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Milk, Meat, and Fish From the Petri Dish—Which Attributes Would Make Cultured Proteins (Un)attractive and for Whom? Results From a Nordic Survey

Christian A. Klöckner[1], Lukas Engel[2], Jana Moritz[3], Rob J. Burton[4], Jette F. Young[5], Ulla Kidmose[5] and Toni Ryynänen[3]*

[1] Department of Psychology, Norwegian University of Science and Technology, Trondheim, Norway, [2] Technical University of Darmstadt, Darmstadt, Germany, [3] Faculty of Agriculture and Forestry, University of Helsinki, Helsinki, Finland, [4] Ruralis—Institute of Rural and Regional Research, Trondheim, Norway, [5] Department of Food Science, Aarhus University, Aarhus, Denmark

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***Correspondence:**
Christian A. Klöckner
christian.klockner@ntnu.no

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Cultured meat, fish, or dairy produced *in vitro* are discussed as one of the most substantial disruptions the food sector might encounter in the coming decades. These cultured proteins are proposed as a potential solution to the detrimental effects industrial food farming and fishing have on the environment and animal welfare as they would allow people to continue consuming meat, fish, or dairy products while at the same time substantially reducing the burden for the planet. For most people, however, this technology is still unknown, and it is largely unclear how they position themselves toward it. This paper presents the results of a representative survey ($N = 3{,}864$) in three Nordic countries (Norway, Denmark, and Finland). After briefly introducing the technological background, respondents spontaneously assessed their general attitude toward cultured proteins, their willingness to try them, and the likelihood that changes in 24 features of cultured protein would improve the respondents' attitude toward cultured protein products. The results showed that people in the studied countries have a neutral to a slightly positive view of cultured protein products. More familiarity seems to improve acceptance. Males, younger people, and vegans/vegetarians are particularly positive. The anticipated attitude change profiles showed that meat-eating identity, social norms, environmental concern, and country yielded the clearest profile differences, whereas health identity, age, innovativeness, income, education, and gender have smaller effects. People on a vegan or vegetarian diet cared less about most of the positive and negative aspects of cultured proteins compared to meat-eaters, with the exception of environmental and ethical aspects.

Keywords: cultured proteins, cultured meat, attitude change, willingness to try, psychological variables

INTRODUCTION

The provision of protein to the world's population in the form of meat, fish, or dairy products is one of the major challenges many societies in the world are facing. Millions of people suffer from malnutrition, and a growing global population will only increase that problem (Wu et al., 2014). The EAT-Lancet Commission identified unhealthy diets and insufficient food supply as a major contributor to morbidity and mortality of 820 million people and concluded that a substantial transformation of the food system is necessary (Willett et al., 2019). In their report, they propose a healthy reference diet, but Tuomisto (2019a) suggests taking local environmental conditions into consideration to ensure that the diet is not harmful to the environment. Also Kim et al. (2020) indicate clearly that the environmental impact of a diet depends strongly on the country the food is consumed and produced.

Animal-based proteins are one of the biggest contributors to the diet-related ecological footprint. Production of farmed meat and dairy products consumes large amounts of water and contributes adversely to land use (Elferink and Nonhebel, 2007; Tuomisto and Teixeira de Mattos, 2011). These industries contribute substantially to climate emissions (Hedenus et al., 2014). Large-scale fishing of wild fish stocks has led to pollution of oceans with abandoned fishing gear (Mullon et al., 2005; Deshpande et al., 2020) as well as fish farming has led to contamination of water (Ballester-Moltó et al., 2017). Intensive animal farming has also been discussed as an ethical challenge (Linzey, 2013) with respect to the treatment of animals in the production process.

One of the possible solutions to these challenges[1] is cellular agriculture or the production of cultured meat, fish, and dairy products (Stephens et al., 2018; Rischer et al., 2020; Rubio et al., 2020). Cultured or synthetic proteins—as we refer to these products in this paper[2]—are meat, fish, and dairy products produced *in vitro* based on cell culturing and bioreactor technologies but without the need to kill animals in the production. Cellular agriculture is divided into cellular and acellular processes and the respective products (Stephens et al., 2018; Tuomisto, 2019b). Cellular products refer to cultured animal, microbial or plant cells, whereas acellular products refer to substances synthesized by microbes, such as milk proteins, ovalbumin, and fatty acids. In life-cycle assessment studies, cultured proteins are estimated to have a substantially lower environmental impact than farmed proteins (Tuomisto and Teixeira de Mattos, 2011; Smetana et al., 2015), especially with respect to greenhouse gas emissions, land use, and water use. However, the environmental impact is still higher than for most plant-based proteins. As a literature review by Sanchez-Sabate and Sabaté (2019) shows that consumers willing to reduce their meat consumption considerably are still a minority, cultured proteins might be a viable alternative for them.

While not yet widely available, cultured protein entered the commercial market in 2020 in the form of three ice cream brands in the U.S. (Perfect Day Foods[3]) and chicken nugget "samples" served 1 day a week in a (single) Singaporean restaurant[4]. At the same time, startup companies around the world are investing heavily in both the development of the technology and forming positive narratives around its virtues (Helliwell and Burton, 2021). However, as these are immature technologies, largely unknown to the general public, it is unclear how consumers position themselves in relation to these products of cellular agriculture, which attributes are essential for acceptance, and which attributes contribute to a positive assessment. With this study, we aim to fill this research gap based on a large representative survey conducted in three Nordic countries (Norway, Denmark, and Finland)[5].

ACCEPTANCE OF CULTURED PROTEINS

Although research on consumer acceptance of cultured proteins is scarce, and to our knowledge, only a few studies have addressed this issue so far, the field is developing quickly. Bryant and Barnett (2018, 2020) reviewed the literature recently, with a first version published in 2018, which only 2 years later needed to be updated substantially. Stephens et al. (2018) criticize social scientific studies in this domain for their limited focus on ethical issues (here: issues connected to if the production of cultured protein is ethically approvable), calling for a broader approach. In the following paragraphs, we briefly summarize the state of knowledge based on these studies. In the case of cultured meat, multiple scholars have studied how consumers perceive cultured meat in different countries using different study design approaches. As alternative proteins like insects, algae, or plant-based products are already on the market, they are often used for comparison to cultured meat to identify consumer preferences, as will be elaborated on in the following paragraphs. Other studies focused on the consumer perception of cultured meat and factors such as socio-demographics, attitudes, psychological factors, meat-eating habits, and perceptions of naturalness.

Cultured Protein in Comparison to Other Meat Alternatives

Bryant et al. (2019), Circus and Robison (2019), Gómez-Luciano et al. (2019), and Onwezen et al. (2021) all conducted studies that compared different alternative proteins with cultured meat. Although all four studies had a different methodological approach, the general consensus is that consumers are least willing to eat insects, followed by cultured meat, and most willing to eat plant-based products. Onwezen et al. (2021) reviewed 91 articles dealing with comparisons of pulses, algae, insects, plant-based meat alternatives, and cultured meat. They

[1]We acknowledge that there are also other solutions in the discussion, primarily plant-based proteins. This paper does not aim to compare these technologies and value one as more important than the other.

[2]They have also been called "synthetic proteins" (e.g., Burton, 2019) amongst other terms.

[3]https://perfectdayfoods.com/

[4]https://www.cnbc.com/2021/03/01/eat-just-good-meat-sells-lab-grown-cultured-chicken-in-world-first.html

[5]Funding was available for conducting the study in Norway, Denmark, and Finland. Other Nordic countries were not included in the study due to lack of funding for these countries.

concluded that the main drivers of acceptance toward food are familiarity, taste, personal attitudes, and food neophobia. Gómez-Luciano et al. (2019) found that cultured protein ranked behind plant-based meat analogs in the preference of consumers in the United Kingdom (U.K.), Spain, Brazil, and the Dominican Republic. Circus and Robison (2019) conducted a similar study in the U.K. with similar results.

Country Differences

Bryant et al. (2019) compared in total 3,030 consumers in China, India, and the USA to identify their preferences between plant-based meat analogs and cultured meat. They showed that Indian and Chinese consumers accept cultured meat and plant-based meat analogs significantly more than Americans. Food neophobia is found to be significantly higher and meat attachment significantly lower in India compared to China and the USA. Gómez-Luciano et al. (2019) compared consumer acceptance of plant-based meat analogs, cultured meat, and insect-based products in the United Kingdom (U.K.), Spain, Brazil, and the Dominican Republic, respectively. The results show that consumers from more economically-developed countries were generally more willing to replace traditional meat with one of the three alternatives, which contradicts the findings by Bryant et al. (2019), where Americans were found to be more critical to new food.

Sociodemographic, Dietary, and Psychological Differences

Generally, it seems that higher educated, younger people, left-leaning voters, and meat-eaters are more willing to accept cultured protein (Wilks and Phillips, 2017; Slade, 2018; Bryant et al., 2019; Mancini and Antonioli, 2019). In an Italian study, Mancini and Antonioli (2019) provided respondents with a description of cultured meat prior to their completing a questionnaire, including the willingness to try (WTT) cultured protein. Weinrich et al. (2020) used a similar approach with German respondents. The results in both studies showed that highly educated and young consumers are more willing to try cultured meat. Zhang et al. (2020) also found—in line with the other studies referenced in this section—that both younger and more educated people were more willing to taste cultured meat.

Francekovi et al. (2021) found that non-meat eaters were less likely to want to try cultured meat than meat-eaters.

Wilks et al. (2019) investigated psychological factors, predictive attitudes, and behavioral intentions toward cultured meat by measuring consumers' worldviews and aversions. They found that consumers with a general aversion to new food, those who were politically more conservative (in line with previous studies), and people with a general distrust of food sciences showed less WTT and/or were less positive toward cultured meat.

The Impact of Familiarity

Bryant et al. (2019) show that higher familiarity with the products (although in the case of cultured meat, not direct experience) predicted higher acceptance (also see Onwezen et al., 2021). Francekovi et al. (2021) conducted a study in Croatia, Greece, and Spain to analyze what potential consumers associate with cultured meat. Their results showed that almost half of the respondents had never heard of cultured meat. Those who had heard of it thought it would be more environmentally friendly, animal friendly, and healthier. Familiarity tends to be significant in accepting novel foods, meaning that once cultured meat products are available and consumers adapt to them, acceptance may increase.

Zhang et al. (2020) also investigated consumer awareness of, acceptance of, and willingness to pay for cultured meat. Their approach differs as they studied consumer perceptions before and after the provision of information about cultured meat. Prior to being informed about cultured meat, a majority of consumers were either opposed to cultured meat or neutral. After receiving more information, the percentage of consumers opposed to cultured meat dropped from 22 to 12%. Most of the respondents were willing to taste (85%) or even purchase (78%) cultured meat after the information.

The Impact of Perceived Naturalness

People who value naturalness in food products are less likely to accept cultured meat (Bryant et al., 2019; Michel and Siegrist, 2019). "Naturalness" is here understood as the degree to which a product is perceived to be of natural origin (e.g., produced in traditional agriculture) as opposed to a technological process where the product is produced "artificially." Wilks et al. (2021) show that these concerns about naturalness are mostly rooted in emotional reactions like disgust or fear and not the product of an analytic thought process. In the study by Francekovi et al. (2021), respondents perceived cultured meat to be unnatural but stated a willingness to purchase it nonetheless once it becomes affordable. Weinrich et al. (2020) also assessed consumers' attitudes toward cultured meat and found that WTT increases if perceived ethical advantages (e.g., better animal treatment) and global diffusion optimism (such as reducing global warming potential) are high. However, the WTT was the lower, the more concerned respondents were about food qualities such as naturalness (Weinrich et al., 2020). In contrast to the studies presented so far, Wilks et al. (2019) found that WTT was not affected by the perceived (un)naturalness of the product.

THE PRESENT STUDY

From the literature review[6] presented above, it is clear that, while a number of studies have investigated the issue, much is still unknown about how consumers relate to the anticipated new cultured meat, milk, and fish products. In particular, the attitudes of Nordic consumers—markets with strong bonds to different types of factory farming (fish, broiler, and pork)—are lacking.

[6]It should be acknowledged that the aim of this paper is not to provide a systematic and comprehensive literature review. To provide a context for our study and inform the development of the survey, we searched scientific data bases (Scopus, Google Scholar) for papers including keywords like synthetic/cultured protein, synthetic/cultured meat, synthetic/cultured dairy products, and consumers, consumer attitudes. Only papers in peer reviewed journals were included in the review. Based on the identified papers, we included more papers that were mentioned in the reference lists of the initial papers.

Furthermore, current scientific knowledge about how consumer sentiment is affected by different product qualities is limited. From a marketing perspective, it is relevant to understand how consumers in this pre-market stage evaluate product attributes and relate them to conventionally farmed animal products. In other words, how much would it improve or detriment the attitudes toward cultured meat if it was perceived, for example, more environmentally friendly, healthier, more expensive, or less tasty than the conventional products?

To address these questions, the aim of this paper is 2-fold. Firstly, to explore the general attitude toward and willingness to consume cultured proteins by Nordic consumers. As such, it represents the first assessment of its kind for Nordic countries. Secondly, to explore the effect changing/improving product attributes has on their attractiveness to consumers. Here we do not simply seek to explore how consumers perceive cultured proteins at the moment (as they are still mostly unknown or only vaguely known to the respondents), but rather to identify the key attributes which would need to be improved to make them more attractive to consumers. As part of this, we will also seek to identify differences between different consumer groups. This is information not only relevant for producers but also in terms of the development of marketing communications and strategies in Nordic countries.

DATA AND METHODS

A large multinational survey was conducted in February and March 2021 in Norway, Denmark, and Finland. Even if we were unable to cover all Nordic countries in our survey due to lack of funding for additional data collections, we would consider the comparison of these three countries interesting in itself. The agriculture profiles of the three countries are different, with extensive fish farming in Norway and pork farming in Denmark, Finland, and Norway having a tradition of openness for new technology, whereas Denmark is closer to the central European skepticism. These aspects should reflect in the assessment of cultured protein technology. The survey was developed based on the literature review, an analysis of communications from the cultured protein industry. As far as possible, existing and validated measurement scales were used (see the introduction of the items below). The survey was constructed in English and then translated to Norwegian, Danish, and Finnish. The translations were then checked against the English version by native speakers of the respective target languages. Cultured proteins were consistently named "cultured/synthetic meat, fish or dairy products" in the survey—see Bryant and Barnett (2019) or Bryant and Dillard (2019) for a discussion on naming effects. The respondents were recruited from large national online panels, and the respondents were reimbursed for their participation by the normal survey panel rewards. No ethical clearance of the study was necessary because no directly and indirectly identifying information has been shared with the researchers by the operators of the panels. The survey companies contracted with the data collection have guaranteed compliance with GDPR and data security procedures. The survey had several sections—not all of which relevant for this paper.

Respondents

The respondents in Norway, Denmark, and Finland were representative with respect to the distribution of genders, education, age, and income. The participants were sampled as a stratified random sample from online panels to fulfill representativity in the aforementioned categories (in comparison to the distribution of the general population older than 17 years). A required sample size per country of at least 1,067 participants was estimated based on a desired confidence level of 95% and <3% error margin. In total 3,864 respondents answered the online questionnaire, of which 1,207 were from Norway 1,203 from Denmark and 1,452 from Finland. Fifty-one percent of the respondents in Norway were male (48.6% female, the remaining 0.4% did not identify themselves in a binary way). In Denmark, 49.3% were male and 50.7% female; in Finland, 49.9% were male and 50.1% female. Age was well-distributed with 171 and 275 respondents in each of the following age groups in each country: 17–29, 30–39, 40–49, 50–59, 60–69, and 70–85 years. Derived from a self-description of their diet, the respondents seem to follow a typical diet for their country with respect to farmed proteins and plant-based proteins. Between 7.9 and 8.5% of the respondents (depending on the country) described themselves as vegetarians or vegans.

Analysis

We followed a Bayesian analysis approach and estimated the means and their credibility intervals, which quantify the uncertainty for the variables in the complete sample and the tested subgroups. Then we used a Bayesian inference approach utilizing Bayes-factors to determine the credibility of the hypotheses of differences between specific groups. Bayesian statistics has a number of advantages over probabilistic approaches usually utilized in psychology and related disciplines (Wagenmakers et al., 2018). These include: (1) Bayesian estimation can quantify uncertainty (which confidence intervals in probabilistic approaches are mistakenly assumed to represent), (2) Bayesian estimation is based on the data itself, not assumptions about the data, (3) in Bayesian inference, the Bayes factor quantifies the evidence for both H0 and H1, so in other words, one gets levels of empirical support that (for example) two means are equal or different, (4) the Bayes factor does not depend on the sampling plan behind the collection of the data. For calculation of the Bayes factors for a *t*-test equivalent situation (see Rouder et al., 2009).

As we were mainly interested in identifying differences between subgroups, we focused on Bayes factor values that provide evidence for H1 (the hypothesis of a difference) being true. In their book on Bayesian modeling, Lee and Wagenmakers (2013) formulate rules of thumb for how to interpret the strength of the evidence for the no-difference (H0) or the difference (H1) hypothesis, and conclude that Bayes factors between 1/10 and 1/30 provide strong evidence for H1, between 1/30 and 1/100 provide very strong evidence, and below 1/100 provide

extreme evidence for H1. We decided to be conservative in our analyses and not interpret H1, where the Bayes factor provides only moderate or anecdotal evidence (Bayes factor 1 and 1/10). We are also not interpreting evidence for H0 (= no difference), but the reader may do so by following Lee and Wagenmakers' advice (Bayes factors between 10 and 30 = strong evidence for H0, 30–100 = very strong evidence for H0, and over 100 = extreme evidence for H0). Our analyses were conducted with the Bayes analysis features of SPSS 27 analysis software using a sample weight correcting for slight deviations from representativity.

Measures

The following sub-sections describe the variables used for the analyses in this paper. Most of the variables were validated in previous studies.

Sociodemographics

The survey included information on the respondents' age, gender, country of residence, the region of their residence within the country, their income, and their highest education. This information was categorized into two or three categories for each variable to allow for the statistical analysis with Bayes factors. Age was grouped into three categories of approximately the same size (respondents under 40, 40–59, and older than 59 years). For gender, only people who identified as males or females were analyzed since the group of people without a binary identification was too small for meaningful analyses. The country of residence was either Norway, Denmark, or Finland. The region within the country was dichotomized into the region of the capital (Oslo, Copenhagen, Helsinki) against all other regions in the country. As very different proportions of the respondents in the three countries were from the capital regions, the analyses of this capital city effect were adjusted for country effects by centering on country means. Income was grouped into three categories (<50,000 Euro net household income per year, 50,000–90,000 Euro per year, and more than 90,000 Euro per year). As the income levels are different between the studied countries, the comparisons between income categories were adjusted for country effects by centering on country means. The highest education was grouped into three broad categories as the educational systems in the three countries are different: basic education, high school education, and university or university college education. Sociodemographics are used as independent variables in the analyses.

Diet

In the first sections of the survey instrument, respondents were asked whether they considered themselves vegetarians, vegans or if they at least sometimes consumed meat or fish. For the analyses of this paper, vegans and vegetarians were combined (as their subgroups were too small to conduct meaningful separate analyses, and preliminary analyses showed that their profiles were not different). Diet type was used as an independent variable in the analyses.

Environmental Concern/Environmental Worldview[7]

At the beginning of the questionnaire, respondents were asked to answer a short version of the New Environmental Paradigm (NEP), which is a standard measure of environmental concern or environmental worldviews validated in many studies (Dunlap and Van Liere, 1978; Dunlap et al., 2000). We used six items[8] (example: "The balance of nature is very delicate and easily upset by human activities"). The Cronbach's alpha of the resulting scale was satisfactory at 0.729. All responses in this question block were measured using a five-point agreement scale (Likert scale). After calculation of the NEP score, respondents were grouped into three equally sized groups of low, medium, and high concern. These categorized variables were used as independent variables in the analyses.

Innovativeness

As cultured proteins are new product categories, the level of innovativeness of the respondents might have an impact on their perception of the product. We used two different concepts of innovativeness: (a) innovativeness in the food domain adapted from the "food neophobia scale" (Pliner and Hobden, 1992), and (b) general innovativeness adapted from the "motivated consumer innovativeness scale" (Vandecasteele and Geuens, 2010). Four items captured food innovativeness (example: "I am curious and will eat almost anything"). As the Cronbach's alpha of the scale was somewhat low (0.560), the effects of food innovativeness should be regarded with caution. General innovativeness was captured by eight items (example: "It gives me a good feeling to acquire innovative products"). Cronbach's alpha indicates excellent internal consistency (0.907). Both innovativeness scales were divided into three equally sized groups for the analyses (low, medium, high). These categorized variables were used as independent variables in the analyses.

Identity

Food is closely related to people's identities. What we eat defines who we are (Fischler, 1988). Therefore, we also captured two facets of food-related identity with questions typically used in identity research (Cameron, 2004; Van der Werff et al., 2014). One facet measured if eating meat (or in the case of vegetarians or vegans avoiding eating meat) is a central part of the person's identity (example item: "Eating meat/vegetarian/vegan food is an important part of who I am"). Five questions were used to capture this identity facet (Cronbach's alpha = 0.818). The second facet quantified if eating healthy is a central part of the person's identity. This was measured with three items (Cronbach's alpha = 0.799; example: "Eating healthy food is an important part of who I am"). Both identity variables were grouped into three equally sized groups (weak, medium, strong identity) and these categorized variables were used as independent variables in the analyses.

[7]For all following scales: Explorative Factor Analyses were conducted to establish that the scale is one-dimensional.

[8]The complete list of items can be obtained on request from the corresponding author.

General Attitude Toward Consuming Cultured Protein

After measuring all variables described above, a section in the survey explained briefly what cultured protein is and how it is produced. The text was as follows:

> *Cultured protein is real animal protein produced outside the animal. It is also called "clean protein," "in vitro protein" or "lab-grown protein." There are two different processes to achieve this: In the first, a small number of muscle and fat cells are taken from a live animal and grown in a liquid feed "serum." Once grown, the cells can be formed into meat/fish to be consumed as, for example, a hamburger, a sausage, a fish filet, or a chicken nugget. There is no GMOs[9] in the final product, but it is possible that GMOs could be used to make the serum. The second process involves taking DNA (genes) for protein/fat production from an animal (e.g., DNA for milk production) and placing it in a yeast. The yeast is then fed sugar and produces the proteins, which can be used to make products such as cheese and ice cream. Although GMOs are used in the production process, again, there are no GMOs in the final product. This is used for products such as milk, gelatine, or egg white.*

After this introduction, the following question was asked: "After reading the explanation above, what is your first reaction on cultured/synthetic meat, fish or dairy?" with five answering categories ranging from "I am in favor" to "I am against." This is the first dependent variable in our analyses for the first objective of the paper. Since it is only one item and no repeated measurements were conducted, no assessment of reliability was possible.

Attitude Changing Features of Cultured Protein Products

Immediately following the above question measuring the first reaction, respondents were asked to assess how much better or worse their attitude toward cultured protein products would become if the aspect in question was fulfilled (e.g., "cultured meat, fish or dairy would be healthier than conventional meat, fish or dairy"). An answer of 1 ("much worse") indicates that the attitude would be much worse if cultured meat, fish, or dairy had the described characteristic, an answer of 3 would indicate no change in attitude, and an answer of 5 ("much better") would indicate a much-improved attitude. In total, 24 aspects were identified based on the industry's communication around cultured protein and research papers of potential benefits and caveats of cultured protein. **Figure 3** displays all 24 aspects. These aspects were used as dependent variables for studying the second objective of the paper. As the aspects were analyzed individually and at only one point in time, no assessment of their reliability was possible.

Intention to Consume Cultured Protein

Afterward, respondents were asked if they would be willing to taste cultured meat, fish, or dairy and if they would be willing to eat them regularly. All six items were combined into one score (Cronbach's alpha = 0.943). This variable is the second dependent variable for the analyses.

[9]GMO, Genetically Modified Organism.

Social Norms

Anticipated social norms are of particular importance for behaviors and products that people have not developed strong attitudes about (Feindt and Poortvliet, 2020). Therefore, we also measured the social norms around the consumption of cultured proteins. We used two items ("I expect that most people, who are important to me, would approve of me consuming synthetic/cultured meat, fish or dairy when they become available" and "I expect that most people, who are important to me, will consume synthetic/cultured meat, fish and dairy products when they become available") to capture both the injunctive and the descriptive component of social norms (Thøgersen, 2006). The items correlated strongly enough (Pearson correlation $r = 0.626$; Spearman-Brown correlation $r = 0.770$) to combine them into one measure, which then was categorized into weak, medium, and strong anticipated social norms for the analyses. This variable was used as an independent variable in the analyses.

RESULTS

The following sections describe the results of our analyses. In the text, the results are presented as figures, but the exact numbers, credibility intervals, and Bayes factors are reported in the **Appendix**.

General Attitude and Intention to Cultured Protein

As can be seen in **Figure 1** (**Appendix Table 1**) below, our respondents report on average just above midpoint (midpoint equals neutral) attitude toward cultured meat, fish, and dairy products. The Norwegian assessment is the same as the overall mean, whereas the Danish is slightly below and the Finnish is slightly higher than the Norwegian assessment. Based on the Bayes factors, there is extreme evidence that the assessments of Denmark and Finland are different from each other, as well as Norway from Denmark. Males are more positive to cultured proteins than females. Vegetarians and vegans are substantially more positive than omnivores. From the analyses, there is extreme evidence for both differences. The youngest age group is substantially more positive than the middle and oldest group, which both score in the negative part of the scale. Evidence for all age differences is extreme.

As **Figure 2** shows (**Appendix Table 1**), the pattern of results is almost the same for the intention to consume cultured proteins, with one interesting difference: Vegetarians and vegans who were substantially more positive to the technologies do not report a higher intention to consume cultured proteins. With consumption intentions, the differences between the three countries are also less distinct as with general attitudes. Also, the intention to consume is strongly characterized by the age and gender effects outlined above.

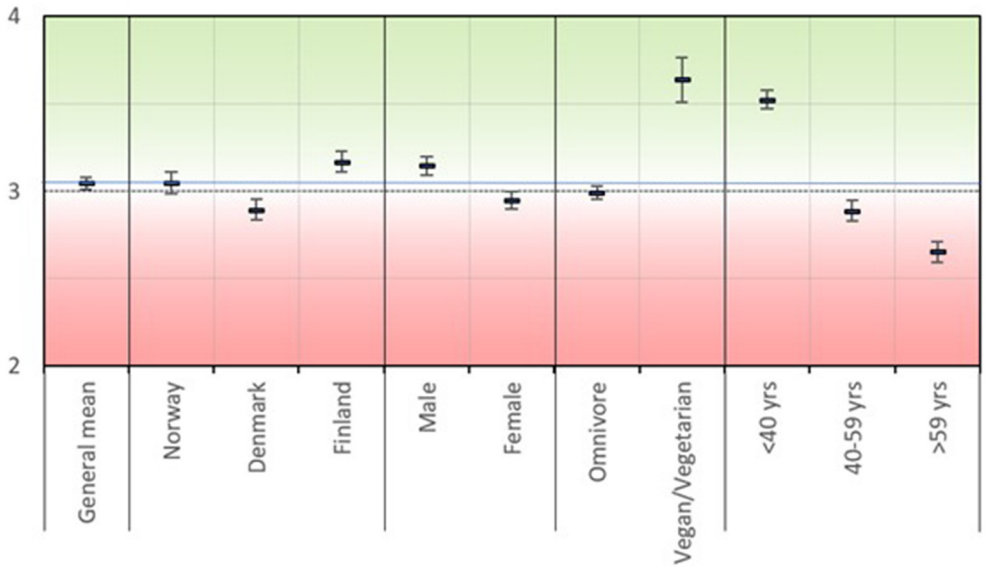

FIGURE 1 | Mean ratings of the general attitude of cultured protein by consumers. The thin blue line represents the general mean across all respondents. The error bars represent 95% credibility intervals.

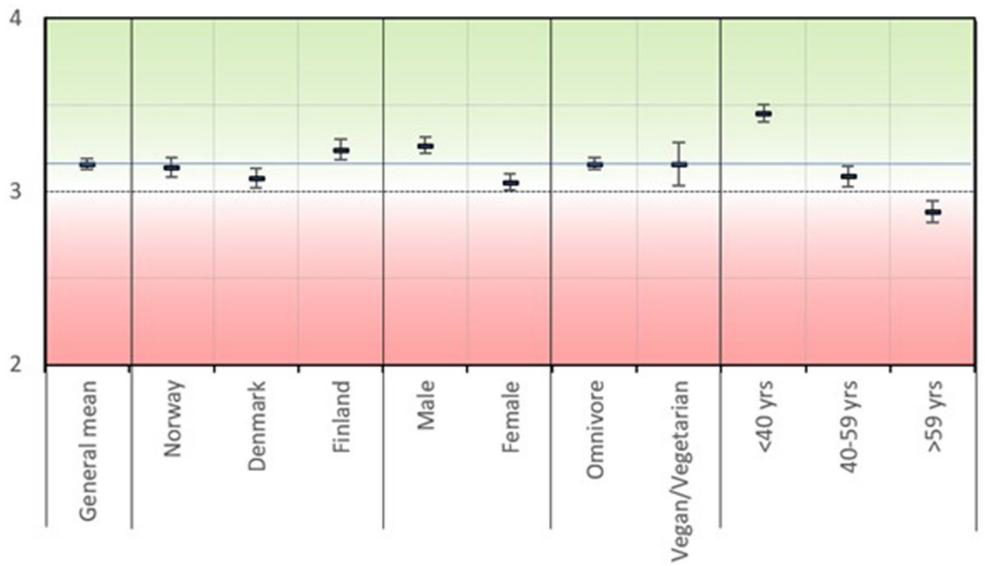

FIGURE 2 | Mean ratings of the intention to consume cultured protein. The thin blue line represents the general mean across all respondents. The error bars represent 95% credibility intervals.

Expected Effects of Attributes of Cultured Protein on the Attitudes

For the second part of the analysis, the profiles of attitude effects were compared for different subgroups depending on the independent variables. As there are many differences with strong, very strong, and extreme evidence, only the most central effects are reported here in the text. The full set of differences is included in **Appendix Tables 2–14**.

However, before the differences between subgroups are examined in more detail, the overall picture for all respondents is presented in **Figure 3**. Attitudes toward cultured protein would improve if 20 out of the 24 tested characteristics relative to conventional products were achieved. The biggest positive impact can be expected for environmental benefits, but also cultured protein being cheaper, healthier, more nutritious, providing better value for money, being more ethical (e.g., with respect to the treatment of animals), providing more vitamins

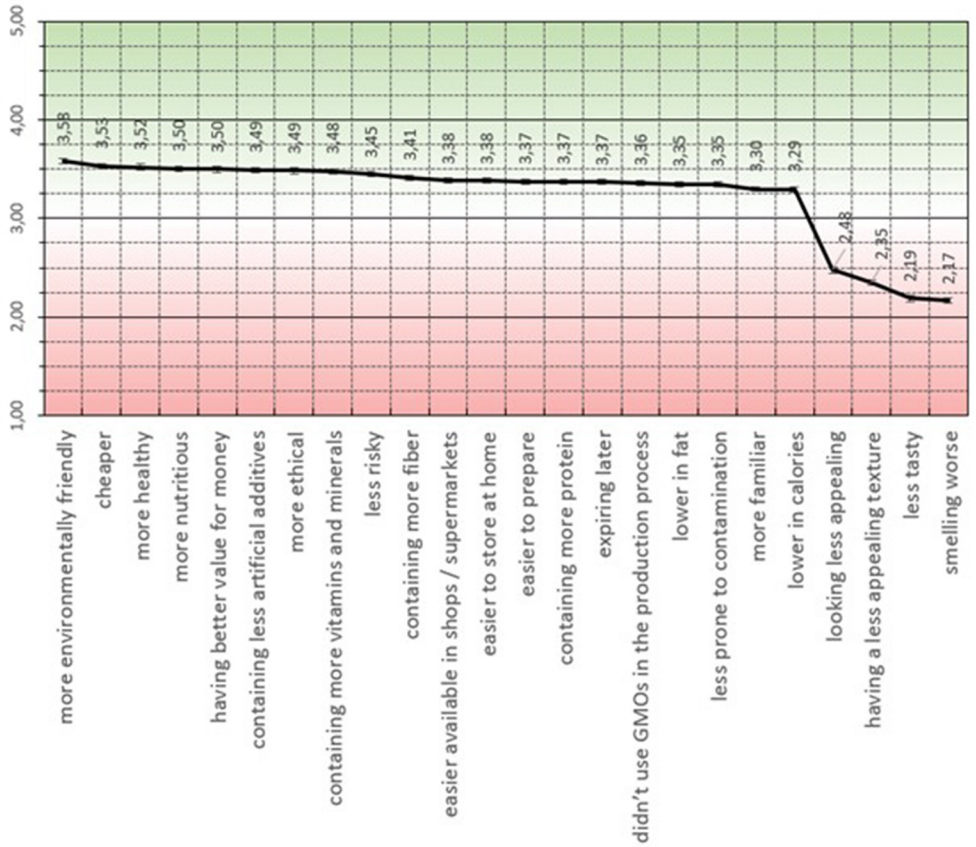

FIGURE 3 | Mean ratings of how much the attitude toward synthetic protein would become more positive or negative if synthetic protein was more of the aspect (e.g., more environmentally friendly) than farmed protein. The error bars represent 95% credibility intervals estimated with Bayesian estimation ($N = 3,864$).

and minerals, and being less risky would be positive. The benefits following these first nine are slightly less impactful, but the differences are small. Of the sensory aspects, bad taste and smell are clearly the factors with the largest negative expected impact on attitudes; bad texture or look are slightly less important but still powerful.

Figure 4a shows clear differences between the countries, with Finland showing stronger anticipated effects of almost all aspects. The differences are particularly noticeable for environmental friendliness and ethical aspects on the positive side, while texture and taste are prominent on the sensory side. Denmark and Norway score similarly to a large degree, even though Denmark scores slightly lower than Norway on the aspects having a positive impact.

Figure 4b shows that gender differences are fewer and smaller than country differences. Only six aspects show differences at all with enough statistical evidence. The biggest differences are for ethical benefits, environmentally friendliness, and if there were no GMOs in the process. For all three of these aspects, females score higher than men, indicating that females would develop more favorable attitudes because of these features than men.

Figure 4c shows that vegetarians/vegans would, across all variables, be less impacted by the 24 attributes than omnivores, with the exception of environmental friendliness, ethical aspects, price, risk, and availability, where vegetarians'/vegans' scores do not differ from the meat-eating majority. Interestingly, vegans/vegetarians would also be less affected by sensory attributes such as taste, texture, appearance, and smell.

The differences with respect to education are relatively small and only substantial enough to contrast the two extreme categories, basic education, and university/college degree (see **Figure 5a**). People with university/college degrees would be more affected by the environmental footprint, perceived ethical benefits, health effects, fewer additives and risks, more minerals and vitamins, but also practical aspects such as availability in shops, storability, and the effort required to prepare the food. On the sensory side, people with high education also anticipate being more influenced by smell and texture.

For income, the effects are also relatively small (see **Figure 5b**). Here the high-income group is different in terms of its assessment of health-related concerns (additives, food risks, fat content). Even smaller are the differences between consumers living in the capitals of their countries and people living in other regions (see **Figure 5c**). Consumers in capitals appear to place more value on the environmental footprint ethical aspects, but also less contamination and higher familiarity.

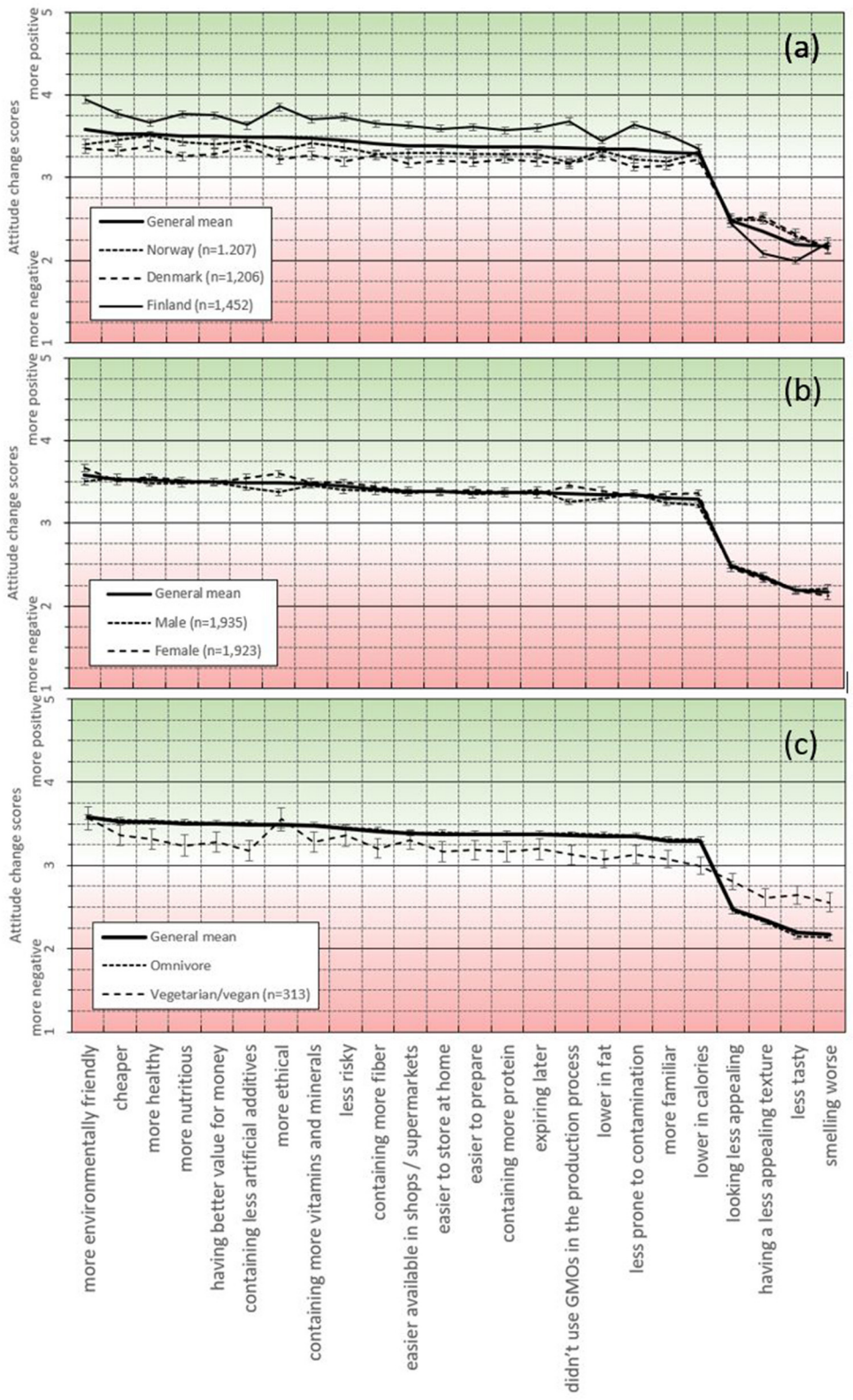

FIGURE 4 | Differences between countries **(a)**, gender **(b)**, and diet **(c)**. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

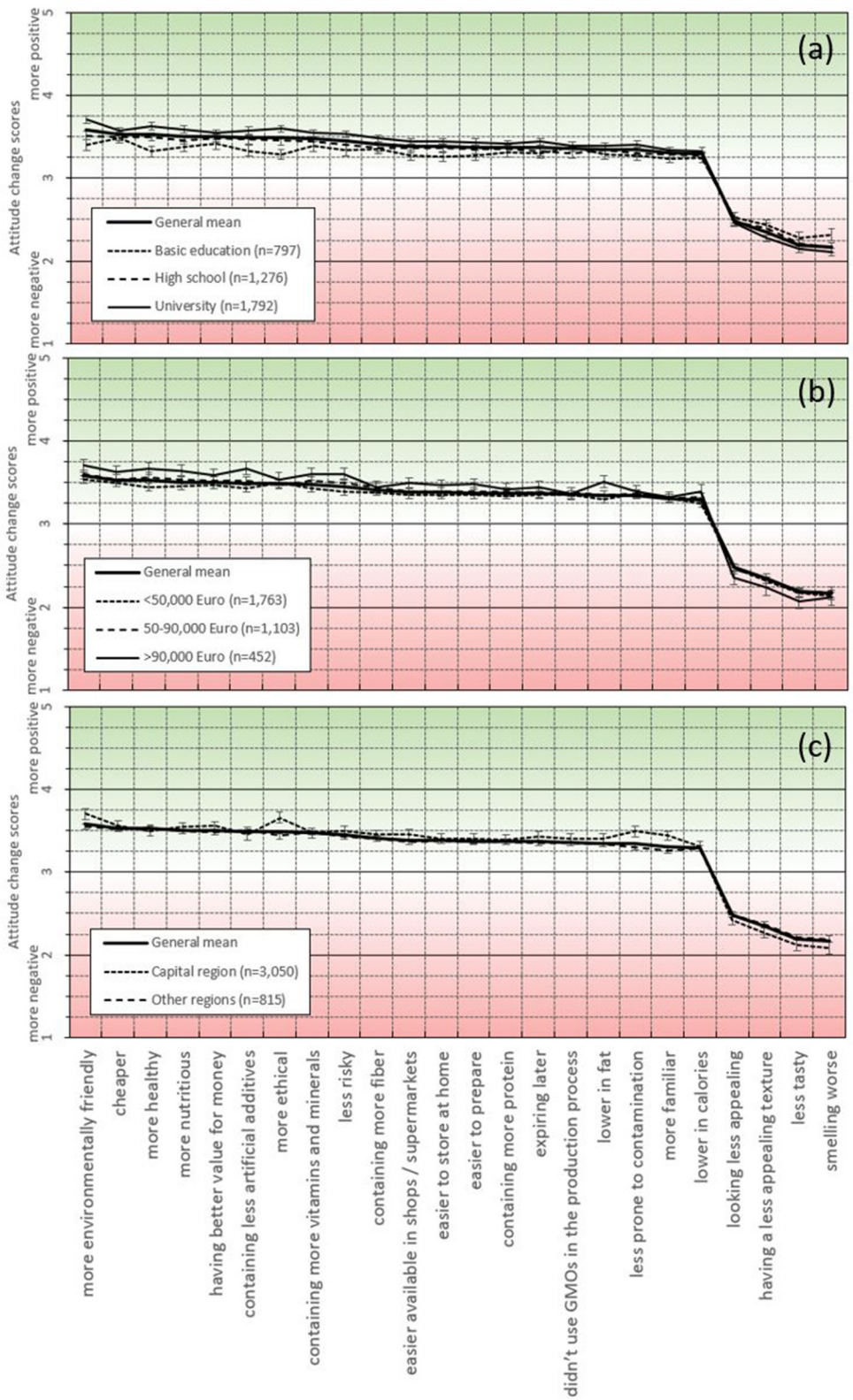

FIGURE 5 | Differences between education **(a)**, income **(b)**, and the capital vs. other regions **(c)**. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

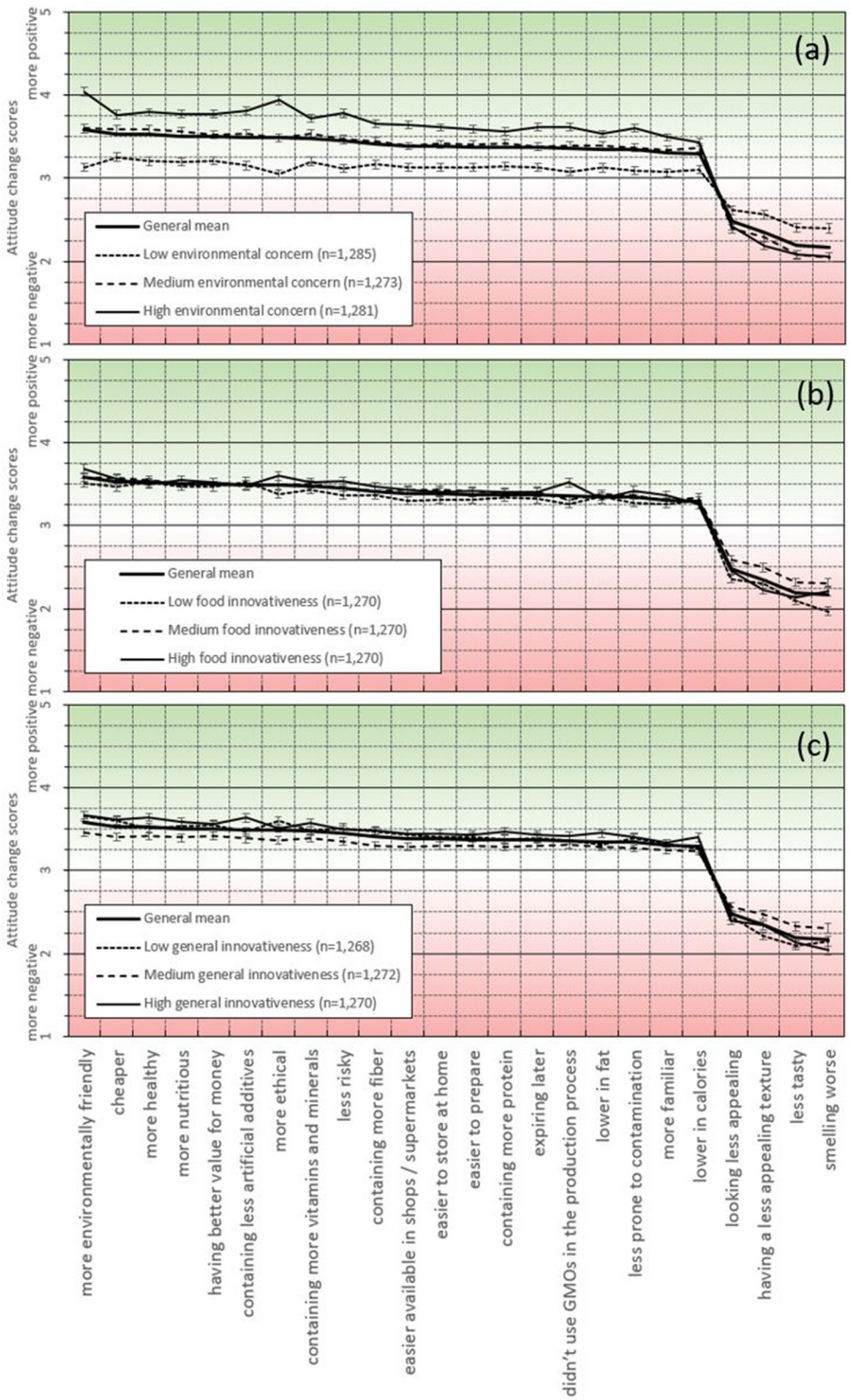

FIGURE 6 | Differences between NEP levels **(a)**, food innovativeness **(b)**, and general innovativeness **(c)**. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

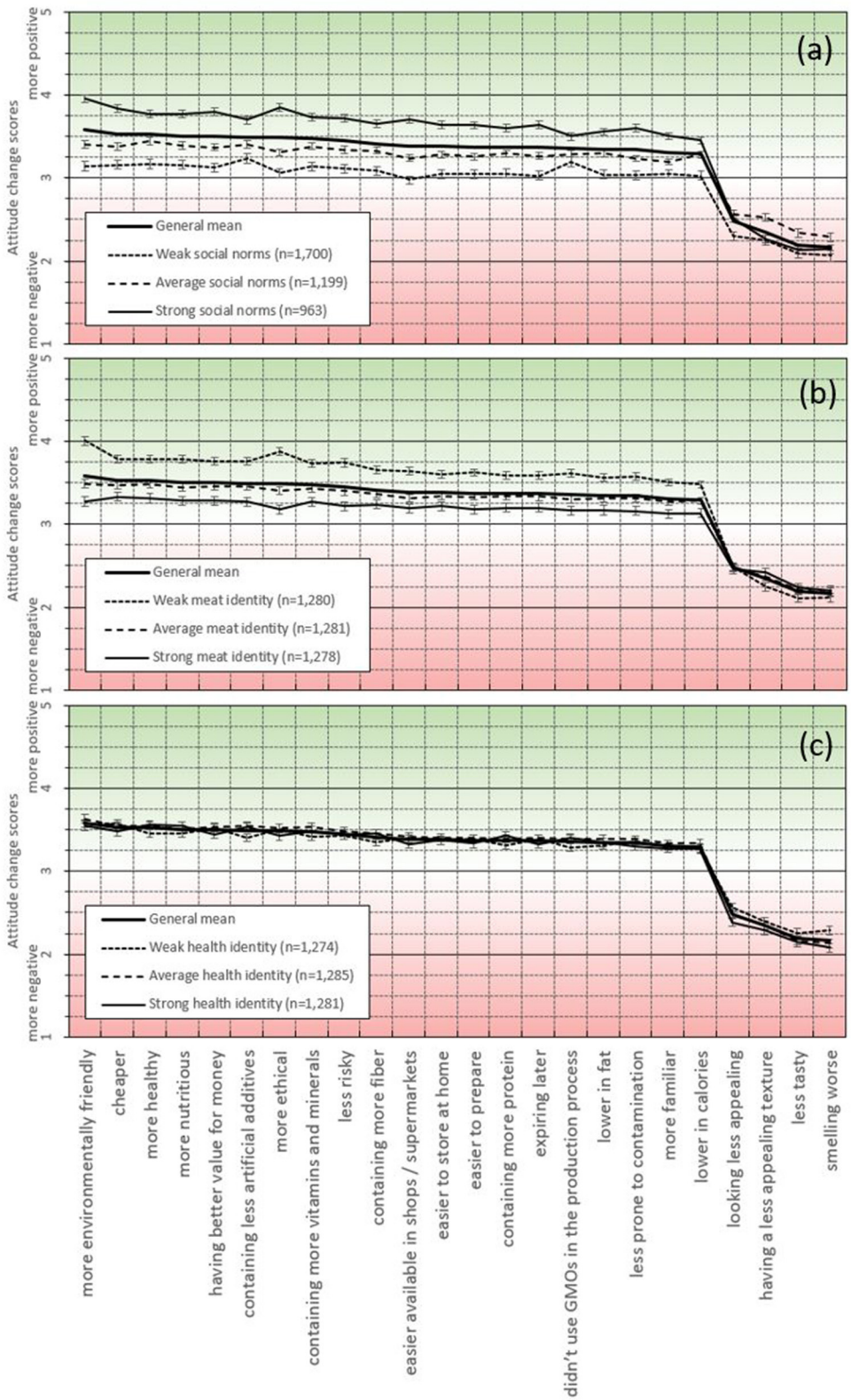

FIGURE 7 | Differences between social norm levels **(a)**, meat identity **(b)**, and health identity **(c)**. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

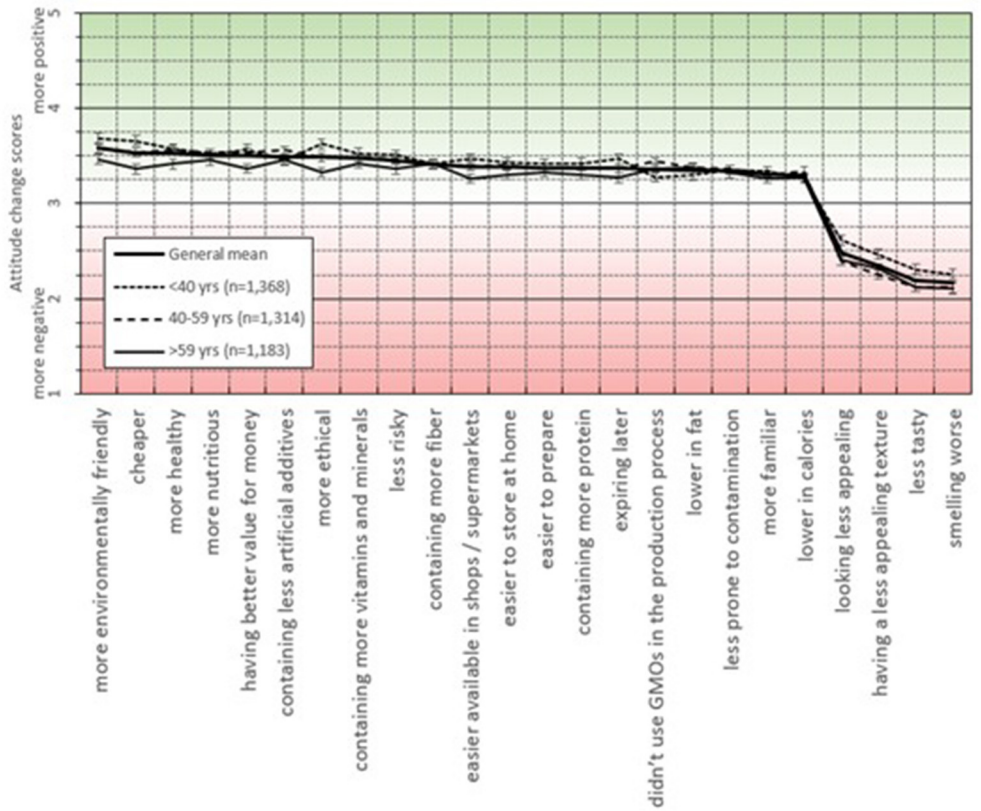

FIGURE 8 | Differences between age groups. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

Of the psychological measures, environmental concern measured with the NEP scale clearly correlates to the impact of the different measures. The higher the environmental concern, the stronger the impact of all aspects (see **Figure 6a**). This effect is especially strong for environmental and ethical considerations. For the sensory features, only the group with low environmental concern differs from the other groups.

The pattern is less clear for food innovativeness (see **Figure 6b**). For GMOs, ethical and environmental aspects, consumers highly open for food innovation react more positively than less innovative people. For the sensory aspects, it is rather the group with low innovativeness which contrasts with consumers with medium food-innovativeness. Respondents who either are very exploratory with food or not at all would react to bad taste, texture and appearance, whereas the ones that have average food innovativeness care less about these aspects. A similar pattern emerges for general innovativeness (see **Figure 6c**). The effects are again not strong, and the most extreme positions can again be found between the medium-level innovative consumers (with the scores closest to the middle of the scale) and the consumers with high innovativeness (often together with the people with low innovativeness).

For social norms, the differences are distinct (see **Figure 7a**). Consumers with anticipated strong social norms would react to changes in the tested features more than people with average and weak social norms. People with average social norms score higher than people with weak norms in almost every aspect. The differences are bigger for the non-sensory than the sensory aspects. A similar picture can be found for (non-)meat-eating identity (see **Figure 7b**). Consumers for whom (not) eating meat is a very important part of their identity score higher on all positive aspects than people with average identity strength, who again score higher than consumers with weak identity links to meat consumption. In the sensory aspects, the differences are almost absent. Health-related identity facets are almost irrelevant for the assessment of the features of cultured proteins (see **Figure 7c**).

Finally, age differences are relatively small (see **Figure 8**). However, between the two most extreme age groups, evidence for differences can be found for environmental and ethical aspects, price, health, and some practical aspects such as availability and expiration dates. For all of those, younger people react more strongly than older people. On the other hand, younger people are less sensitive to deviations in taste, smell, appearance, or texture.

DISCUSSION

Our study of anticipated consumer attitude change given specific features of cultured protein products like meat, fish, or dairy

was conducted in the context of an emerging research field. Within this field of cellular agriculture, we contribute with our study in two distinct aspects: (a) we provide data on consumer perceptions in three Nordic countries (Norway, Denmark, and Finland), and (b) we shift the perspective from looking at consumers' current attitudes toward anticipated changes in attitudes if the cultured product has different qualities to conventional meat, fish or dairy. Our results showed some interesting patterns.

Consumers' first impression of the technology is cautiously positive. The general attitude is neutral to slightly positive, and the willingness to taste is slightly above the neutral midpoint of the scale. We also find statistically relevant differences between the three studied countries, with Finland scoring more positively than Norway and Denmark. We interpret this as resulting from a higher familiarity of Finnish consumers with the technology due to recent media publicity. This finding that familiarity increases a positive attitude is in line with findings by Bryant et al. (2019). Males are more positive and more willing to taste or consume cultured proteins. The older the respondents are, the less positive and less willing to taste cultured protein they are, which corresponds to similar findings by Mancini and Antonioli (2019).

An interesting and novel finding is that vegetarians/vegans are substantially more positive about the technology but do not report a higher willingness to taste or eat cultured proteins than meat and fish eaters. From this, we can conclude that vegetarians/vegans perceive cultured protein as a promising technology to reduce the environmental or ethical footprint of meat that other people consume.

We can also draw conclusions concerning how to make cultured protein products more desirable to consumers from the analysis of the anticipated attitude change profiles. Inferior taste, smell, texture, or appearance of cultured meat, fish, or dairy as compared to conventional products would be unacceptable as it would substantially impair the development of positive attitudes toward cultured protein. Technology developers must therefore focus on improving the smell, appearance, taste, and texture and make it similar to conventional products. This will help to comply with the expectation of consumers because the consumers do not consider the product less sensorically rich but at the level with the farmed product. Many aspects are expected to have a positive impact on attitude development, such as lower environmental footprint, better price, better health-related qualities, better nutrition, better value for money, less artificial additives, more ethical production processes, and fewer food-related risks. Technology developers and product marketers should, therefore, also focus on these aspects.

However, there are differences between compared subgroups. In general, respondents in Finland were more extreme in their assessments, potentially reflecting a higher familiarity with the technology. Gender differences in the attitude profiles are minimal, but females would be more positive to products with a good environmental and ethical profile while being more opposed to the use of GMOs in production. Vegetarians/vegans show, in general, a less distinct attitude profile, as changing both the positive and sensory features of the product would make less of a difference for them, with the exception of the environmental and ethical features of the product. This might be an indication that, at least in part, this group is not considering consuming the cultured products themselves.

The effect of education is relatively small, which is in line with previous research (Mancini and Antonioli, 2019). However, in general, it appears that highly educated respondents will be more strongly influenced by the qualities of the product—-in particular, environmental, ethical, and health aspects. The high-income group similarly expects product qualities to strongly influence their attitudes, this time, particularly qualities related to health and the environment. There are minor differences related to the proximity of the respondents' residence to the capital. Comparing populations in capital city regions with other regions, we found that those in the capital region believed their attitudes would be more positive than those more distant from the capital if the cultured protein products were more environmentally friendly, more ethical, more familiar, and less prone to contamination.

Environmental concern (as measured by the NEP) had a strong influence on the attitude profiles, as respondents with great concern were substantially more responsive to both positive features such as environmental footprint and ethical aspects and sensory aspects. Food innovativeness, which is a reversed version of food neophobia (see Method section), has only a limited impact on some aspects, particularly environmental aspects, ethical aspects, and the absence of GMOs in the production process if the respondents had a higher level of innovativeness. The group most indifferent to the sensory aspects (taste, smell, texture, look) was the group with a medium level of food innovativeness. General consumer innovativeness also has only a limited influence, with the medium innovativeness group again more indifferent than the other two groups.

Substantial differences can be found for social norms. The more persons anticipate that people important to them would support their consumption of cultured protein and would consume it themselves, the more positively they believe they will react to improvements in the positive aspects. This is especially distinct for environmental and ethical aspects. For the sensory aspects, the differences between the groups are less distinct, and the average social norms group shows the greatest level of indifference. Having a strong identity connected to the consumption of meat (or avoiding the consumption of meat) makes the positive aspects of cultured protein less relevant. Consumers with weak meat-related identities expect to react more positively to improvements of all positive aspects, particularly environmental and ethical aspects. This can be interpreted as that people for whom eating meat is an important part of who they are will not respond as positively to cultured meat in general and, therefore, will also not respond to improvements in the positive dimensions. Differences in health identity are largely irrelevant for the attitude profile.

Finally, age leads to minor differences in the attitude profiles. Younger people expect more positive changes, especially for

ethical improvements, price, and availability. They would also respond less negatively to the negative aspects.

This study presented a number of aspects to consumers' attitudes regarding cultured foods and extended the knowledge in this quickly developing field. However, there are also some limitations that need to be acknowledged. Firstly, as it has been shown before that the name that is used on synthetic protein products is strongly impacting the respondents' attitudes to them (Bryant and Barnett, 2019; Bryant and Dillard, 2019), the results presented here are only valid for the naming that was chosen in the questionnaire ("synthetic/cultured meat, fish, and dairy products"). A different name might yield different results, which is why core parts of the survey should be repeated with a systematic variation of different names. A related potential limitation is that the survey was conducted in three languages, of which two are very similar (Danish and Norwegian), whereas the third belongs to a completely different language family. This might have caused different nuances in the questions, especially in the Finnish version, which might explain some of the differences between the countries.

Furthermore, the survey asked for meat, fish, and dairy combined, which makes the answers less specific to one type. This was consciously chosen because a specific version for each type of protein product would have extended the questionnaire substantially. However, this has the effect that potential differences in attitudes to meat, fish, and dairy products cannot be captured. The three product types also differ in their production methods, which again might potentially mask different attitudes to different types of technology. Follow-up studies that address these details specifically are necessary to complement this study. Finally, the large sample size gives the statistical analysis high levels of power to detect also small differences. Combined with the high number of exploratory comparisons conducted in this paper, the likelihood of detecting random differences increases. However, to counteract this danger, we decided to interpret only the differences with the strongest statistical evidence.

CONCLUSION

Our study shows that consumers in the Nordic countries are currently having a neutral to slightly positive attitude toward cultured protein products such as meat, fish, or dairy. The comparison of the countries indicates that a higher degree of familiarity might improve acceptance. Males and younger consumers are particularly positive; vegans and vegetarians evaluate the technology as positive and would try the products to the same degree as meat-eaters. The anticipated attitude change profiles show that meat-eating identity, social norms, environmental concern, and structural or cultural differences (as reflected in market differences and the cultural conditions of the countries compared) yield the clearest profile differences, whereas health identity, age, innovativeness, income, education, and gender have minor effects if any. People on vegan or vegetarian diets show less concern for most of the aspects of cultured proteins as compared to meat and fish eaters, with the exception of environmental and ethical aspects. Cultured protein products will likely enter the market as a rare, high-end product first, appealing to innovators. However, our results show that innovativeness is a rather unimportant feature of potential users, but strong social support and environmental concern at the same time characterizes the likely early users. Concerned, younger meat-eaters might be the likely target group. Appealing to them might be important for the industry in the phase of establishing cultured protein.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://doi.org/10.5281/zenodo.6326869.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CK was the main responsible for developing the survey and the study design, cleaning and analyzing the data, developing the idea for the paper, writing the first draft, and contributed to achieving funding for the research. LE contributed to the data curation and data analysis, commented on the first draft, and contributed to the final version of the manuscript. JM conducted the literature review, provided the first draft of the theory section of the manuscript, commented on the first draft, and contributed to writing the final version of the manuscript. JY contributed to achieving funding for the research. JY and UK commented on the questionnaire, the first draft, and contributed to the final version of the manuscript. TR contributed to designing the literature review, achieving funding for the research, commented on the first draft, and contributed to the final version of the manuscript. The final version of the manuscript was approved by all authors.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.847931/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.