Fishing for Solutions: Nomenclature of Cell-Cultivated Fish Products

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Article

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Fishing for Solutions: Nomenclature of Cell-Cultivated Fish Products

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Abstract

In recent decades, marine resources have faced extreme environmental pressures due to growing global fish consumption. Both commercial fishing and aquaculture harm the environment, threaten public health, and entail morally dubious practices. While consumers have increasingly become aware of the implications of the global fishing industry, most still want to eat seafood. Recent advancements in food technology have resulted in the successful production of cell-cultivated fish. Grown from real fish cells, cell-cultivated seafood avoids many of the issues associated with conventional fish production. Although cell-cultivated seafood will soon be available to consumers, there is not yet consensus on a 'common or usual name', a requirement of the US Food and Drug Administration for novel foods. We present a public discourse analysis, and the results of two online US-based surveys (n=2,452 and n=1,839) analyzing consumer acceptance and understanding of key terms used to describe cultured fish. Adult participants were tested for knowledge and acceptability of multiple descriptive terms: Bio-crafted, Bio-Cultivated, Cell-based, Cultivated, Cultured, Molecular, and the coined term 'Novari'. The Control was a description of the product coupled with realistic packaging a consumer may expect to find once the product is available for purchase. The discourse analysis indicated that there is no current consensus on terminology used to describe cell-cultivated meat, and that some of the most commonly-used terms currently tend to be used in a negative context. Our Phase I survey revealed that names such as 'cell-based' and 'bio-crafted' were more likely to be understood, but relatively unappealing, while names such as 'cultivated' and 'Novari' were more appealing, but less likely to be understood. Our Phase II survey further revealed that the term 'cell-cultivated' combined promising elements of these terms, and was subsequently more appealing than 'cell-based' and better-understood than both 'cultivated' and 'cell-based'. That said, none of the names tested outperformed the control group in consumer ability to identify the product accurately.

1. Introduction

1.1 Commercial Fishing: Environmental Impact

The environmental effects of commercial fishing are evident in biodiversity loss and oceanic ecosystem disruption. Since the mid-1990s, marine populations have experienced a severe decline (Pauly & Zeller, 2016, Pauly & Zeller, 2017). Harmful industrial fishing practices such as trawling and overfishing are the primary driver of population decline, and since 1996, total global catches have decreased at a rate of 1.2 million tons annually (Pauly & Zeller, 2017, Pauly et al., 2002). Overexploitation of fish stocks affects biodiversity and population resilience, resulting in the breakdown of ecosystems (Sala et al., 2021, Pauly & Zeller, 2016). The United Nations (U.N.) reported in 2015 that 33% of marine fish stocks faced harvesting at unsustainable levels (United Nations, 2018). Additionally, commercial fishing practices and associated fishing equipment are responsible for catching unwanted, damaged, inedible, or unprofitable fish — these are ultimately discarded. Consequently, an estimated 10.8% (9.1 million tonnes) of annual global catch is wasted (Gilman et al., 2020, Zeller et al., 2017).

In addition to overfishing risks, warming oceans present an existential threat to ocean biodiversity. Climate-related changes influence the ocean's ecology, physics, and chemistry, hindering marine life resilience to overfishing (Sala et al., 2021, Rashid Sumaila & Tai, 2020, Free et al., 2019). . In response to the negative externalities associated with commercial fishing, aquaculture has gained popularity; however, this practice has problems of its own.

1.2 Aquaculture: Environmental Impact

The aquaculture industry positions itself as a more sustainable alternative to commercial fishing. By breeding fish in captivity, aquaculture-farmed fish reduces wild fish catch required to meet consumer demands. In 2020 aquaculture accounted for 46% of total global fish production and 52% of consumption (FAO, 2020). The Food and Agriculture Organization (FAO) predicts that annual aquaculture production will reach 109 million tonnes by 2030, and industry growth will increase 30.1% between 2018 and 2027 (FAO, 2018a, FAO 2018b). Estimates suggest that by 2030, aquaculture will represent 60% of fish available for human consumption (Ghamkhar & Hicks, 2020). However, aquaculture production presents its own set of environmental, social, and animal welfare challenges

Aquaculture effluent may contribute to high levels of nitrogen and phosphorus in the local aquatic environment. Effluent contamination results in harmful algae blooms and eutrophication (Herath & Satoh, 2015, Mente et al., 2006). In addition to environmental contamination, farmed fish may carry pathogens and contribute to disease spread and ecosystem disruption in documented escapes from aquatic containment (Madhun et al., 2014, Lafferty et al., 2015) (see section 1.5). Aquaculture feed (fishmeal) includes wild-caught fish ingredients associated with microplastic contaminants (see section 1.5), presenting a pathway to pollution through fish excrement.

Aquaculture relies on the commercial fishing industry to provide protein-rich fishmeal and fish oil for aquaculture feed, placing further stress on wild fish stock. Fishmeal consists primarily of oily fish such as sardine, anchovy, capelin, and menhaden, historically susceptible to overfishing (Idyll, 1973, Barlow, 2003, Lindegren et al., 2013). Fishmeal is applied in both terrestrial animal farming and aquaculture and provides protein, vitamins, minerals, and lipids for animal growth (Kok et al., 2020). In turn, an average of 25% of commercial fishing annually is utilized for fishmeal and fish oil (Cashion. et al., 2017). Of that 25%, ~90% is food-grade fish, resulting in ~18 million tons of commercially caught fish utilized for other than direct human consumption (Cashion. et al., 2017). The fishmeal supply chain has global implications. Overfishing of sardines has contributed to fish stock collapse in Indonesia and India in the last five years — disrupting the livelihood of thousands of small-scale fishers (Warren & Steenbergen, 2021, Kripa et al., 2018). The recent fish stock collapses in India, Vietnam, and the Gambia are correlated with fishmeal demand for China, Norway, and Scotland aquaculture (Changing Markets Foundation, 2019, Naylor et al., 2009). Accordingly, aquaculture production (particularly fishmeal) further contributes to fish stock decline and disruption of marine ecosystems (Changing Markets Foundation, 2019, Naylor et al., 2009).

In response to pressures on declining fish stock exacerbated by aquaculture fishmeal demand, terrestrial crops, such as soy, have contributed to aquaculture feed. However, with the addition of plant protein sources, the lifecycle footprint of aquaculture extends beyond the marine border to include terrene externalities such as pesticide use, soil erosion, and land-use change. Lifecycle assessments have shown that 90% of cumulative environmental impact in aquaculture is attributed to feed alone (both land and marine-based) (Little et al., 2018). Thus, some may conjecture that aquaculture has failed to deliver a more sustainable fish. Additional problems linked with the conventional fishing industry include health risks and moral implications associated with both wild-caught and farm-produced fish.

1.3 Human Health Implications

Fish consumption presents risks to human health. Microplastic contamination of fresh and saltwater ecosystems poses hazards for both animal and human health. Mercury bioaccumulates through marine trophic levels, magnifying the risk of mercury poisoning in humans. Finally, the introduction of antibiotics to aquaculture systems poses a risk of antimicrobial resistance and presents a global health crisis.

1.3.1 Microplastics:

Microplastics, identified as plastic particles under 5 millimeters in size, pose a threat to seafood consumers. Microplastics are available to every level of the marine food web, from primary producers to the highest trophic levels. However, plastic contamination of marine animals is dependent on individual susceptibility and the severity of exposure (Smith et al., 2018, Lusher et al., 2017, United Nations, 2016). Aquatic microplastic contamination in fish intended for human consumption is well-documented in commercial and aquaculture fish (Lusher et al., 2017, Rochman et al., 2015). Additionally, microplastics bioaccumulate via trophic levels in marine environments, potentially increasing their potency in higher-trophic level fish intended for human consumption (Costa et al., 2020, Farrell & Nelson, 2013, Mattsson et al., 2018). High trophic level fish such as tuna are popular among consumers, increasing microplastic contamination risk potential. Human exposure to ingested microplastics includes risks such as changes in gut microbe composition (Salim et al., 2013), persorption through intestinal epithelium (Powell et al., 2007, Volkheimer, 1977), inflammatory lesions, and increased risk of neoplasia (Prata et al., 2020).

The connection between microplastics and human health has gained attention in recent years. Some research shows microplastic concentration remains in marine digestive tracts; thus, removing gastrointestinal tracts before consumption may reduce human health risks (Duis & Coors, 2016). Alternatively, fish traditionally consumed whole (with digestive tracts intact) may lead to greater microplastic exposure in humans (Lusher et al., 2017, Van Cauwenberghe & Janssen, 2014). Whole fish used in fishmeal production for aquaculture presents a similar dilemma, with a higher potential of contamination due to processing fish with intact digestive tracts (Thiele et al., 2021). Human health is thus put at risk through the transfer of contaminants from consumed fish.

The controlled environment and shortened lifespan of aquaculture-raised fish may conjecture living conditions that limit microplastic contamination in humans. However, research intimates that aquaculture activities, including feed, are correlated with microplastic contamination (Smith et al., 2018, Lusher et al., 2017). A recent estimate suggested that over 300 million microplastic particles may be released annually through aquaculture alone (Thiele et al., 2021).

1.3.2 Mercury Exposure:

Methylmercury (MeHg), a highly toxic organic form of mercury, is the primary source of human mercury exposure. Between 80% and 90% of organic mercury in a human body is from fish and shellfish consumption (Hong et al., 2012). MeHg is present in both saltwater and freshwater fish (Dong et al., 2015). Toxic levels of MeHg are present in seafood globally in developed and developing countries (Sheehan et al., 2014, Mahaffey et al., 2004). All fish and shellfish contain some levels of MeHg, but these levels concentrate at each trophic level (Silbernagel et al., 2011).

Preferred fish, or prized fish such as tuna, have the highest levels of MeHg due to their location on the trophic scale and bioaccumulation capacity (Murata et al., 2019). Seafood is the predominant source of exposure for methylmercury (MeHg) in humans (Hong et al., 2012, Mergler et al., 2007). Overexposure to MeHg presents neurotoxic, reproductive, and cardiovascular risk (Hong et al., 2012, Grandjean et al., 2003, p. 22). Consequently, the continued consumption of fish increases the chance of mercury-induced health risks in humans.

1.3.3 Antimicrobial Resistance:

Increasing demand for fish contributes to overcrowded conditions in aquaculture that present breaches in animal welfare rights —and a grave threat to human health (see section 1.3.4). Overcrowding in terrestrial and aquaculture concentrated farming necessitates antibiotic use to mitigate disease transmission facilitated by crowded conditions (Kirchhelle, 2018, Miranda et al., 2018, Lee et al., 2013). The World Health Organization (WHO) has identified the over-utilization of antibiotics in animal production as a contributor to growing global antimicrobial resistance — and a global health risk (WHO, 2020, WHO, 2017). Antimicrobial resistance contributes to human morbidity rates globally, and estimates suggest that antimicrobial resistance may be responsible for up to ten million deaths by 2050 (MacFadden et al., 2018). Connections between aquaculture consumption and the transfer of antimicrobial resistance in humans are well-researched (Heuer et al., 2009, Akinbowale et al., 2006, Kruse & Sørum, 1994). Antimicrobial resistance originating in aquaculture may directly infect humans via antimicrobial-resistant bacteria in fish or transferred through the environment or via horizontal gene transfer — where human pathogens act as transfer agents of antimicrobial-resistant genes originating in aquaculture (WHO et al., 2006).

The over-utilization of antibiotics in fish and corresponding antimicrobial-resistant bacteria (AMR) is well documented (Cabello et al., 2016, Done & Halden, 2015). The antibiotics used in aquaculture are primarily those used in human health and thus present a global health dilemma if antimicrobial resistance occurs (Reverter et al., 2020, MacFadden et al., 2018, Done & Halden, 2015). Further exacerbating the overuse of antibiotics in aquaculture, climate change research suggests that warming temperatures are associated with a higher likelihood of disease outbreak, antibiotic use, and presence of AMR bacteria in aquaculture (Reverter et al., 2020, MacFadden et al., 2018, Marcos-López et al., 2010) Recent review of AMR Bacterial research suggested that highest AMR levels in Aquaculture were in LMIC that were economically vulnerable — especially in Africa and Southeast Asia, further compounding risk in already-vulnerable populations (Reverter et al., 2020).

The administration of antibiotics in aquaculture is released into the water via feed, direct application, and fish waste. The presence of antibiotics facilitates opportunities for resistance building, either in the aquatic environment or within fish digestive systems (Preena et al., 2020, Reverter et al., 2020, Kemper, 2008). Intensive animal production, including aquaculture, contributes to antimicrobial resistance. Aquaculture's contribution to the global health emergency of escalating antimicrobial resistance is an externality associated with its goals to meet consumer demands and support food security. The crisis of antimicrobial resistance must be urgently addressed and mitigated.

1.4 Moral Implications:

As well as the environmental and human health impacts of the fish industry, there are widespread violations of human and animal rights.

Firstly, emerging research has exposed frequent human rights infringements in the aquaculture and commercial fishing industries (Nakamura et al., 2018, Lewis et al., 2017). Workers are frequently required to be at sea for weeks or months, isolated from friends, family, and law enforcement. This is exacerbated by many fishing vessels sailing under 'flags of convenience' belonging to countries with lax enforcement (Armstrong, 2020).

Secondly, the populations of many coastal communities worldwide depend on fish for sustenance, and overfishing is decimating their primary food source (FAO, 2018a, Smith et al., 2011, FAO, 2005). Small local subsistence fishermen cannot compete with vast international trawlers, which essentially leads to the dynamic of globally affluent consumers taking food from the mouths of globally poor consumers.

Thirdly, although fish are less likely than other food animals to be perceived as emotional or intelligent, research suggests that fish have the capacity for cognitive, behavioral, and pain-reception abilities (Franks et al., 2021). Farmed fish are commonly affected by a litany of welfare issues, including overcrowding, stressful conditions, and proliferation of diseases, including viruses, sea lice, and chlamydia (Lafferty et al., 2015, Taranger et al., 2014, Kebbi-Beghdadi et al., 2011).

1.5 Consumer Fish Consumption and Alternatives

Alternatives to commercial fishing and aquaculture are needed to sustain global future consumption demands and meet the UN sustainable development goals (SDGs) of ending hunger globally (SDG #2) and achieving sustainable consumption and production (SDG #12) (United Nations, 2015). Despite the environmental, ethical, and health issues attached to fish consumption, global projections suggest rising fish demand (Free et al., 2019). In simulations of future consumption trends, drivers of consumption are determined by population growth and income. Accordingly, areas that anticipate rising income (in particular, China, India, and Southeast Asia) expect escalating fish demand (The World Bank et al., 2013). By 2030, fish production will increase by 23.6 percent compared to 2010 levels (Free et al., 2019).

While trends in vegetarianism and veganism are gaining traction, the rate of plant-based diet adoption is not significant enough to combat rising meat demand from rapidly developing countries. Additionally, meat consumption is ingrained in culture and conceptions of wealth and prosperity, influencing consumer choices and willingness to transition to plant-based diets (Happer & Wellesley, 2019, Bereżnicka & Pawlonka, 2018). Moreover, fish has been historically touted as a health food (Swanson et al., 2012) and for health-motivated fish consumers, fish alternatives (e.g. tofu and seitan) may not contain EPA and DHA — drivers of health-related fish consumption. Absence of EPA and DHA may limit health-motivated consumers' willingness to transition to plant-based alternatives (Pieniak et al., 2008, Alcorta et al., 2021). Food choice predictors greatly influence consumer diets. Analysis of food choice predictors revealed convenience, price, and taste as most significant predictors in contrast to environmental concerns (Fotopolous et al., 2009; Januszewska et al., 2011; Lennernäs et al., 1997). Consequently, fish alternatives must be convenient, affordable, tasty, and contribute to human health to drive food choice change.

Advancements in cell-cultivated seafood technologies present a pathway forward by introducing a comparable product to conventional seafood with potentially lower environmental externalities and health risks. Cell-cultivated meat, the practice of growing meat directly from cells, offers a solution to the environmental, ethical, and health-related issues connected to traditional fish consumption. Furthermore, by producing only the edible portions of a fish that are intended for human consumption, cell-cultivated fish eliminates the wastage inherently linked to fish supply chains. Current estimates suggest 10.8% of annual global catch is discarded and (Gilman et al., 2020, Zeller et al., 2017). The controlled production environment eliminates microplastic and mercury contamination and removes the need for antibiotic application. Cultivated fish is organoleptically comparable to conventional meat, offering consumers, for the first time in history, the choice to eat fish without contributing to an animal's death and the myriad of environmental impacts associated with conventional fish production. Moreover, consumer research suggests that the market is primed for cultivated fish. In a recent consumer study produced by the Good Food Institute (GFI), 35% of respondents found cultivated seafood appealing and 38% suggested they would consider purchasing it in the future (Good Food Institute & Kelton Global Research, 2021).

1.6 Nomenclature Debate - Consumer and Regulatory Acceptability

A current issue in the commercialization of cell-cultivated fish is the product's nomenclature and product labeling. Precise labeling is a crucial aspect of commercializing novel foods as consumers must feel comfortable with the product and understand its origins. 73% of consumers in the GFI report cited they were concerned about food poisoning, indicating a misunderstanding of the production of cultivated fish and its safety risks (Good Food Institute & Kelton Global Research, 2021). The nomenclature debate must take into account risk-adversity and consumer willingness to try novel products.

The U.S. Food and Drug Administration (FDA) requires that all foods have labeling depicting a "common or usual name." The regulation, 21CFR101.3, requires that the "common or usual name" accurately identifies and describes the product in the most direct and straightforward terms possible to ensure informed customer decisions (FDA, 2020a). In 2020, the FDA called for labeling comments, encouraging discourse on cell-cultivated seafood labeling (FDA, 2020b). Previous research on nomenclature has primarily focused on consumer acceptance, rather than identifying a common or usual name that may be regulated by the FDA (Bryant & Barnett, 2019). Currently, only one other research paper distinguishes nomenclature preference of cell-cultivated fish in the U.S. response to the FDA. The research, produced by Hallman and Hallman (2020), utilized an online between-subject experiment to test common or usual names using packages of three types of seafood consumers may expect to encounter in the supermarket. In the study, 3,186 U.S. adults read the terms“cell-cultured seafood,” “cultivated seafood,” “cell-based seafood,” “cultured seafood,” as well as the phrase, “produced using cellular aquaculture” (Hallman & Hallman, 2020). The study determined that “cell-based seafood” performed the highest out of the names tested. This paper builds on Hallman and Hallman work, first by considering whether a common and usual name already exists as evidenced by online usage, and second to consider a broader range of potential labels on a range of criteria.

2. Methods

2.1 Procedure

2.1.1 Brandwatch Public Discourse Analysis

Before the experimental part of the study, we wanted to conduct an exploratory part to identify (a) which names or terms for cell-cultivated seafood were most commonly used currently, and (b) whether there was a term which was sufficiently widely-used to be considered 'common and usual'. To this end, the social listening platform Brandwatch was employed to measure the use and sentiment of different terminology.

Table 1: Brandwatch Search Terms

Search terms included in the Brandwatch search
Cellular agriculture; cell-based seafood; lab-grown seafood; cellular aquaculture; clean seafood; cultured seafood; cultivated seafood; cell-cultured seafood; cellular seafood; manufactured seafood; artificial seafood; animal-free seafood; cell-grown seafood; slaughter-free seafood; cell-based/cultured seafood; synthetic seafood; test tube seafood

This process involved compiling content which discussed cell-cultivated seafood from online sources including news sources, blogs, forums, and social media platforms including Twitter, Reddit, and Tumblr. The search included a list of terms (see Table #1), searching for worldwide content in the English language during the period 1 January 2019 - 14 December 2020.

Content was removed if it was identified by Brandwatch as an advertisement or as pornographic. Content which was retained was classified as positive, negative, or neutral using Brandwatch's sentiment analysis, which gauges sentiment by analysing context, language, and emojis.

Based on learnings from Brandwatch data and previous nomenclature study, Hallman &Hallman, two nationwide surveys took place in the United States in early 2021. In partnership with The Yale Center for Customer Insights, two surveys were produced and conducted. The purpose of both studies was to test consumer understanding of the product, willingness to purchase, and willingness to consume products based on nomenclature. Test names were based on Hallman & Hallman's (2020) research.

2.1.2 Phase I Survey

The Phase I survey took place between January 7- 10, 2021. The survey was an experimental between-subjects set-up whereby participants were randomly allocated to one of seven different labels, plus a control group (see Table 2).

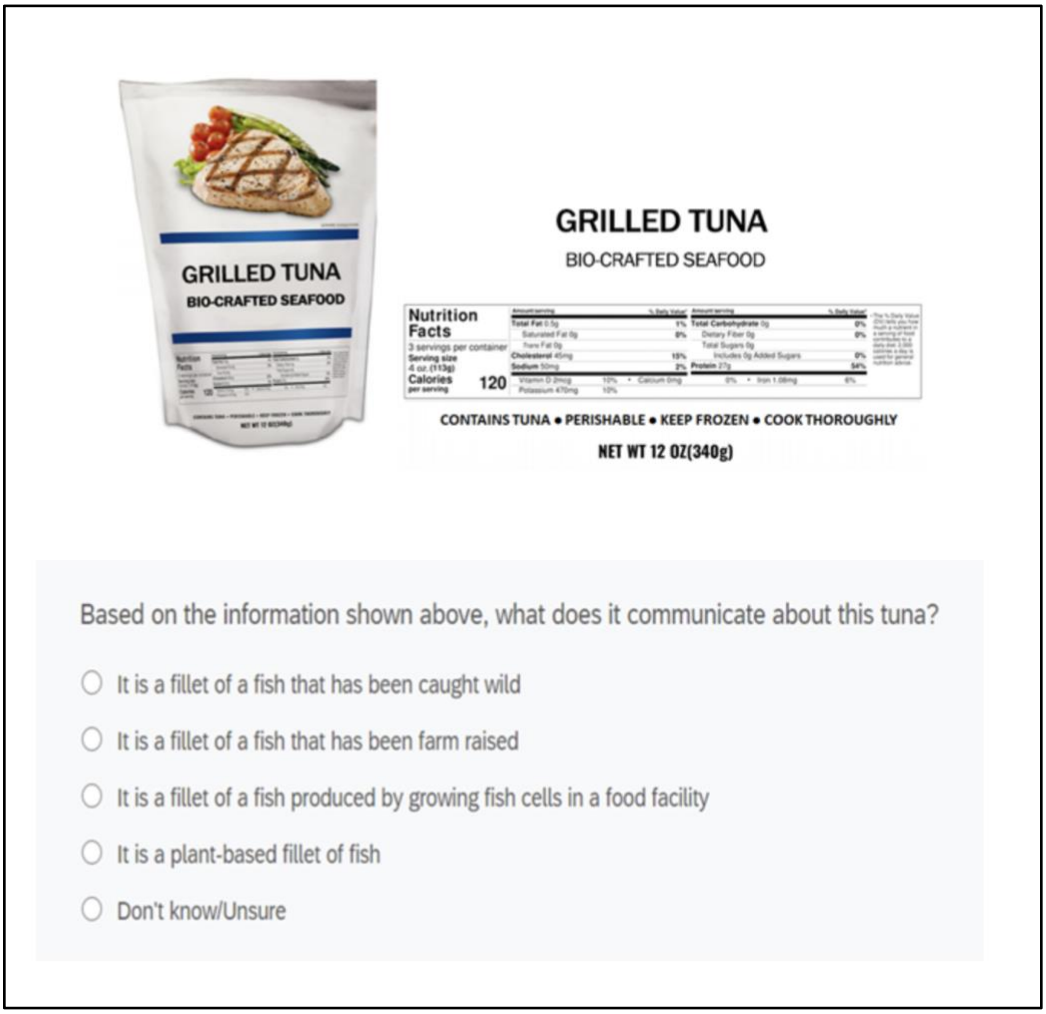
Table 2: Phase I Test Names

Nomenclature Terms
1. Bio-crafted; 2. Bio-Cultivated; 3.Cell-based; 4. Cultivated; 5.Cultured; 6. Molecular; 7. Novari[1]; 8. Control

In addition, we tested the eight terms with both salmon and tuna fillets, meaning that the experiment consisted of sixteen (8 x 2) conditions. As an example of what a respondent would have seen while taking the survey, Figure 1 shows one cell from the above study design: "bio-crafted" + tuna. A "don't know/unsure" option was included in the response options, allowing for a more precise measure of consumer understanding by reducing guessing.

[1] *Novari is a coined term (derived from the Latin verb "novo" or "to make new") and was added to the study to assess how a term with no previous obvious connection to seafood source (conventional or cultured) would fare in terms of consumer understanding and appeal.

Figure 1: An example of what a participant saw in one Phase I condition.



The control included an image of a plain package of either salmon or tuna, the word "salmon fillet" or "grilled tuna" depending on which treatment the respondent was given, a short description of the technology, and a nutrition label associated with conventional salmon or tuna (Figure #1).

Figure 2: What participants saw in the control condition (Salmon, Phase I).

During the survey, participants first read information about the study and gave their informed consent to take part. Participants then indicated which groceries they had bought in the last 3 months, and if they had bought fish, they indicated which types of fish they had bought. Based on this information, participants were then allocated to a condition which corresponded to fish they had recently bought so that they would be potentially interested. Salmon buyers were assigned to a salmon condition, and tuna buyers to a tuna condition. Respondents who indicated that they purchased both were randomly assigned one of the two fish.

After being exposed to their corresponding condition, participants answered five questions about cultivated fish: (1) which, from a list, was the correct description of the fish, (2) how appealing they found the fish, (3) how likely they were to purchase the fish, (4) whether it was safe to eat for someone who is allergic to fish, and (5) why it would/not be safe to eat for someone who is allergic to fish.

In the final part of the survey, participants answered demographic questions including their age, gender, income, and region. They also answered some quality control questions so that we could remove illegitimate responses; responses were removed if they were incomplete, under 18, failed one of two basic attention check questions, indicated that they do not eat salmon or tuna, or indicated that they or their family work in fish production, advertising or marketing.

2.1.3 Phase II Survey

The Phase II survey was very similar in structure to the Phase I survey; the aim here was to get more detailed insights about promising names identified in Phase I. The only difference from the procedure for Phase I was having different (and fewer) names (Table 3).

Table 3: Phase II Test Names

Nomenclature Terms
1. Bio-crafted; 2. Cell-based; 3. Cell-cultivated; 4. Novari; 5. Control

2.2 Participants

Given the large number of different name conditions tested, our stringent filtering criteria, and our desire to be able to detect small-to-medium differences between conditions, we recruited a large sample. In Phase I, we recorded a total of 5,165 responses, of which 2,452 were included in the final sample. In Phase II, we recorded a total of 3,859 responses, of which 1,839 were included in the final sample. For both Phases, this large sample size allowed for approximately 150-170 respondents per cell for each fish, giving the survey adequate statistical power to detect a small-to-medium effect (Cohen, 1992).

Participants were recruited from Prolific, and were each paid $0.48 USD for their participation. Further information on participant demographics is given in the relevant results sections.

2.3 Analysis

Analysis of the Brandwatch data used simple descriptive statistics. In particular, the number of mentions, percentage of the total mentions, and the percentage of each term that was mentioned in a positive, negative, or neutral context was reported.

Each empirical study was monadic, meaning that participants could not take part in both Phase I and Phase II. Within each study, each name was tested on two different types of fish. We treated the results as two sets of experiments, applying analyses independently to each type of fish within each study.

We used between-subjects one-way ANOVAs to compare mean appeal scores and mean purchase intent scores between the different experimental conditions. Additionally, we used chi square analyses to compare the proportion of respondents in each condition who correctly identified the product, and who thought that it was not safe for consumption given a fish allergy. Alongside the inferential statistical analyses, we present graphs so that the findings can be intuitively accessed by non-scientists.

3. Results

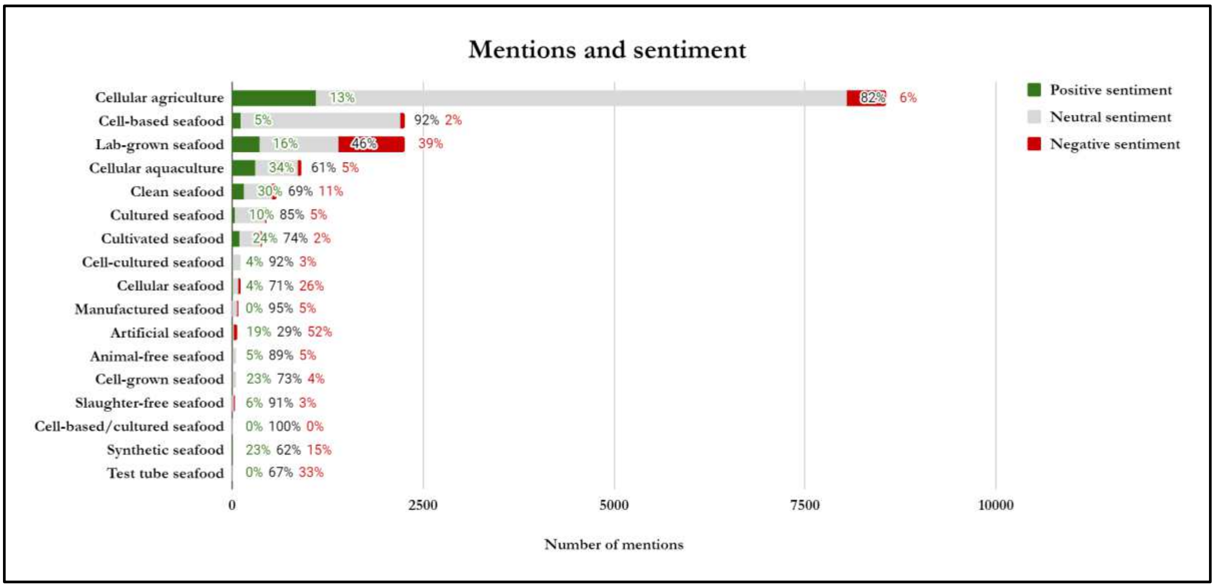
3.1 Brandwatch Public Discourse Analysis

The results of the Brandwatch analysis of common and usual terms are represented in Table 4, and Figure 3.

Table 4: Brandwatch Mentions and Sentiment

Term	Number of mentions	Percentage of total mentions	Positive sentiment	Neutral sentiment	Negative sentiment
Cellular agriculture	8,474	54%	13%	82%	6%
Cell-based seafood	2,277	14%	5%	92%	2%
Lab-grown seafood	2,240	14%	16%	46%	39%
Cellular aquaculture	904	6%	34%	61%	5%
Clean seafood	527	3%	30%	69%	11%
Cultured seafood	458	3%	10%	85%	5%
Cultivated seafood	386	2%	24%	74%	2%
Cell-cultured seafood	118	0.7%	4%	92%	3%
Cellular seafood	112	0.7%	4%	71%	26%
Manufactured seafood	78	0.5%	0%	95%	5%
Artificial seafood	65	0.4%	19%	29%	52%
Animal-free seafood	56	0.4%	5%	89%	5%
Cell-grown seafood	55	0.3%	23%	73%	4%
Slaughter-free seafood	32	0.2%	6%	91%	3%
Cell-based/cultured seafood	16	0.1%	0%	100%	0%
Synthetic seafood	13	0.1%	23%	62%	15%
Test tube seafood	3	<0.1%	0%	67%	33%

Figure 3: Brandwatch Mention sand Sentiment Distribution



As shown, cellular agriculture was by far the most commonly-used term of those searched, but this is a broad term which encompasses all cell-cultivated products (including meat and poultry) and thus cannot be used as a proxy for classifying sentiments of cell-cultivated fish. Of the terms which referred to cell-cultivated fish in particular, the most common were 'cell-based seafood', 'lab-grown seafood', 'cellular aquaculture', 'clean seafood', 'cultured seafood' and 'cultivated seafood'. All other terms searched represented less than 1% of the total mentions and are included as reference, but not critically examined further.

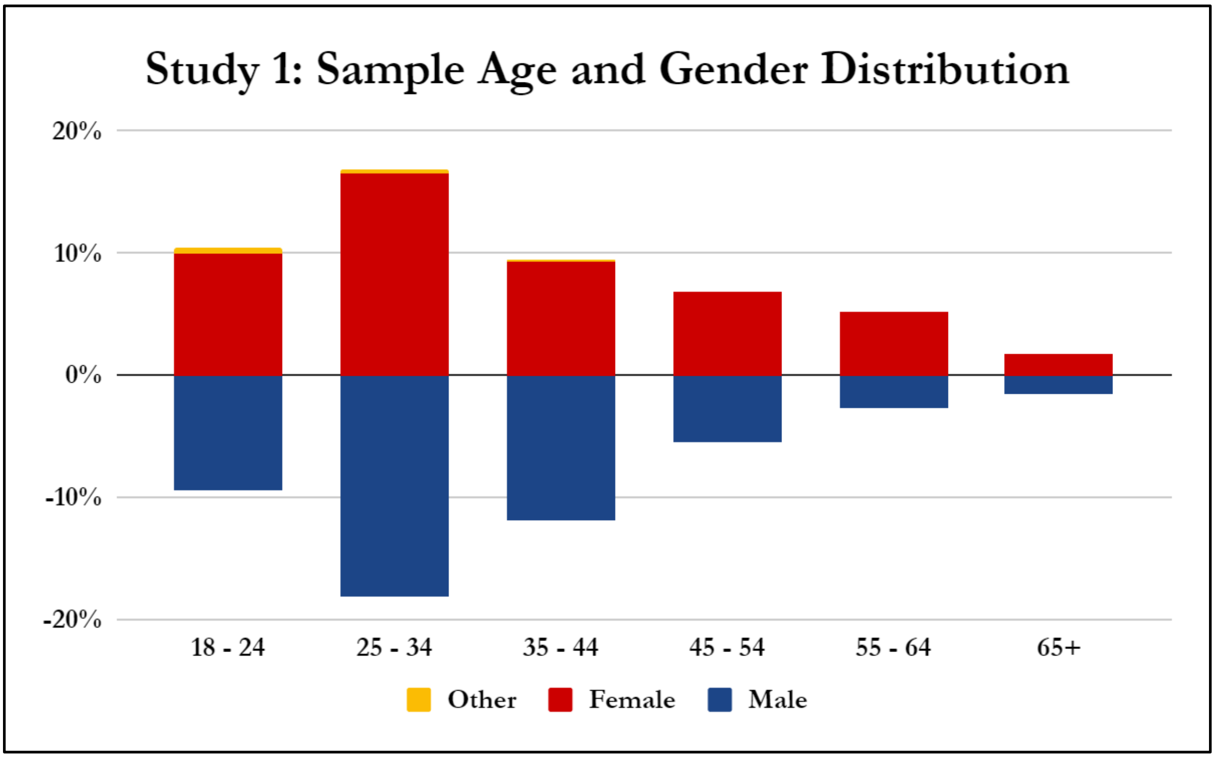
The analysis identified "lab-grown seafood" as a carrier of most negative sentiments (39%), and can therefore be taken to be alarming or off-putting to consumers. This coincides with previous research, which found that consumers were significantly less likely to eat 'lab grown meat' compared to 'clean meat' (Bryant & Barnett, 2019). The term 'clean seafood', although presenting relatively high, is problematic as it does not meet the FDA's "common and usual" labeling guidelines of accurately identifying and describing the product. Using "clean" as a modifier may falsely lead customers to assume it is cleaned conventional fish (prepared for sale), and may cause friction with would-be collaborators in the incumbent industry by implying that conventional fish is 'dirty' (Greene & Angadjivand, 2018). Finally, 'cellular aquaculture', a term which refers to the seafood products encompassed within cellular agriculture, is trademarked and may not be used as a common or usual name (Hallman & Hallman, 2020). Consequently, the Brandwatch analysis suggested that there is currently no predominant positively-associated term for cell-cultivated fish. To our knowledge, Hallman & Hallman represents the only other nomenclature analysis for cell-cultivated fish through the regulatory lens of the FDA. Analysis of Survey I and Survey II is intended to further inform the selection of terms suitable for name or statement of identity for cell-cultivated seafood.

3.2 Phase I Survey

3.2.1 Demographics

The age and gender distribution for Phase I study is shown in Figure 4.

Figure 4: Age and gender distribution in the sample of Phase I.



Participants were evenly split with 49% females and 49% males. An additional 2% self-reported other/preferred not to answer. 46% of participants had purchased both tuna and salmon in the previous three months. 36% bought salmon only, and 18% purchased tuna only.

3.2.2 Salmon

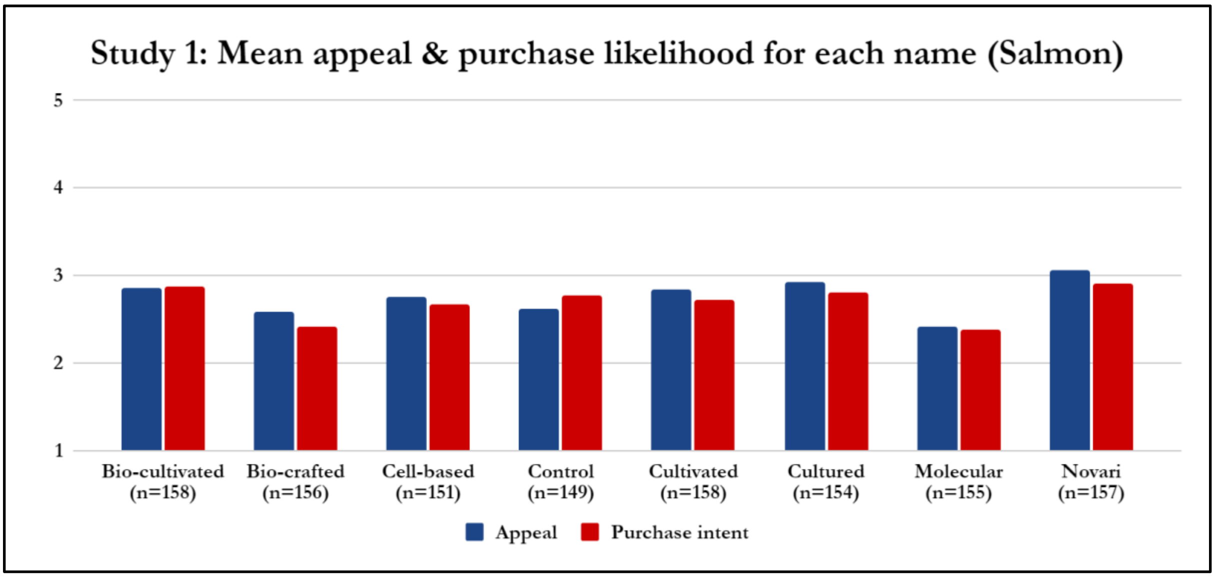
In Phase I, seven different cell-cultivated fish terms were comparatively analysed for appeal, purchase intent, understanding of allergies and safety, and correct identification of description (Table 5).

Table 5: Acceptance and understanding measures for each name in Phase I (salmon).

Phase I (Salmon)		Bio-cultivated (n=158) [a]	Bio-crafted (n=156) [b]	Cell-based (n=151) [c]	Control (n=149) [d]	Cultivated (n=158) [e]	Cultured (n=154) [f]	Molecular (n=155) [g]	Novari (n=157) [h]
Appeal	**Mean**	2.86 [g]	2.58 [h]	2.76	2.61 [h]	2.84 [g]	2.93 [g]	2.41 [aefh]	3.06 [bdg]
	SD	(1.10)	(1.22)	(1.26)	(1.31)	(1.32)	(1.21)	(1.18)	(1.18)
Purchase intent	**Mean**	2.88 [bg]	2.42 [ah]	2.67	2.77	2.72	2.81	2.38 [ah]	2.91 [bg]
	SD	(1.21)	(1.26)	(1.30)	(1.36)	(1.38)	(1.26)	(1.19)	(1.24)
Safe to eat if allergic	**Yes**	5.7%	7.7%	7.9%	4.7%	5.1%	3.2%	5.8%	7.0%
	No	54.4%	46.2%	47.7%	59.7%	68.4%	66.2%	52.9%	51.6%
	Don't Know	39.9%	46.2%	44.4%	35.6%	26.6%	30.5%	41.3%	41.4%
Choose description	**Correct**	50.6%	66.7%	72.8%	97.3%	22.2%	33.1%	54.2%	24.2%
	Incorrect	24.8%	11.5%	7.3%	2.0%	58.3%	39.6%	7.7%	22.2%
	Don't Know	24.7%	21.8%	19.9%	0.7%	19.6%	27.3%	38.1%	53.5%

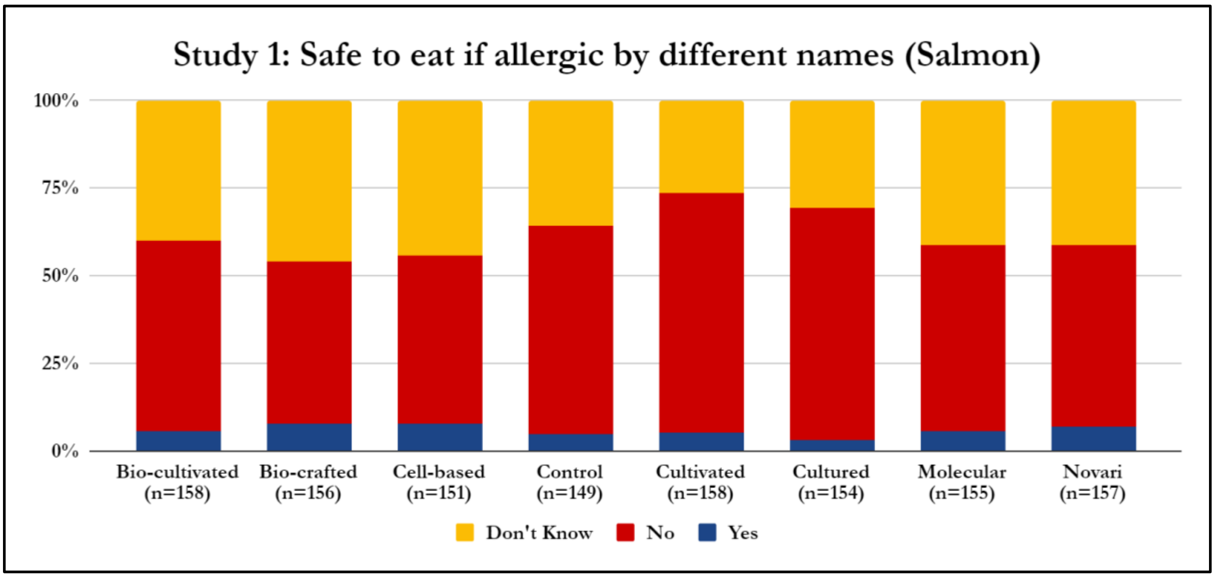
Superscript letters represent significant differences from other conditions, as labelled in the first row.

Figure 5: Mean appeal and purchase likelihood scores for each name in Phase I (salmon).



As Figure 5 shows, Novari salmon was scored the highest in terms of mean appeal and mean purchase intent. Cultured, cultivated, and bio-cultivated also scored reasonably high in terms of appeal and purchase intent, while 'molecular' scored the lowest. A one-way ANOVA revealed that the differences between groups were statistically significant for both subjective appeal ($F(7,1230)=4.630$, $p<0.001$ | $\eta^2=0.02$) and purchase intent ($F(7,1230)=3.755$, $p<0.001$ | $\eta^2=0.01$). See Table X for pairwise comparisons.

Figure 6: Percentage who thought it was safe for somebody with a salmon allergy to eat cell-cultivated salmon for each name in Phase I.



As shown in Figure 6, a small minority (<8%) in all names thought that cell-cultivated salmon was safe to eat for somebody who is allergic to salmon. Some terms, such as 'cultivated', produced a relatively high proportion believing that it is not safe for somebody with a salmon allergy, whereas others such as 'cell-based' and 'bio-crafted' resulted in a relatively high proportion being unsure whether it would be safe. A chi square analysis indicated that these proportions differed significantly between conditions ($\chi^2(14)=30.919, p=0.006$ | $V=0.112$).

Figure 7: Percentage who selected the correct definition of cell-cultivated salmon for each name in Phase I.

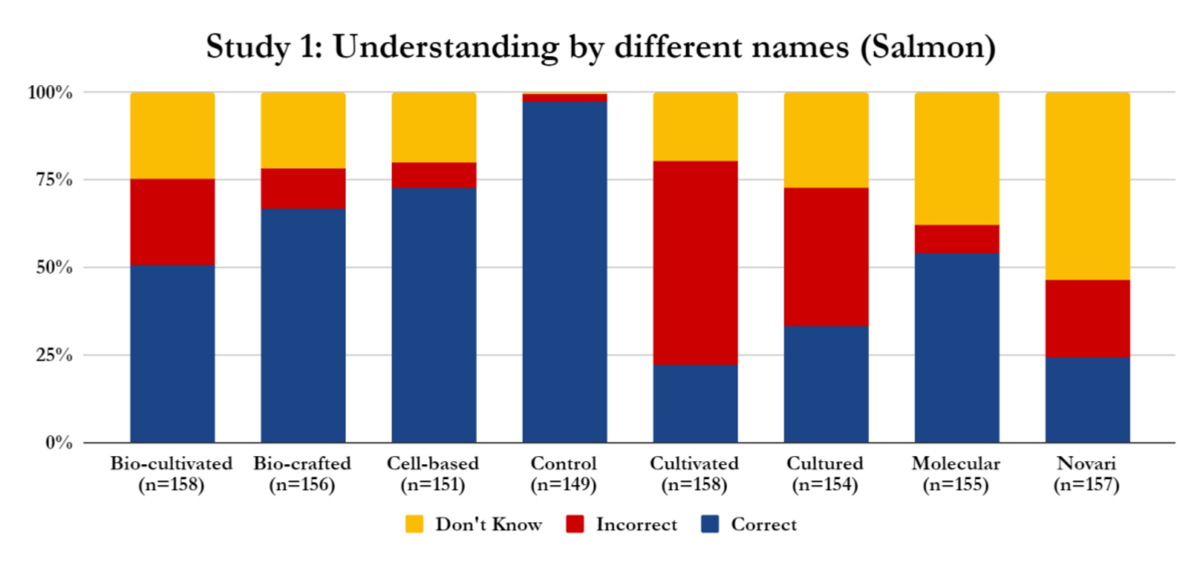


Figure 7 shows the proportion of people who selected the correct definition of cell-cultivated salmon under each different name tested. As shown, the control condition (i.e. the explanation of cell-cultivated salmon) with no specific label resulted in the highest proportion of people selecting the correct definition (>97%), followed by 'cell-based' and 'bio-crafted' where 73% and 67% selected the correct definition respectively. 'Cultured', 'cultivated', and 'Novari' salmon were associated with a low proportion of people selecting the correct definition (33%, 22%, and 24% respectively), but unlike 'cultured' and 'cultivated', which lead to a high proportion of people guessing the incorrect definition, 'Novari' lead to more people saying they did not know. 'Novari' is a coined term and was included in the survey as an experimental condition. In particular, those who read about 'cultured' and 'cultivated' salmon frequently mistook the product for one produced in aquaculture. A chi square analysis indicated that the proportions differed significantly between conditions ($\chi^2(14)=426.303, p<0.001$ | $V=0.396$).

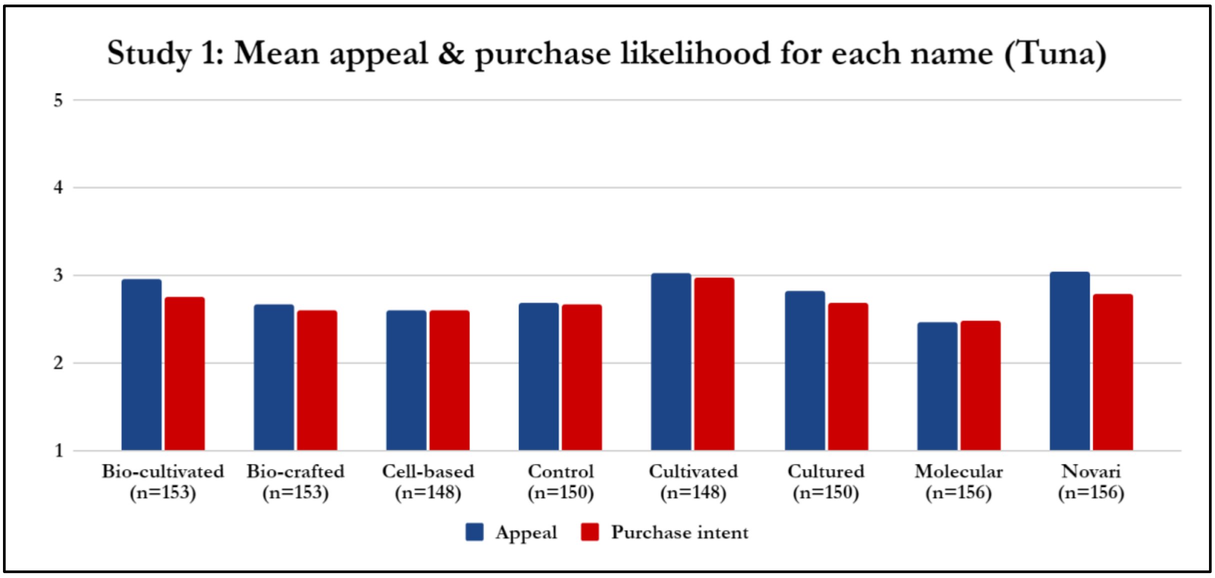
3.2.3 Tuna

Table 6: Acceptance and understanding measures for each name in Phase I (tuna).

Phase I (Tuna)		Bio-cultivated (n=153) [a]	Bio-crafted (n=153) [b]	Cell-based (n=148) [c]	Control (n=150) [d]	Cultivated (n=148) [e]	Cultured (n=150) [f]	Molecular (n=156) [g]	Novari (n=156) [h]
Appeal	**Mean**	2.95 [g]	2.67	2.6	2.68	3.02 [g]	2.83	2.47 [aeh]	3.04 [g]
	SD	(1.24)	(1.40)	(1.27)	(1.34)	(1.19)	(1.30)	(1.34)	(1.13)
Purchase intent	**Mean**	2.75	2.6	2.6	2.67	2.97 [g]	2.68	2.49 [e]	2.79
	SD	(1.22)	(1.43)	(1.33)	(1.32)	(1.32)	(1.30)	(1.35)	(1.17)
Safe to eat if allergic	**Yes**	8.5%	9.8%	7.4%	7.3%	7.4%	4.7%	9.0%	2.6%
	No	54.9%	49.0%	51.4%	53.3%	62.2%	60.0%	46.2%	50.0%
	Don't Know	36.6%	41.2%	41.2%	39.3%	30.4%	35.3%	44.9%	47.4%
Choose description	**Correct**	48.4%	58.2%	73.6%	92.7%	25.0%	30.7%	57.1%	24.4%
	Incorrect	22.8%	22.2%	8.2%	7.4%	53.4%	30.7%	8.9%	24.3%
	Don't Know	28.8%	19.6%	18.2%	0.0%	21.6%	38.7%	34.0%	51.3%

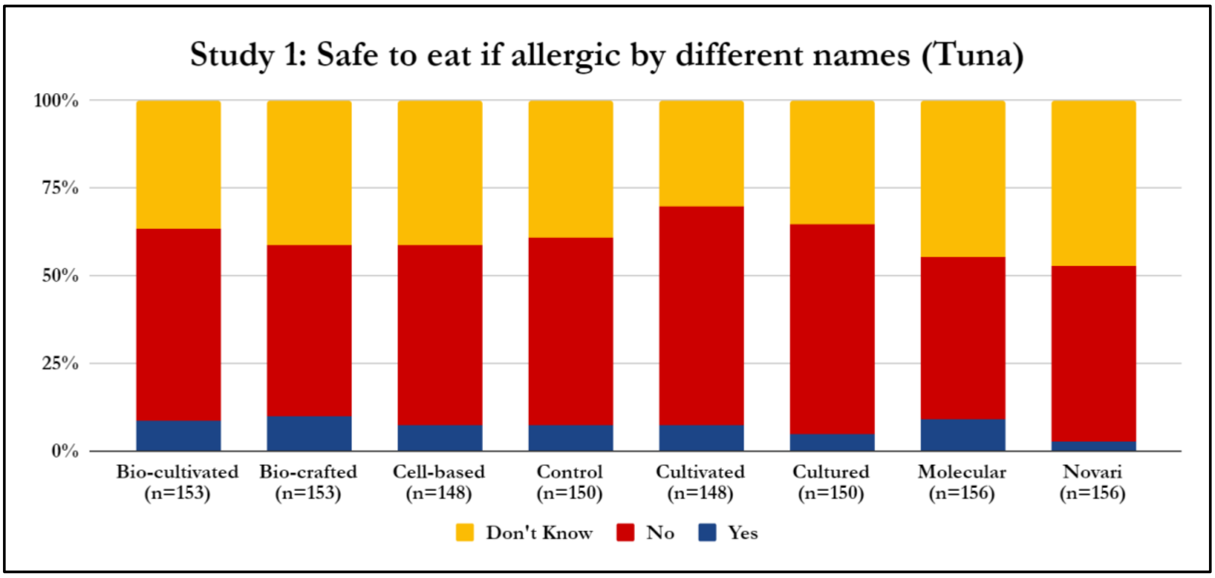
Superscript letters represent significant differences from other conditions, as labelled in the first row.

Figure 8: Mean appeal and purchase likelihood scores for each name in Phase I (tuna).



As shown in Figure 8, the pattern of results for tuna was similar to that of salmon. One-way ANOVAs indicated that there were significant differences between conditions in mean appeal ($F(7,1206)=4.140$, $p<0.001$ | $\eta^2=0.02$) and a marginally significant difference between conditions in mean purchase intent ($F(7,1206)=1.884$, $p=0.069$ | $\eta^2=0.01$). See Table X for pairwise comparisons.

Figure 9: Percentage who thought it was safe for somebody with a tuna allergy to eat cell-cultivated tuna for each name in Phase I.



Again, Figure 9 shows a similar pattern for tuna as we observed for salmon; less than 10% in each condition said that it was safe for somebody with a tuna allergy, and a higher proportion thought that it was not safe in the 'cultivated' and 'cultured' conditions, while higher proportions were not sure in the 'Novari' and 'molecular' conditions. A chi square analysis indicated that there was a marginally significant difference in proportions between the groups ($\chi^2(14)=22.481$, $p=0.069$ | $V=0.096$).

Figure 10: Percentage who selected the correct definition of cell-cultivated tuna for each name in Phase I.

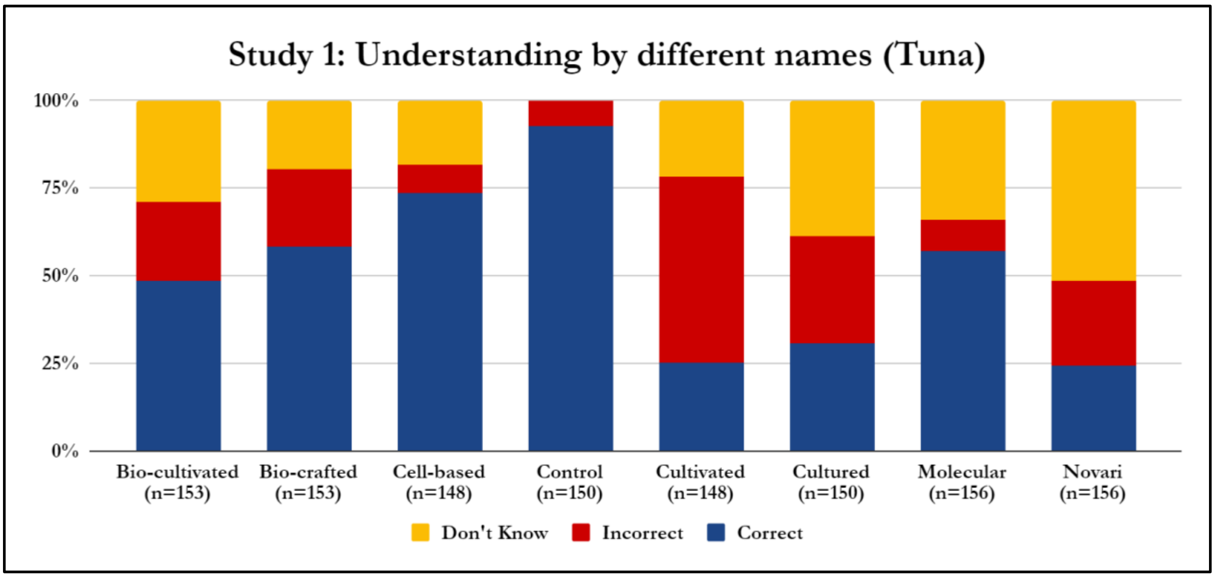


Figure 10 again shows a similar pattern for tuna as we see for salmon: the control condition (full explanation with no label) lead to the highest proportion selecting the correct definition (93%) whereas 'cultured', 'cultivated', and 'Novari' lead to the lowest proportions (25%, 30%, and 24% respectively). Again, 'cultivated' and 'cultured' tuna were frequently mistaken for aquaculture, whereas 'Novari' tuna had the highest rate of uncertainty. A chi square analysis indicated that the proportions differed significantly between conditions ($\chi^2(14)=351.091$, $p<0.001$ | $V=0.362$).

3.2.4. Summary

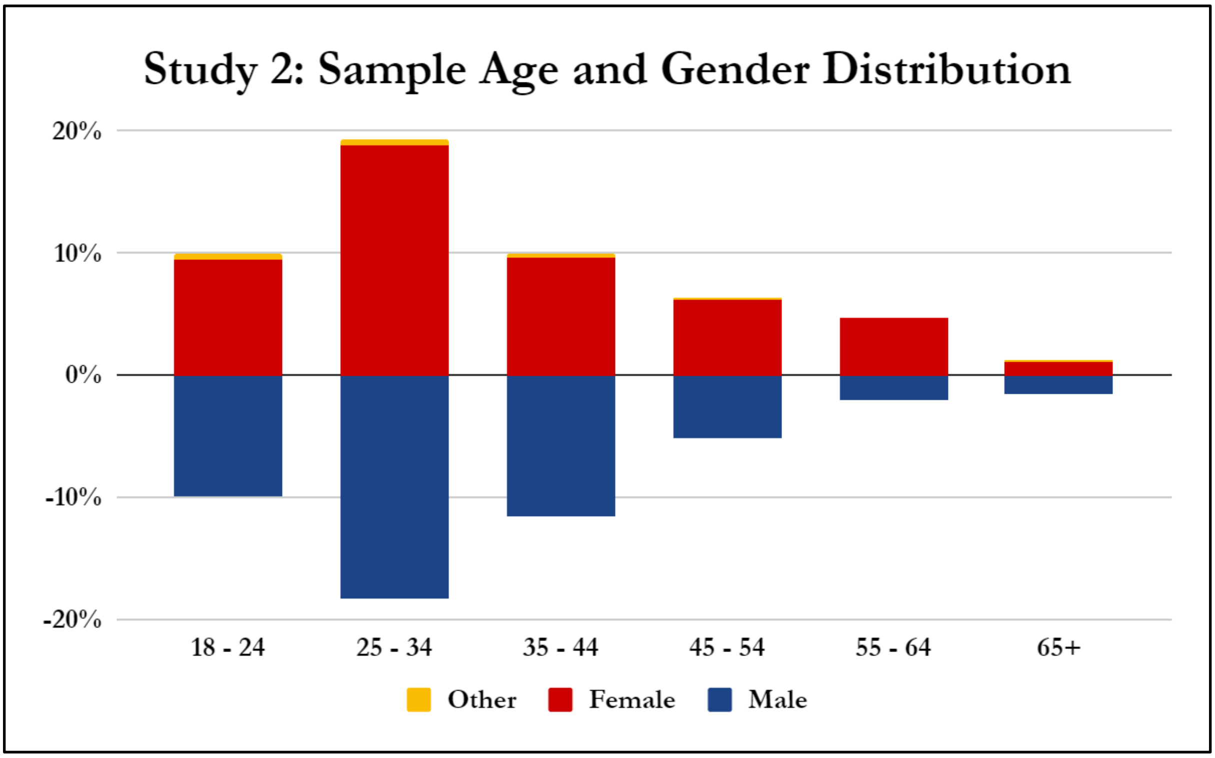
The most significant insight from Survey I is the consumer's ability to identify the product origin via the control phrase accurately — a crucial standard for establishing a 'common or usual name,' according to FDA requirements.. The addition of a short description (control) was significantly more successful in enabling consumers to accurately identify the source of the product in both the salmon (>97%) and tuna (93%) cohorts. Conversely, 'cultured,' 'cultivated,' and 'Novari' showed higher uncertainties in both salmon and tuna groups. Two hypotheses emerged from Survey I. Firstly, the addition of "cell" in the name may increase understanding of product origin (73.6% and 72.8% accuracy in tuna and salmon, respectively). Second, many respondents (30.7% for tuna and 39.6% for salmon) inaccurately identified the origin of 'cultured seafood' —likely due to the overlap with aquaculture. Accordingly, we selected four names for Study II (plus control), based on findings from Study I: Bio-crafted, Cell-based, Novari, Cell-Cultured.

3.3 Phase II survey

3.3.1 Demographics

The age and gender distribution of the sample in Phase II is shown in Figure 11.

Figure 11: Age and gender distribution in the sample of Phase II.



Phase II had the same gender stratification as in Phase 1 (49% Female, 49% Male, 2 other/preferred not to say). 47% of participants had purchased both tuna and salmon in the previous three months. 35.7% bought salmon only, and 17.2% purchased tuna only.

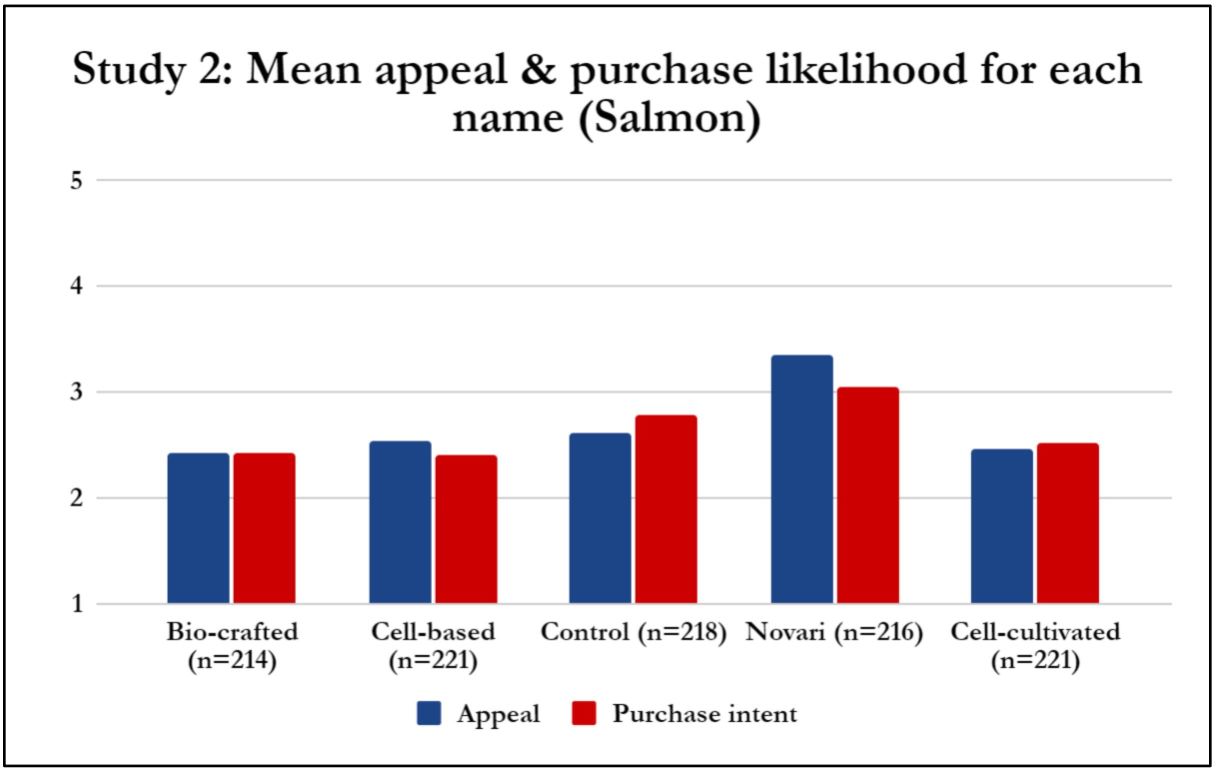
3.3.2 Salmon

Table 7: Acceptance and understanding measures for each name in Phase II (salmon).

Phase II (Salmon)		Bio-crafted (n=214) [a]	Cell-based (n=221) [b]	Control (n=218) [c]	Novari (n=216) [d]	Cell-cultivated (n=221) [e]
Appeal	Appeal	2.43 [d]	2.54 [d]	2.62 [d]	3.34 [abce]	2.46 [d]
	SD	(1.12)	(1.24)	(1.29)	(1.04)	(1.22)
Purchase intent	Purchase intent	2.43 [cd]	2.40 [cd]	2.78 [ab]	3.05 [abe]	2.52 [d]
	SD	(1.18)	(1.25)	(1.40)	(1.16)	(1.22)
Safe to eat if allergic	Yes	1.9%	2.3%	3.2%	2.3%	7.2%
	No	65.0%	66.1%	75.2%	88.4%	67.4%
	Don't Know	33.2%	31.7%	21.6%	9.3%	25.3%
Chose description	Correct	67.8%	71.5%	97.2%	5.1%	85.1%
	Incorrect	7.9%	8.6%	2.3%	20.3%	3.2%
	Don't Know	24.3%	19.9%	0.5%	74.5%	11.8%

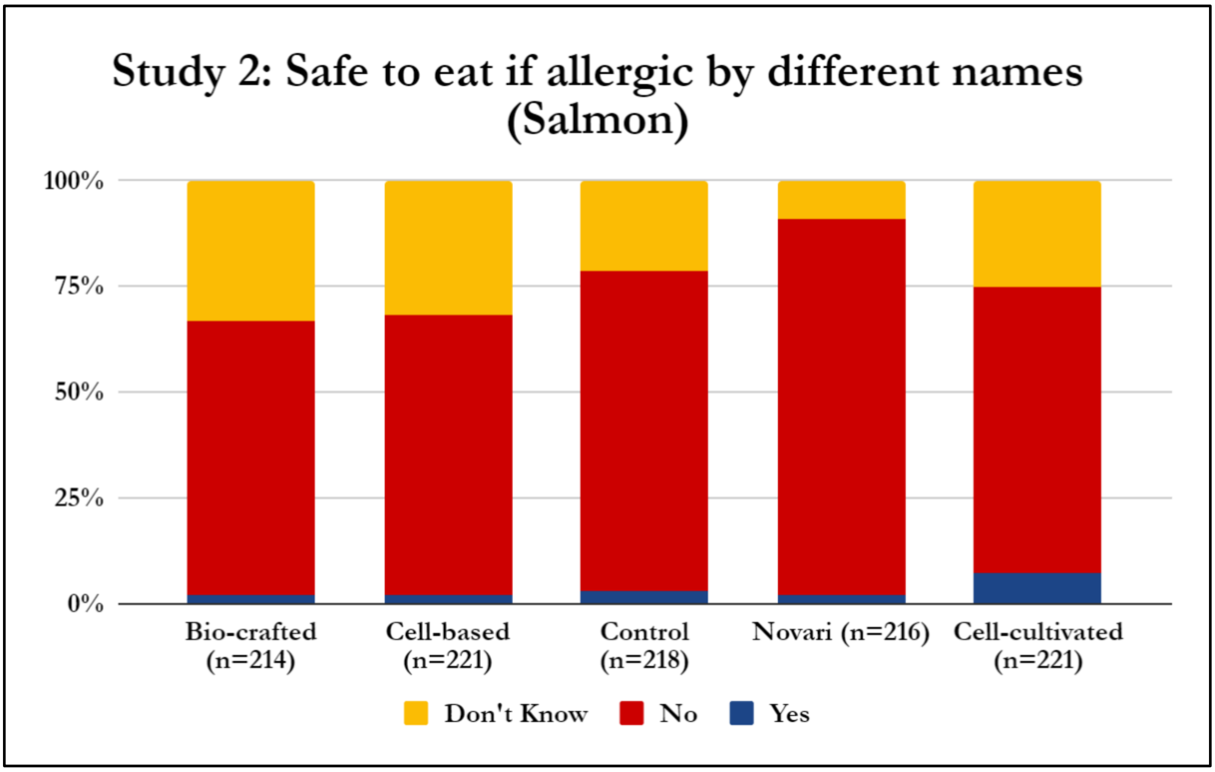
Superscript letters represent significant differences from other conditions, as labelled in the first row.

Figure 12: Mean appeal and purchase likelihood scores for each name in Phase II (salmon).



As Figure 12 shows, Novari salmon scored the highest in terms of mean appeal and mean purchase intent, while each of the other names scored lower than the control. A one-way ANOVA revealed that the differences between groups were statistically significant for both subjective appeal ($F(4,1085)=22.137$, $p<0.001$ | $\eta^2=0.07$) and purchase intent ($F(4,1085)=10.457$, $p<0.001$ | $\eta^2=0.04$). See Table 7 for pairwise comparisons.

Figure 13: Percentage who thought it was safe for somebody with a salmon allergy to eat cell-cultivated salmon for each name in Phase II.



As shown in Figure 13, a small minority (<8%) in all names thought that cell-cultivated salmon was safe to eat for somebody who is allergic to salmon. Some terms, such as 'Novari', produced a relatively high proportion believing that it is not safe for somebody with a salmon allergy, whereas others such as 'cell-based' and 'bio-crafted' resulted in a relatively high proportion being unsure whether it would be safe. A chi square analysis indicated that these proportions differed significantly between conditions ($\chi^2(8)=57.091$, $p<0.001$ | $V=0.162$).

Figure 14: Percentage who selected the correct definition of cell-cultivated salmon for each name in Phase II.

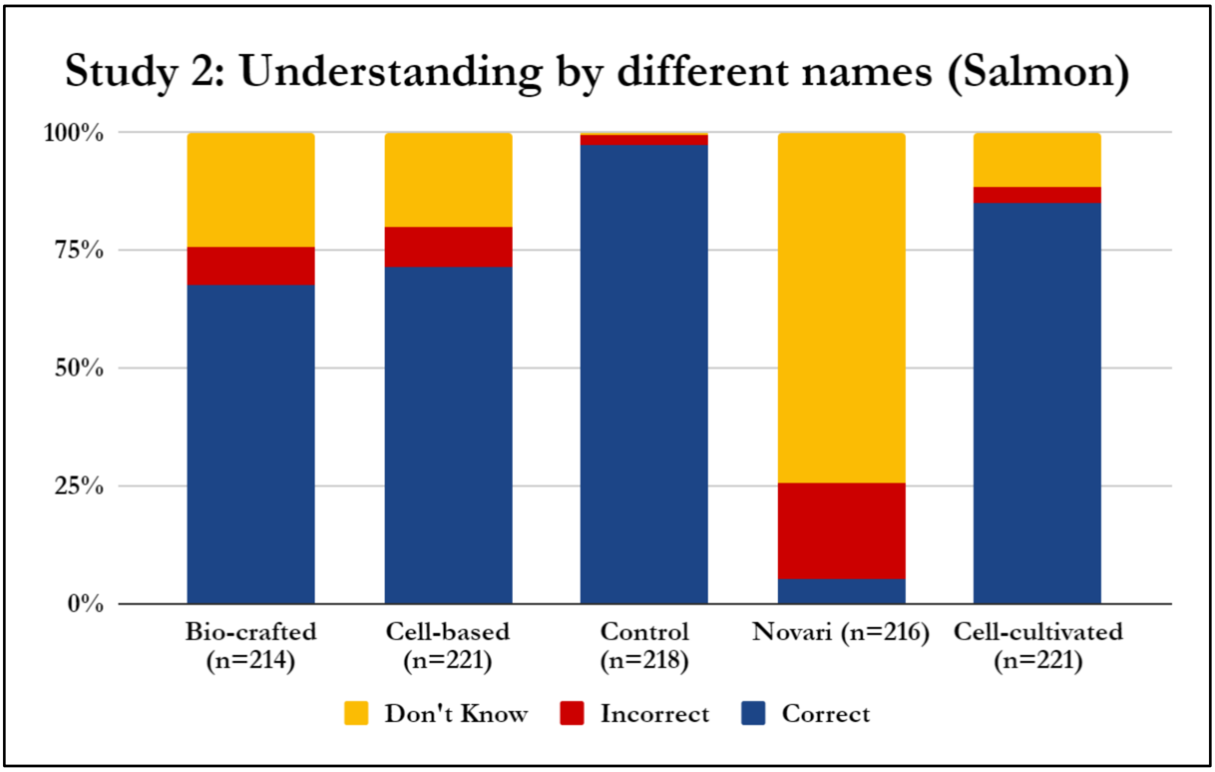


Figure 14 shows the proportion of people who selected the correct definition of cell-cultivated salmon under each different name tested. As shown, the control condition (i.e. the explanation of cell-cultivated salmon) with no specific label resulted in the highest proportion of people selecting the correct definition (>97%), followed by 'cell-cultivated' 85% selecting the correct definition. 'Novari' was associated with the lowest proportion of people selecting the correct definition (5%). A chi square analysis indicated that the proportions differed significantly between conditions ($\chi^2(8)$=512.333, p<0.001 | V=0.463).

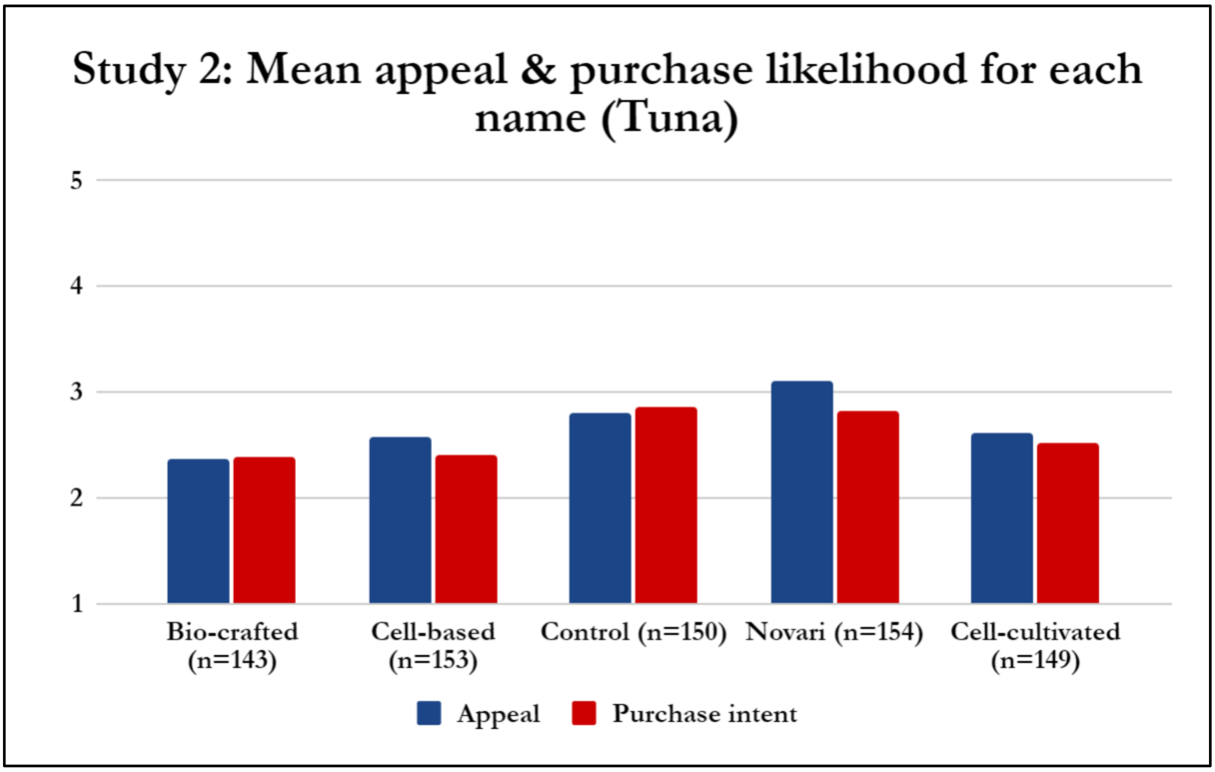
3.3.3 Tuna

Table 8: Acceptance and understanding measures for each name in Phase II (tuna).

Phase II (Tuna)		Bio-crafted (n=143) [a]	Cell-based (n=153) [b]	Control (n=150) [c]	Novari (n=154) [d]	Cell-cultivated (n=149) [e]
Appeal	**Appeal**	2.36 [cd]	2.58 [d]	2.81 [a]	3.1 [abe]	2.61 [d]
	SD	(1.30)	(1.32)	(1.31)	(1.06)	(1.21)
Purchase intent	**Purchase intent**	2.39 [cd]	2.40 [cd]	2.85 [ab]	2.82 [ab]	2.52
	SD	(1.34)	(1.37)	(1.41)	(1.19)	(1.26)
Safe to eat if allergic	**Yes**	3.5%	5.2%	4.7%	1.3%	4.0%
	No	65.7%	67.3%	75.3%	86.4%	63.1%
	Don't Know	30.8%	27.5%	20.0%	12.3%	32.9%
Chose description	**Correct**	67.1%	69.9%	98.7%	2.6%	78.5%
	Incorrect	7.7%	7.2%	1.4%	20.1%	6.7%
	Don't Know	25.2%	22.9%	0.0%	77.3%	14.8%

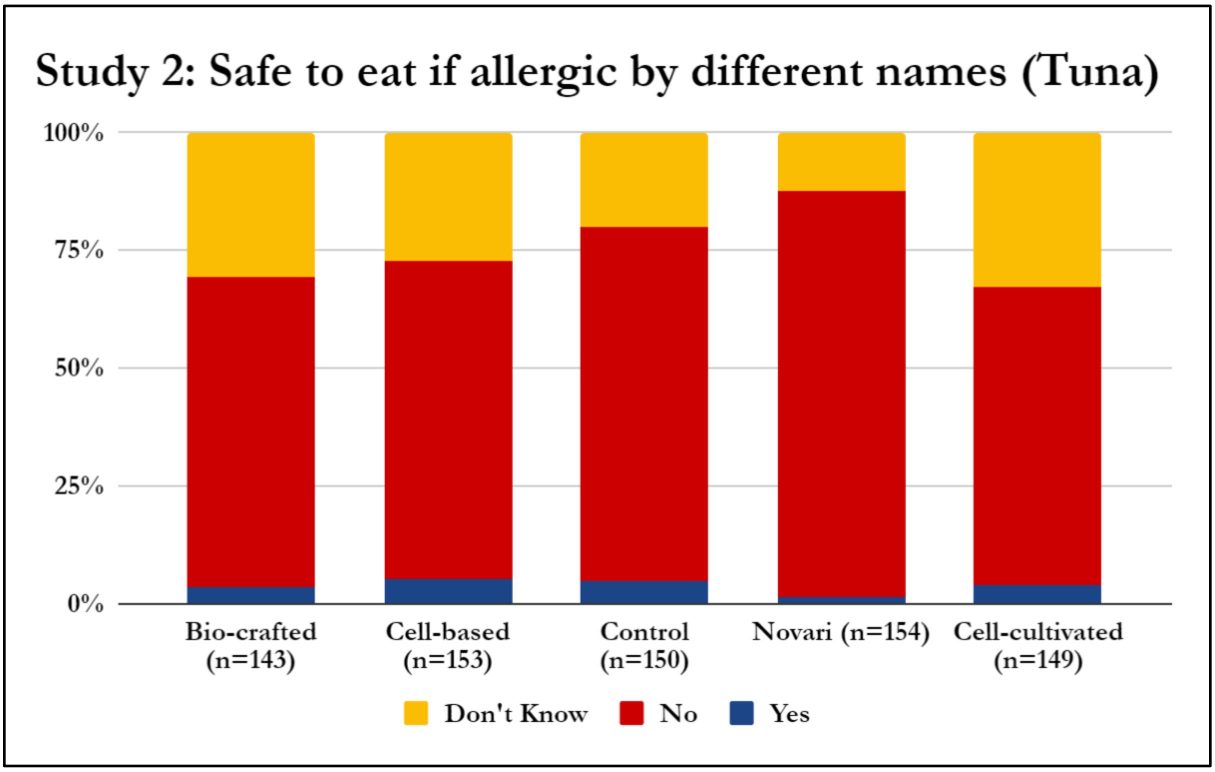
Superscript letters represent significant differences from other conditions, as labelled in the first row.

Figure 15: Mean appeal and purchase likelihood scores for each name in Phase II (tuna).



As shown in Figure 15, the pattern of results for tuna was similar to that of salmon: again, 'Novari' was associated with the highest appeal score, whereas the control condition was associated with the highest purchase intent. One-way ANOVAs indicated that there were significant differences between conditions in mean appeal ($F(4,744)=7.562$, $p<0.001$ | $\eta^2=0.04$) and in mean purchase intent ($F(4,744)=4.287$, $p=0.002$ | $\eta^2=0.02$). See Table 8 for pairwise comparisons.

Figure 16: Percentage who thought it was safe for somebody with a tuna allergy to eat cell-cultivated tuna for each name in Phase II.



Again, Figure 16 shows a similar pattern for tuna as we observed for salmon; less than 5% in each condition said that it was safe for somebody with a tuna allergy, and a higher proportion thought that it was not safe in the 'Novari' condition, while a higher proportion were unsure in the 'bio-crafted' and 'cell-cultivated' conditions. A chi square analysis indicated that there was a marginally significant difference in proportions between the groups ($\chi^2(8)=28.922$, $p<0.001$ | $V=0.139$).

Figure 17: Percentage who selected the correct definition of cell-cultivated tuna for each name in Phase II.

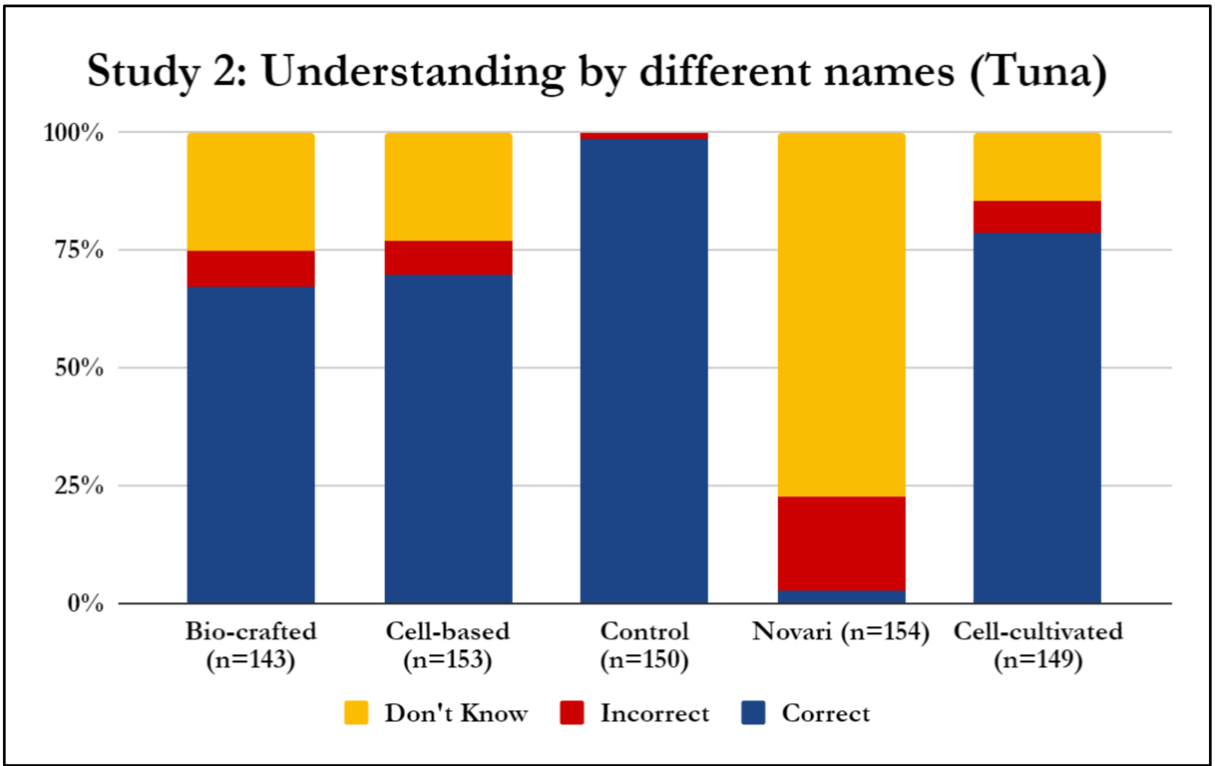


Figure 17 again shows a similar pattern for tuna as we see for salmon: the control condition (full explanation with no label) led to the highest proportion selecting the correct definition (99%) whereas 'Novari' led to the lowest proportion (3%), with over 75% unsure of the meaning. A chi square analysis indicated that the proportions differed significantly between conditions ($\chi^2(8)=361.916, p<0.001$ | $V=0.468$).

3.3.4. Summary

Aligned with Survey I results, the control in Survey II significantly outperformed the other terms concerning consumer understanding of product description with salmon and tuna at 97.2% and 98.7% accuracy, respectively. However, we did find that the new term 'cell-cultivated' fish was both more clear and more appealing compared to 'cell-based' and 'bio-crafted'. The term 'Novari' performed highest in the accurate identification of the presence of allergens.

4. Discussion

4.1 There is currently no common and usual term

There are a few pertinent results from the above to be interpreted. Seafood labeling guidance from the FDA suggests that a name that has been recognized nationally in the U.S. and is commonly used by consumers to identify a product may be an acceptable market name (FDA, 2020c). However, the Brandwatch assessment indicated that there is currently no consensus on the terminology used to refer to cell-cultivated seafood in the public discourse. Several different terms were used, including cell-based and lab-grown; of the most commonly used terms, 'lab-grown' was associated with the most negative sentiment and should be avoided.

The lack of a commonly used name is an issue as FDA regulation for the naming of novel foods 21CFR102.5 states:

"The common or usual name of a food, which may be a coined term, shall accurately identify or describe, in as simple and direct terms as possible, the basic nature of the food or its characterizing properties or ingredients. The name shall be uniform among all identical or similar products and may not be confusingly similar to the name of any other food that is not reasonably encompassed within the same name. Each class or subclass of food shall be given its own common or usual name that states, in clear terms, what it is in a way that distinguishes it from different foods (FDA, 2020)."

Cell-cultivated fish is comparable in most respects to conventionally produced fish. Thus the 'distinguishing factor' required in the descriptive terminology is the production method and should be evident in the nomenclature. Nomenclature guidelines also require identification of 'characterizing properties or ingredients' — which may include allergens. Notwithstanding, the FDA requires labeling all allergen-containing foods (such as fish), including single-ingredient products (such as canned fish). The addition of the required phrasing "contains fish" on packaging may reduce the necessity for the common or usual name to explicate the presence of fish (Klein, 2021, FDA, 2020).

Adopting a standard or usual name for novel cell-cultivated seafood products requires detailed analysis and discussion among regulators, consumers, and industry leaders. However, consumer awareness building is perhaps the most crucial aspect to establishing a common and usual name. Greater consumer awareness of cell-cultivated fish, its allergen content, and its origin may inform the adoption of a common or usual name, per FDA seafood labeling requirements (FDA 2020c). Industry leaders should consider informational campaigns focused on product description coupled with environmental, social, and health benefits.

4.2 Cell-cultivated seafood: achieving accuracy and appeal

Phase I findings indicated that some terms, including 'cultivated', 'cultured', and 'Novari', were associated with the highest appeal and purchase intent but with the lowest understanding of what the product actually is. Many people incorrectly understood 'cultured' and 'cultivated' to refer to aquaculture in the context of seafood (a problem not encountered for cultivated meat where no such confusion exists), while over 50% of respondents indicated that they did not know what Novari was.

On the other hand, terms such as 'cell-based' and 'bio-crafted' were more well-understood, although they still performed more poorly than the control (a description of cell-cultivated seafood with no particular name). Moreover, they tended to be the lowest ratings in terms of consumer appeal and purchase intent; previous research has indicated that invoking science and technology imagery is likely to be unappealing in this context (Bryant & Barnett, 2019). Interestingly, these terms were also associated with the highest number of people being uncertain about the allergenicity of these products.

Phase II tested a term that combined some of the components of the promising names from Phase I - 'cell-cultivated' aimed to increase clarity compared to 'cultivated' and increase appeal compared to 'cell-based'. In fact, Phase II findings indicated that 'cell-cultivated' was associated with an even greater understanding of the product than 'bio-crafted' or 'cell-based', as well as slightly higher purchase intent (though the latter was not statistically significant). 'Cell-cultivated' was the only term tested which achieved more than 75% understanding.

Previous research has indicated that the imagery of cultivation is a positive one in this context (Szejda et al., 2019), and the similarity of 'cell-cultivated seafood' to the commonly used term 'cultivated meat' is likely to increase consumer understanding further by making it clear that they belong to the same category of products.

This research adds to the discussion of Hallman and Hallman (2020), who assessed common or usual names for cell-cultivated seafood. Though they did not test the term 'cell-cultivated', they did find that the term 'cell-cultured' and the phrase 'cultivated from the cells of' were both seen as relatively clear and appropriate, yet relatively unappealing. The use of 'cell-cultivated' appears to solve this problem by using the relatively appealing and consistent 'cultivation' terminology while making it clear that the cultivation is from cells, not conventional aquaculture.

That said, our analysis indicated that there is no consensus on a commonly-used name currently, and that all of the names tested were not as successful at describing the product as a short description (i.e. the control group). As cell-cultivated products gain market prominence, consumer awareness is likely to rise — leading to a better understanding of the products and the emergence of a distinct common or usual name that allows consumers to distinguish between cell-cultivated and conventionally produced seafood. In the interim, our research has shown that a single or compound word is inadequate, and we recommend adopting a short, descriptive phrase (such as that found in control).

4.3 Limitations

One limitation of this study is simply the nature of online surveys as imperfect. We are relying on participants' self-reported attitudes and intentions, which may not translate into real action, particularly because the context of an online survey is very different from buying groceries. That said, we attempted to bridge this gap by using images of product packaging to make the experience seem more situation-relevant. We also had a large nationally-representative sample and a robust series of quality and attention checks, so the data quality here is likely relatively high.

4.4 Future research

Future research could investigate the possibility of an as-yet-undiscovered term for cell-cultivated fish, which is both appealing and intuitive. We tested the novel term 'Novari' in this study and found that it achieved the former but not the latter. Research could also explore which specific forms of regulatory approval and on-package labels would be most reassuring to consumers who are considering trying cell-cultivated seafood. Social research could also explore the types of cell-cultivated seafood dishes consumers will find most appealing, in order to guide product development.

5. Conclusion

As we have argued in this paper, widespread adoption of these products could yield significant benefits for the planet. Cell-cultivated fish offers a substitute for conventional fish consumption, potentially mitigating many negative impacts of the conventional fish industry. Consumers are more aware than ever of food choice implications and have expressed a willingness to transition to more sustainable options, including cell-cultivated fish (Good Food Institute & Kelton Global Research, 2021). Cellular aquaculture companies in the United States, Hong Kong and Singapore have successfully produced salmon, tuna, and shrimp products — pending regulatory approval (Mellon, 2020). Industry leaders, investors, and policymakers suggest a 1-5 year timeline for wide-scale market availability (Mellon et al., 2021). Thus, there is an urgency to address regulatory issues (such as adopting a common or usual name) as regulations may lag behind consumer demand and industry innovation. If we achieve the necessary advancements in technology and regulation, cell-cultivated seafood can secure great improvements in animal treatment, environmental outcomes, and public health.

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