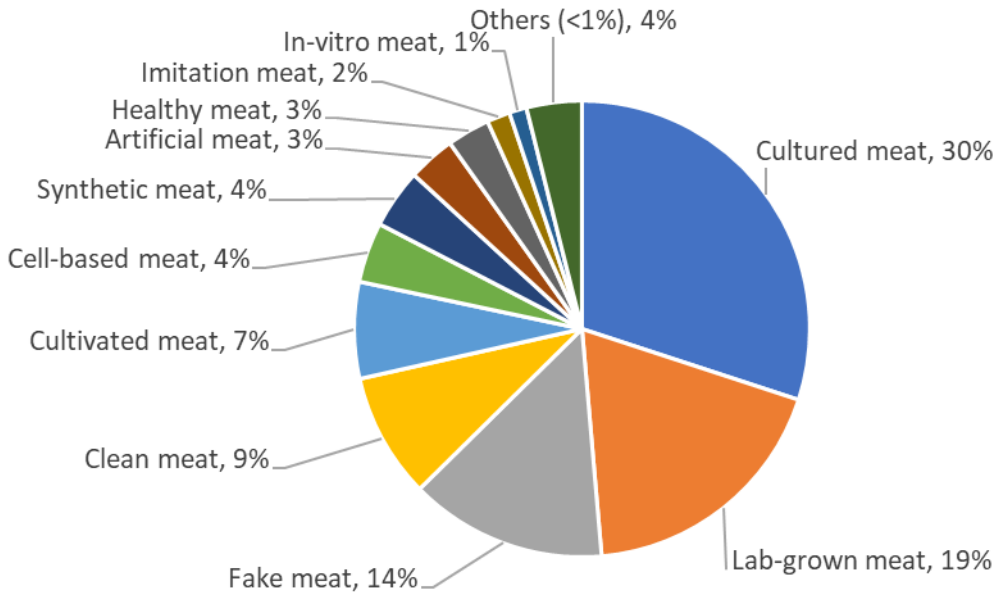


Figure 2.b: Relative share of the various synonyms



Note: "fake meat" and "imitation meat" were also used for other meat analogue types; "healthy meat" occurred in many unrelated contexts

Source: Davies, M. 2016. Corpus of News on the Web (NOW). https://www.english-corpora.org/now.

4. Impact of the terminologies

4.1. Public perception and acceptance of modifier terminologies

Participants in studies on acceptance of cell-based meat and the impact of terminology thereon are mainly from Western countries (United States of America, United Kingdom of Great Britain and Northern Ireland, European Union) with a few exceptions (Brazil, People's Republic of China). Studies carried out with other languages are not found with the current strategy. These are actually forward-looking studies because the products had not yet been launched on the markets at the time of study. Singapore might offer the opportunity to gauge consumer perception and acceptance in practice as "cultured" chicken products are already marketed and available in restaurants. Singapore's Agency for Science Technology and Research (A*STAR) has also put out articles in local media outlets as early as 2019 with the term "cultured meat", which could have helped consumers become more familiar with both the terminology and technology around "cultured meat". Singapore, as a high-income and high-tech country with a diverse ethnic population, might not be representative of other countries in the region, however.

In the introduction to their study, Bryant and Barnett (2019) provide an overview of the various terms for cell-based food encountered in the scientific literature and beyond. They also point out the importance of names and labels that directly or indirectly impact consumers' perceptions and appeal of the product. These authors also note that certain widely used names, such as "artificial meat" or "synthetic meat", may indirectly suggest vague and confusing concepts of "natural meat" to be associated with conventional meat. In the same study, the authors analysed consumer perceptions of four concepts in more detail: "animal-free" meat, "clean" meat, "cultured" meat, and "lab-grown" meat. The participants (N=185) in this study made statistically significantly more positive associations with "clean" meat than with the other three concepts. In addition, "clean" meat and "animal-free" meat triggered more positive attitudes than "lab-grown" meat (Bryant and Barnett, 2019). In fact, negative associations arose particularly with "lab-grown" meat , whereas "clean meat" was associated with positive attributes. However, there is a problem with calling the product "clean" meat, as it implies that conventional meat is unclean in some way, which indirectly raises often unsubstantiated negative connotations for conventional meat. The outcomes were considered to prove the importance of *how* "cell-based" meat concepts are named in order to avoid negative perceptions and improve acceptance of these food products.

Possidonio *et al*. (2021) also noted that when the modifier term "lab-grown" was used for meat instead of the term plant-based meat (rather than other modifiers for cell-based meat), Portuguese consumers linked negative attributes to the concept of "cultured" meat more than to that of plant-based meat substitutes. "Lab-grown" meat was also perceived as having the lowest sustainability, the highest price and caloric value of all meat substitutes. The authors hypothesize that, indeed, the use of the term "lab-grown" alone might have evoked images of artificial production environments. In addition, consumer perceptions of the term "lab-grown" meat are affected by how the products are presented. This was supported by the observation that when terms were associated with pictures of the corresponding food products (alone or in a meal), a picture of "lab-grown" meat that was included into a meal markedly increased consumers' positivity to it on many scores (Possidonio *et al.*, 2021).

In contrast to the findings of Bryant and Barnett (2019), Krings *et al.* (2022) attributed the lower popularity of "clean meat"-based dishes than of conventional meat dishes by consumers from Western countries who were omnivores, but neophobic towards food technology to the perceived lower safety and/or artificiality of "clean meat" dishes (Krings, Dhont and Hodson, 2022). These studies indicate that the choice of the comparators used for "cell-based" meat concepts and the way "cell-based" meat concepts and products are presented (such as a term alone or visualized together with a product) have an influence on consumer perception.

As for Brazil, various large meat-producing companies have indicated their intention to develop and market cell-based meat within the next few years. Regulation on approval and labelling still has to be developed, though, pending the outcomes of research on food hazards (Costa, 2022). Consumer research in Portuguese shows that a significant proportion (>34 percent) of interviewed Brazilian respondents were willing to consume cell-based meat (Bryant and Krelling, 2021; Forte Maiolino Molento *et al.*, 2021). There is variability, though, between interviewees of different age groups and from different urban areas of Brazil when asked if they would consume "meat from cellular agriculture" (Forte Maiolino Molento *et al.*, 2021). After having been presented texts with one out of four different names for cell-based meat, subjects in another study found "clean meat" to be less descriptive and less distinguishable from conventional meat and plant-based alternatives than "cultivated meat", "cell-based meat", and "slaughter-free meat" (Bryant and Krelling, 2021). It should be noted that both these studies were performed using the Portuguese equivalents of the English modifier terms. Bryant *et al.* (2019) did a pre-test among Chinese consumers to rank various potential names for cell-based meat in Mandarin for appeal and descriptiveness. Based on the outcomes, these authors selected the term "purity meat" (similar to "clean meat"), for use in a survey to further study consumer perception.

4.2. Language barriers and translation issues

Language-specific perception barriers may also exist for the use of certain terminologies. Direct translation from English may not always be straightforward, or might be problematic due to non-familiarity or negative connotations of the translated terms. For example, several respondents to a consumer survey in Japan expressed their dislike of the translation of "cultured" meat into Japanese (*Baiyo-niku*) (CAIC, 2021).

Among ten cell-based meat-related terms submitted to a cross-section of German society in a study survey, "direct meat" (Direktfleisch in German) attained the highest scores for appeal, accuracy, and clear differentiation. This term was nonetheless excluded from further study due to its dissimilarity to the English synonyms currently used and the low acceptability among industrial stakeholders (Janat *et al.*, 2020). Similar issues in perception of specific terms might also exist in other languages, and should be evaluated before using terms.

Bryant *et al.* (2019) employed back-translation of cultured-meat-related terms and a study questionnaire from English into Mandarin to achieve equivalent meaning. Back-translation entails the translation of a questionnaire into a target language by a bilingual person as a first step. This translated text is subsequently translated back into the source language by another bilingual person who is unaware of the original text. The original text and the second translation can then be compared. Any ambiguities and discrepancies can then be resolved, and the text revised and refined accordingly (Jones, 1998).

4.3. Modifier terminologies that are fit for purpose

Hallman and Hallman (2020) extended on the findings by Bryant and Barnett (2019) in their study on possible names for "cultured" seafood products. They noted that past consumer studies had focused on meat, yet that the category of "cultured" seafood products was also at an advanced stage of development. Moreover, previous studies had not addressed the distinguishability between "cultured" and conventional products. In the case of seafood, there is already a need to distinguish products of farmed and wild-caught seafood, and this now needs to be further clarified for the term "cultured" seafood as well.

The authors formulated three additional requirements for a designation for cell-based food products, namely that they 1) are appropriate from the consumers' point of view; 2) do not disparage one or any other category of foods; and 3) do not raise a response inconsistent with the idea that "cultured"

seafood is safe, healthy and nutritious. The term chosen should be able to modify not only seafood but also poultry and meat. Three additional phrases were used for the investigation, including "produced using cellular aquaculture", "cultivated from the cells of ....", and "grown directly from the cells of ..." (Hallman and Hallman, 2020).

All the concepts using the term "cell" were most accurately identified as being neither farm-raised nor caught in the wild, and also scored significantly lower in consumer acceptance than the conventional products (Hallman and Hallman, 2020). All concepts used were equally well identified as products not to be consumed by people who are allergic to seafood. The phrases "cultivated from the cells of ...." and "grown directly from the cells of ..." were most accurately identified as not being "ocean-caught" or "farm-raised". They were also somewhat less appetizing (17-18 percent versus 26 percent) than the other concepts, and evoked the least positive initial responses. With several others, participants imagined products labelled with these two phrases to be less tasty and less safe to eat as well. They also thought products labelled with the concepts "cell-cultured" and "cultivated from the cells of ..." to be less nutritious than conventionally farmed and wild-caught seafood (Hallman and Hallman, 2020). The authors abandoned "cultivated", "cultured", and "produced using cellular aquaculture" due to an apparent misidentification as being from conventional aquafarming, widely known as aquaculture. They also abandoned the descriptors "cultivated from the cells of ...." and "grown directly from the cells of ..." given the negative responses to these concepts and the association with genetic modification. Survey participants expressed positive initial responses to the two remaining concepts of "cell-based" and "cell-cultured". While both these concepts performed well on many counts, "cell-based" outperformed "cell-cultured" in terms of perceived nutritional value and taste of the product, purchasing intention, and consumption advice to children. The authors concluded that "cell-based" met all criteria and was an appropriate name for product description (Hallman and Hallman, 2020).

In a follow-up study, the authors compared the two selected terms "cell-based" and "cell-cultured" in a more focused way using a group of American consumers as respondents (Hallman and Hallman, 2021). Participants (N=1200) were shown two pictures of imaginary pouches containing salmon substitute products. The front of the pouch featured a picture of a salmon fillet (suggested serving), the name "Atlantic salmon fillets" in large font with a smaller subscript "cell-based" seafood on the left and "cell-cultured" seafood on the right, on top of a nutritional fact table plus storage advice and product weight (Figure 3).

Figure 3: Product packaging shown to participants in the study

Source: Hallman, W. K. & Hallman, W. K., II. 2021. A comparison of cell-based and cell-cultured as appropriate common or usual names to label products made from the cells of fish. Journal of Food Science, 86(9): 3798-3809. dx.doi.org/10.1111/1750-3841.15860.

The outcomes confirmed those of the previous study in that many participants correctly identified both products as not being derived from farm-raised or wild-caught fish, and that they should not be consumed by persons with allergies. For the remaining incorrect identifications, "cell-cultured" was more often associated with farm-raised products than "cell-based", which was also the case for ocean-caught fish. Moreover, many participants correctly assumed that both products were derived from salmon cells. Initial, subsequent, and overall reactions to "cell-based" were more positive than to "cell-cultured". Products with both concepts performed equally positive in some respects: consumers considered both somewhat-to-moderately safe to eat, moderately nutritious, slightly good-tasting, and neither natural nor unnatural. "Cell-cultured" was associated more with genetic modification than "cell-based", while purchasing and tasting intentions were slightly greater for "cell-based" than for "cell-cultured" products (Hallman and Hallman, 2021).

Ong *et al.* (2020) also studied the term "cell-based" meats, reviewing the evolving production and regulatory landscapes for these products. As regards nomenclature, they considered the possibility of adding additional terms implying edibility, healthiness, sustainability and no involvement of animals. While for edibility, the ingredients and production processes used should be proven to be safe, various claims and labelling rules and guidelines may apply to claims of healthiness, sustainability and absence of cruelty to animals. As regards healthiness, depending on the regulatory frameworks, certain claims may be permitted provided that evidence can be provided in support of these claims. The authors considered that reference to "animal-free" might still be controversial as cells from animals will be used as donors in the initial stage, although the use of lines of immortalized cells could further decrease dependency on animals, as does the avoidance of the use of animal-derived additives to the production media (Ong *et al.*, 2020).

Szejda *et al.* (2019), in collaboration with several cell-based food companies, carried out a study in which focus groups (N=27) discussed a narrative for the "cultured" meat presented to them, followed by another study with segmented consumer groups (enthusiasts, sceptics, opponents). They concluded that, for example, the concepts "cultivated" meat and "cultured" meat had the most appeal, and were moderately descriptive. "Cell-based" and "cell-cultured" were only somewhat appealing yet scored better on the descriptiveness scale as being moderately to very descriptive. The modifiers "cultivated", "cultured", and "cell-based" differentiated moderately and moderately to very much from conventional meat. It was argued that "cultivated" evoked positive responses, considering appeal, neutrality, and descriptiveness criteria, for many of the participants.

4.4. Other considerations for terminologies

4.4.1. Allergen labelling

The product noun, such as "salmon" in the collocation "cultured salmon" might impart important information to allergy patients who are allergic to the traditional form of the product from the same animal species (salmon in this example). It is important to ensure that the modifiers do not conceal this, such as in the example "cell-based artificial salmon product" (Lamb, 2018).
In addition, it is also important to consider proper allergen labelling, as cell-based food products can have the same level of risks for allergic reactions as conventional counterparts (Hallman and Hallman, 2020). This will entail the declaration of ingredients (listed on the product label) that may cause hypersensitivities, such as egg, crustaceans, fish, and milk (Codex Alimentarius, 2018). These may then have to be highlighted in bold font, for example, so as to stand out for consumers reading the product label.

4.4.2. Commodity terminologies in the regulatory framework

While no internationally harmonized definition of the term exists and nothing indicates restrictions on the use of any terms, there are potential and significant restrictions in many countries on using commodity terms such as "meat", "chicken", "fish", "milk" and so forth. Cell-based food can be

considered a “novel food” in certain jurisdictions (e.g. in the European Union), which may place additional requirements on the terms used and provides an opportunity to define terms, as certain regulatory requirements of “meat” may not apply to this type of product (Seehafer and Bartels, 2019). In the United States of America, new agency regulations for labelling of meat and poultry products derived from animal cells is under consultation in a so-called “advance notice of proposed regulation (ANPR)” (USDA, 2021). While the ANPR touches upon issues of regulation and safety, it is notable that it also addresses the various aspects identified by the scientific investigations into the impact of naming of these products on acceptance and interpretation accuracy.

4.4.3. The term “cellular agriculture”

As of February 2022, several terms are in use in science, industry and the media, such as “cellular agriculture”, “cellular food technologies”, “cell-based techniques” and “cell-based food production". The use of these terms is currently dictated by the end user, and no studies have been performed on the perception and acceptance of alternative terms by different social or professional groups.

The term “cellular agriculture” is used by many stakeholders and it indicates the production method that can be used to make acellular or cellular products, where acellular products are made of organic molecules like proteins and fats and contain no cellular or living material in the final product, while cellular products are made of living or once-living cells. For example, acellular animal-sourced foods (like milk proteins or gelatine) are produced without animals through fermentation using micro-organisms like yeast or bacteria (often referred to as precision fermentation). In contrast, cellular products are formed by growing cells from a particular animal species and tissue type *in vitro*, followed by assembly of cells on a scaffold to form tissue-like structures and further processing into products (Rischer, Szilvay and Oksman-Caldentey, 2020). The use of the term is also documented in various sources (CAIC, 2021).

However, it should also be noted that for the scientific community, the term “cellular agriculture” encompasses not only the production of cell-based food but also the utilization of cell cultures of a whole variety of host organisms (animals, plants, microorganisms) for the production of agricultural food products rather than production from farmed animals or crops (Mattick, 2018, Rischer, Szilvay and Oksman-Caldentey, 2020).

Table 2 gives a summary of the various studies we analysed into detail on the impact of terminology on the perception of cell-based meat products by consumers. The results show that “cultivated” was the preferred modifier in 5 studies, while “cultured” and “cell-based” were preferred twice in separate studies and “clean” in one study.

Table 2: Studies on modifier terminologies for cell-based food products, their preferred use and associated attributes

Sector/social group	Country	Term preference	Preference (%) or best perception/acceptance	Study set-up	Reference
Consumers Cell-based food industry Non-profit advocates	USA	Cultivated	Preference of consumers based on survey, and of relevant companies and associations. Appeal: cultivated and cultured more appealing than cell-based and cell-cultured. Descriptiveness: cell-based and cell-cultured more descriptive than cultivated and cultured. Differentiation from conventional meat: cultivated, cell-based, and cultured were moderately and cell-cultured was moderately to very differentiating. Differentiation from plant-based meat: all terms were moderately differentiating.	Mixed methods consumer survey and focus groups (N=27). University students: participants expressed a diverse range of political views, skewed toward a younger age (primarily 18-21 years), majority female (59%), and the majority were omnivores.	(Szejda, 2019) *Survey report*
Consumers	USA	Clean	"Clean meat" showed significantly more positive associations than "animal-free", "cultured" or "lab-grown". "Clean meat" and "animal-free meat" also triggered more positive attitudes - and "clean meat" more positive intentional behaviours - than "lab-grown meat".	Between-subjects design (N = 185). Participants' perception assessed for 4 product names: (1) "cultured meat", (2) "clean meat", (3) "lab-grown meat", and (4) "animal-free meat". Participants were recruited through Amazon MTurk (online platform), and were 57.8% male, 42.2% female, aged 20-68 years (mean = 34.86, standard deviation (SD) = 10.38). The country was not recorded, though 75% of MTurk workers are in the USA.	(Bryant and Barnett, 2019) *Scientific article*
Cell-based food industry	Worldwide	Cultivated Cultured	75% preference. 20% preference.	Study poll - 49 company CEOs consulted.	(Friedrich, 2021)

Sector/social group	Country	Term preference	Preference (%) or best perception/acceptance	Study set-up	Reference
					Poll report
Cell-based food industry	Worldwide	Cultivated Cultured Cell-based Cell-cultured	37% preference. 25% preference. 18% preference. 7% preference.	Analysis of websites, LinkedIn profiles, and media statements of all known cultivated meat start-ups.	(Byrne, 2021) *Survey report*
Cell-based food industry	USA	Cultivated Cell-based	Preferred terms – neutral and scientifically accurate, and clear distinction from "plant-based protein" and "animal-based meat".	Statement by AMPS Innovation member companies.	(AMPS, 2022) *Opinion*
Consumers	USA	Cell-based	Cell-based best term for clarity, perception and acceptance. Cell-based seafood, cell-cultured seafood, cultivated seafood, and cultured seafood were compared.	Between-subjects online experiments (N=3186). Study participants were recruited from a web-based consumer panel with more than 3.2 million active members enrolled in the United States. The experiment was performed during an 18-day period in 2020. A total of 8 485 randomly selected E-rewards panel members were sent an e-mail invitation to participate in the study. Demographic information (education level, year of birth, ethnicity, race, and gender) was used to produce a sample balanced to 2010 USA census data.	(Hallman and Hallman, 2020) *Scientific article*
Consumers	USA	Cell-based	Cell-based versus cell-cultured seafood was compared.	Two-group between-subjects design (N=1200).	(Hallman and Hallman, 2021)

Sector/social group	Country	Term preference	Preference (%) or best perception/acceptance	Study set-up	Reference
				Data were collected in 2020. Study participants consisted of adult American consumers (18 and older) recruited from the YouGov.com web-based consumer panel. A sample of 1 600 participants were selected to produce the final dataset, matching a sampling frame derived from the 2018 American Community Survey. Of these 1 600 participants, 1 200 were randomly assigned to one of the two experimental conditions. A total of 591 participants viewed packages displaying the "Cell-Based Seafood," and 609 viewed packages displaying "Cell-Cultured Seafood." Median length of the experiment was 11.8 minutes. Consistent with census data, 51.3% of the 1 200 participants were female. Mean age was 47.41, SD = 17.69.	*Scientific article*

Sector/social group	Country	Term preference	Preference (%) or best perception/acceptance	Study set-up	Reference
Consumers	UK and USA	Cultivated Cultured	Preferred terms for social context and product packaging, and considered more appealing. Both terms were perceived very similar. Cell-based and Cell-cultured not the preferred terms, but considered more descriptive. Both terms were also perceived as very similar.	Survey and experiments - (N=2 292 for USA and N=2 270 for UK). Sampling protocol to match adult population aged 18--74 years, by interlocked sex and age groups to fit within generational groups. Geographical region and race/ethnicity quotas in the USA, and region quotas in the UK were accounted for.	(Szejda, 2021) *Survey report*
Consumers	Portugal	N.A.	Only the term "lab-grown" was included in comparison between eight different food products: red and white meat, fish and seafood, insects, legumes, tofu, seitan, and lab-grown meat. "Lab-grown" meat was perceived negatively as the least natural and most processed of all meat alternatives, associated with health risks and artificiality and it was seen as the least sustainable and most expensive.	Study 1 (N=138) - participants 58.1% female, aged 18-52 years (Median age = 26.77, SD = 8.89). More than half (58.9%) had a higher education degree (BSc, MSc or Doctorate), 38.8% had completed secondary education and 2.3% primary education. Most participants included animal products (meat or fish) in their diets (82.8%), 3.7% followed a vegetarian diet, and 6% a vegan diet; 7.5% reported to have "other" dietary orientations.	(Possidonio *et al.*, 2021) *Scientific article*

Sector/social group	Country	Term preference	Preference (%) or best perception/acceptance	Study set-up	Reference
				Study 2 (N=285) - participants (68% female) aged 18–66 years (M = 30.21, SD = 10.19). More than half (56.8%) had a higher education degree (BSc, MSc or Doctorate), 41.1% completed secondary education, and 2.1% primary education. Most participants were employed (60.4%) or students (22.1%). Most participants included meat or fish in their diets (59.6%), and 15.1% followed a vegetarian diet, 21.1% had a vegan diet, and 4.2% reported "other" dietary orientations. On average, participants lived in predominantly urban areas.	
	EU, UK, USA	N.A.	The "clean meat" label was evaluated negatively. The authors mention that the term "clean" meat was chosen, as it tends to be associated with more positive evaluations of the product compared with other labels such as "cultured", "*in vitro*", or "lab-grown" meat. Thus one of the more positive labels was used to avoid strong negative effects induced by the label alone. Images of "clean meat"-labelled dishes were more negatively evaluated than images of "regular meat"-labelled dishes by omnivores. "Clean meat"-based dishes	Experiment 1 - participants (N = 270) recruited through the crowdsourcing platform Prolific and received financial compensation. Only omnivores were retained. The sample consisted of 54.9% men and 45.1% women, with a mean age of 30.42 years (SD age = 10.95). Most	(Krings, Dhont and Hodson, 2022) *Scientific article*

Sector/social group	Country	Term preference	Preference (%) or best perception/acceptance	Study set-up	Reference
			were perceived as lower in safety and/or lower in naturalness.	participants were from the EU (45.3%), the UK (27.9%), or the USA (11.4%). Experiment 2 - participants (N = 626) were recruited through opportunity sampling on social media and received no financial compensation. Only omnivores and vegans retained. Sample consisted of 21.8% men and 78.2% women, with a mean age of 36.41 years (SD age = 16.41). Of this sample, 455 were omnivores (74.7% women; Median age = 37.47 years, SD age = 17.07) and 171 were vegan (87.8% women; Median age = 33.35 years; SD age = 14.45). Participants were not asked for their nationality. Experiment 3 - participants (N = 273) were recruited through the crowdsourcing platform Prolific and received financial compensation. Only omnivores were retained. The sample consisted of	

Sector/social group	Country	Term preference	Preference (%) or best perception/acceptance	Study set-up	Reference
				56.1% men and 43.9% women, with a mean age of 28.19 years (SD age = 9.36). Most participants were from the EU (57.4%), the UK (18.7%), and the USA (6.7%).	

Source: Authors' own elaboration.

5. Discussion

Overall, through the examination of both scientific and grey literature, “cell-based”, “cultivated” and “cultured” are the three major terminologies used or preferred by consumers, industry and the authorities. These terms are also commonly used in scientific publications, but a broader range of terms can also be found in many cases in science, including the terms “*in vitro*”, “artificial” and “clean” that were used more frequently in the early days of the technology developments. However, industry prefers to use “cultured”, “cultivated” or cell-based”, while the media use a more diverse array of terms including, but not limited to, “cultured”, “lab-grown”, “fake”, “clean”, “cultivated”, or “cell-based”.

As for consumers, only a small number of well-designed quantitative studies in a limited number of countries have addressed the appropriateness and relevant consumer perception and acceptance of different terminologies. Moreover, these studies did not always include the same set of terms to be analysed and compared. Despite these limitations, consumer studies indicated that the term “cultivated” was often considered the most appealing, and “cultured”, “cell-based” and “clean” to a lesser extent. These studies did not always test whether these four terms were also considered to be the clearest.

It is recommended that, from the early stages, the national competent authorities establish clear and consistent terminologies that fit in with their national and language contexts so that they can mitigate potential miscommunications on this subject in the future. If English is the language to be used, based on the data currently available and consumer studies, the potential candidates are “cell-based”, “cultivated” or “cultured”, whereby the specific use might be further determined by the target audience or language-specific associations of these terms. It is important to note that “cultured” and “cultivated” may be wrongly interpreted when used for cell-based seafood products, as both terms can be perceived as being “farmed fish” (Hallman and Hallman, 2020). In addition, United States’ federal agencies use the term “cultivated” to identify farmed shellfish. To make the terminology non-commodity-specific, “cell-based” may be useful as in cell-based food, cell-based food products, or cell-based food production, while “cultivated” and “cultured” most likely need to be followed by a commodity name, such as meat, chicken, fish and so forth.

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