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Public Perceptions of Alternative Protein Sources: Implications for Responsible Agrifood Transition Pathways

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Abstract: Our agrifood systems require transformation to meet today's challenges, especially the growing demand for protein. Promising alternative protein sources include algae, crickets and jellyfish, but little is known how the public perceives these future options. We argue that to identify responsible pathways for the protein transitions, the public's views need to be explored. Consequently, the aim of this study was to understand public perceptions of three alternative future pathways for protein transition. Our survey of 474 respondents in Germany showed that the consumption of algae in the future is perceived as possible and more probable than the consumption of animal-based sources of proteins such as cricket and jellyfish. Gender, age, geographical location and food habits were found to influence these perceptions. Reflecting on the differences in the public perceptions of three alternative protein sources, we discuss how inclusive these future visions are and how to manage the innovation and transition responsibly.

Keywords: agrifood transitions; alternative protein sources; responsible innovation; inclusion; public perception

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1. Introduction

Agrifood systems face major challenges such as climate change, population growth and the reduction in arable land [1–3], and transformation has become necessary [2]. In particular, the importance of alternative protein sources is increasing to meet the growing protein demand [4,5] and reduce the ecological, social and health impacts of intensive livestock farming [6].

In so-called protein transitions, alternative pathways towards more sustainable production and consumption of proteins are possible [7]. The future could entail a change to a predominantly vegetarian diet, organic meat, plant-based meat substitutes, cultivated meat or fish, or so-called low-carbon proteins such as algae, insects or jellyfish [3,7–11]. In the wake of varied transition pathways, it remains unclear if and how the protein transitions will contribute towards the sustainable development goals of 'zero hunger', 'good health and well-being', 'clean water' and 'responsible consumption and production', among others.

To address such concerns, Klerkx and Rose [12] argue that transition pathways should be organized responsibly by (1) articulating inclusive visions of the future, (2) reflecting on different innovations and (3) anticipating their impacts, as well as (4) changing the direction of innovation in a responsive way. Although their arguments are focused on transitions to Agriculture 4.0, they apply also to more narrowly scoped protein transitions. In line with Klerkx and Rose [12], we argue that to enable a responsible protein transition, it is necessary for various stakeholders to reflect and articulate their visions of the future so that inclusive visions can be identified and responsible innovation can be fostered to realize them (cf. 'responsible innovation' by Stilgoe et al. [13]). Foresight and future studies examine the perceptions of the future but typically focus on expert views. To articulate inclusive future visions, it is, however, important that those with marginal engagement in the development of innovation, namely, future consumers, can also express what futures they can imagine for themselves and for society at large [9]. However, future studies which reveal the lay public's views on the future of proteins are scarce. Consequently, our aim is to investigate how the future visions of consuming alternative proteins are seen by the public and to contribute to identifying responsible pathways for protein transitions.

In order to enhance the prospects of responsible protein transitions, this paper aims to contribute to articulating the inclusive visions of the future of protein by addressing the questions of what protein sources people imagine as possible for their own future diets and what futures they see as probable for society at large. To answer these questions, we investigated the public perceptions of the possibility (how possible a certain future is considered to be for oneself) and probability (how likely a certain future is considered to be for society) of the future consumption of algae, crickets and jellyfish under non-specific future scenarios as well as in extreme scenarios in an online survey (n = 474) in Germany. The approach allowed us to gain insights into the societal attitudes accompanying the agrifood system transformation, which we use to discuss how inclusive the future vision of each transition pathway is and to recommend responsible approaches to innovations enabling protein transitions, which take the public views into account. We thus elaborate the importance of the inclusiveness-sensitive approach for a responsible agrifood system transformation process.

The remaining of the paper is organized into five sections. The next section discusses foresight and future studies focused on the selected alternative proteins and identifies the research gaps. Section Three outlines the methodology. Section Four reports the results, which are then discussed in Section Five.

2. Future Visions of Alternative Protein

Foresight and future studies differentiate between possible, probable and desirable futures [14–16]. By analyzing possible and probable futures, (1) important developments and structures are explored from the perspective of the present and (2) participation in shaping the future is enabled [16]. The evaluation of possible futures is performed before evaluating the probable and desirable futures [14]. Previous foresight and future studies in the food context have mainly involved experts to assess different futures [17–21]. However, to promote responsible transition pathways, public views on the future also need to be examined.

In the following we discuss past foresight and future studies examining the future visions of alternative protein sources, namely, algae, crickets and jellyfish, with the focus on possibility and probability. Consumer acceptance studies that examine the extent to which alternative proteins are accepted at present are not discussed (e.g., [22–32]).

2.1. Algae

Algae are gaining increasing attention as an alternative protein source [4,33]. In the following, as well as in our survey, we refer to the term 'algae' whereby no distinction is made between macro- and microalgae and their subspecies, although their metabolic profiles are different [34]. However, a distinction between the two was not considered for two reasons: (1) both macro- and microalgae are recognized as good alternative protein sources [35] and (2) the lay public does not distinguish between macro- and microalgae [36]. However, both are rich in proteins, lipids, carbohydrates, fatty acids, minerals, carotenoids and chlorophylls [37–39], and their cultivation is more sustainable compared to meat proteins (chicken, pork or beef) [3,36]. Several food products that contain microalgae already exist on the market (e.g., oat and rice cakes, juices, smoothies, noodles). They are consumed mostly in the regions of Asia and North America, but interest in European markets is increasing [35,37]. For example, 5720 algae-containing products (80.2% are food) were imported into the European market in the period 2015–2019. This represents 43.7% of their worldwide import [40]. Furthermore, in Germany, microalgae food and feed products (e.g., astaxanthin as food ingredient/additive, Spirulina and Chlorella as dietary supplements), as well as producers (e.g., Blue Biotech, Roquette Kloetze), can be found (for an overview see Enzing et al. [41]).

Further studies examined the possibility of algae (or plant-based proteins) as an alternative source of protein. A recent large-scale Delphi survey with 85 participants in Germany (47% knew nothing about microalgae, 41% knew the topic from the media, 15% had already consumed microalgae) looked at public perception and possible narratives for microalgae (assessing expectability, desirability and popularity). The most popular and desirable narrative was that of a sustainable diet, but at the same time it was seen as difficult to implement. According to the authors, the controversial result (prominent and desirable and at the same time not feasible) might be related to the dilemma of who microalgae should appeal to: the broad public or selected groups [42]. The expected inclusiveness of algae consumption was, however, not examined. Additionally, algae [43] and plant-based proteins [18] were envisaged as possible future scenarios for future food in Norway.

Some studies already examined how the future of algae is perceived. They showed that experts assumed algae to play an increasingly important role in sustainable nutrition in the future [19,20,41]. However, the estimates of the probability of algae becoming relevant for the food sector vary. Already in 1976, a Delphi study stated that the development of new food sources such as algae might occur on a large scale in the 1990s [44]. In 2014, Enzing et al. [41] showed that one-third of experts assumed that microalgae will replace existing food and feed products in Europe in 2020–2022. A total of 14% of the experts predicted that this is likely to happen after 2025. A horizon scanning study from 2023 envisaged algae production for food and feed in Europe for 2030 [20]. While some of the past predictions were not accurate, they show that the importance of algae as alternative protein sources had been recognized years before.

While the studies discussed above bring useful insights into the future visions of algae proteins, it is still unclear how inclusive these visions are. First, the lack of consensus among the experts in some of the aforementioned studies indicates that the perceptions of the future of algae are not unanimous. Second, past studies uncovered the visions of experts but not those of lay citizens. An exception is the Delphi study with the general public in Germany by Rossmann and Roesch [42]. The study captured expectations of microalgae diets and focused in particular on normative projections of microalgae production and consumption (e.g., (1) inexpensive and unpretentious, (2) health and wellness, (3) do it yourself and (4) feed and save the world). However, in the case of Germany, the questions remain: How possible and likely does the general public in Germany perceive the consumption of algae to be? Who shares this vision of the transition pathway and who does not?

2.2. Crickets

Interest in crickets as one of the most promising insect species is increasing [45,46]. Crickets, along with grasshoppers and locusts, account for 13% of the insect species consumed worldwide, making them one of the most commonly eaten insect species [47]. Crickets show a valuable nutritional profile compared to other food sources, especially in terms of protein, but also energy, fats and fatty acids [45,48,49]. They are farmed with lower greenhouse gas emissions compared to chicken, pork or beef [10]. The species mainly farmed for human food products is the house cricket (*Acheta domesticus*) [50]. Food products such as protein bars, flour and cookies are already on the Western market [51]. In 49 countries worldwide crickets are already consumed, but this includes only four European countries (Belgium, Netherlands, Poland, Switzerland) [45]. Thirty-five companies in Europe are known to sell crickets, including seven to nine in Germany [52].

Additional foresight research explores the possibility of crickets as an alternative protein source. For example, in 2020, the majority of Canadian consumers were reported to appreciate insects as a source of protein, but consider their consumption undesirable [22]. After eating cricket protein powder, they were willing to buy cricket powder and recommend it to others. A future where entomophagy becomes prevalent is considered as possible but numerous obstacles must be overcome [17]. These findings validate the perception that insects are one of the most controversial alternative proteins [5].

The expected probability of crickets becoming particularly important in the food industry is dated as 2030 in Europe, according to market forecasts from 2021 and 2022 [53,54]. It is also anticipated that the number of European consumers eating insects will increase from nine million in 2019 to 390 million in 2030 [53].

Even though there is a rising interest in crickets, or insects in general, as an alternative source of protein—especially due to the recent approval of three insect species under the EU novel foods regulation, including crickets [55]—whether they are considered as possible futures by the broader public in many countries, including Germany, remains uncertain. Consequently, it is unclear how inclusive the vision of eating crickets is.

2.3. Jellyfish

Jellyfish are considered as a novel food, especially promising when resources become scarce due to climatic changes [11,56]. Even if jellyfish consist of 95% of water, they are also 4–5% of protein, which makes them rich in proteins and minerals and low in calories and fats [57]. Their production is expected to have a low CO_2 impact [11,58]. The consumption of jellyfish (e.g., in salads, fried or boiled) is widespread in Asian countries, especially in China [57,59–61], but the interest in Western countries is increasing [62,63]. Already in 1994, Hsieh and Rudloe [64] stated that jellyfish fisheries for food production have great potential in the USA. However, the consumption of jellyfish is not yet permitted in the EU [65] and the data on jellyfish consumption in Europe and in Germany are very limited [61,64].

Foresight studies on the public perceptions of consuming food containing jellyfish in the future are lacking. However, a tasting study with volunteers allergic to seafood found that 91% of the participants were willing to include jellyfish (*Catostylus tagi*) in their regular diet. One of the greatest benefits reported was that they did not cause the same allergic reactions as other seafood [60].

Jellyfish are a potential alternative protein source, which still needs deeper investigation [56]. In particular, the perceptions of the general public need to be further investigated to facilitate an inclusive protein transition.

2.4. Comparison of Algae, Crickets and Jellyfish

To the best of the authors' knowledge, there is one study in which the three alternative protein sources of interest were examined jointly. Palmieri et al. [61] investigated the current levels of consumer acceptance of algae, insects and jellyfish in Italy and showed that the willingness to try new foods and include them in the regular diet was highest for seaweed (macroalgae), followed by jellyfish and insects. Gender, age and dietary habits were shown to be the most important factors differentiating the consumers' attitudes towards the alternative proteins. Men were more willing to try insects and jellyfish than women (similar to the findings of Torri et al. [56]). Furthermore, the willingness to consume alternative protein sources decreased with increasing age (similar to the findings of Onwezen et al. [66]).

However, it is conceivable that although consumers are not ready to accept jellyfish and insects into their diets just yet, most see them as possible or even probable and desirable futures. If so, these protein sources would have the potential to contribute to inclusive transitions, albeit in the longer term. To our knowledge, future-oriented studies of the public perceptions of the three alternative protein sources are missing. The past studies mainly focused on the expert perspective, with a few exceptions [42], as discussed above. However, multi-perspectives and broad participation are important to capture current perceptions of possible and likely futures, but not with the aim of predicting futures as accurately as possible [67]. We therefore find it essential to assess the perceived possibility and probability of the three protein sources among the potential future consumers. Accordingly, our study investigates the perceptions of the future of protein sources by applying research approaches of future studies (surveying perceived possibility and probability) and aiming at broad participation of the lay public.

3. Materials and Methods

The online survey within the research project food4future, funded as part of the German Federal Ministry of Education and Research's funding line Agricultural Systems of the Future, was conducted from 16 November 2020 to 22 May 2021. The survey was distributed across various channels (social networks such as Facebook, the project website, media reports and press releases) in order to reach a broad spectrum of German consumers. Please note that only the aspects relevant to the study are described here.

The comparison of algae, crickets and jellyfish as promising alternative protein sources offers heterogeneity on different levels: On the one hand, we look at algae-based and animal-based (crickets, jellyfish) alternative proteins. On the other hand, we examine already established alternative proteins (algae, e.g., in the form of sushi), emerging alternative proteins (crickets) and rather unknown alternative proteins (jellyfish).

3.1. Alternative Protein Sources

The participants were asked to assess the extent to which they perceive eating algae, crickets and jellyfish as possible and probable.

Possible futures. Respondents were asked "Can you imagine algae/crickets/jellyfish as part of your future diet (raw or, for example, processed in a ready meal?" and were given a four-point scale (from 'thumbs down' to 'thumbs up').

Probable futures. The item "Do you think it is likely that algae/crickets/jellyfish will become part of the normal diet in the future?" was used to measure perceived probability, using a four-point scale (from 'thumbs down' to 'thumbs up').

Extreme future scenarios. Each participant was presented with two extreme future scenarios at the beginning of the survey before responding to the questions. The scenarios were developed within the research project: (1) 'No trade' scenario in which international food trade is disrupted and (2) 'No land' scenario, in which the land scarcity does not allow for food cultivation. Participants were asked on the same page what they considered possible and probable under normal and extreme scenarios. The item "Imagine that the extreme scenarios described at the beginning become reality. Do you think it is likely that algae/crickets/jellyfish will become part of the normal diet under these scenarios?" was used to measure perceived probability under extreme future scenarios, using a four-point scale (from 'thumbs down' to 'thumbs up').

3.2. Personal Characteristics

To better understand who shares the future visions of selected alternative proteins, we collected data on five personal characteristics. These variables were selected as some consumer acceptance studies show that they differentiate between people with different attitudes towards alternative proteins in the presence. For example, we investigated age and *gender*, as willingness to consume insect-based products was shown to be lower among older people [31,32] and women [27–30]. Seaweed-based products are more accepted among women [26] and those with higher *levels of education* and *living* in more urban environments [25]. Similarly, food habits (e.g., vegan, vegetarian, flexitarian, omnivore) are associated with different attitudes towards alternative proteins, while adventurous *eating habits*, exemplified by seeking food sensation and innovation, were found to positively affect the willingness to consume insects (effect size $r = 0.29$, meta-analysis) [24]. However, there is still no clarity on how these personal characteristics refer to the perceptions of algae, crickets and jellyfish. Some studies found no significant effects of gender [22], age [31] and education [23,27,31], and comparative studies are missing, highlighting the need for further research. The items used to measure each variable are presented in Table S1 in Supplementary Materials.

3.3. Procedure

The first page of the online survey provided general information about the food4future project including a link to the project website. On the second page, a video introducing the two extreme future scenarios was presented to each participant, emphasizing that the scenarios are unlikely, but that the goal is to prepare for different futures by exploring food and technology innovations. Following the video, participants confirmed their agreement to the data privacy policy to proceed the survey. Participants were then asked about their personal characteristics. Next, each protein alternative was presented, followed by questions about its perceived possibility and probability under non-specific and extreme future scenarios on the same survey page.

3.4. Data Analysis

Descriptive statistics were calculated to assess the extent to which alternative protein sources were seen as possible and probable. The non-parametric Friedman tests were used to compare if consumption of the three alternative protein sources in the future was seen as equally possible and probable (under non-specific and extreme scenarios) because the variables did not exhibit a normal distribution, as assessed through visual inspection and the Shapiro–Wilk test ($p < 0.05$). If applicable, post-hoc analysis with Wilcoxon rank-sum tests were performed with a Bonferroni correction applied.

To shed light on social groups which share (or do not share) the future visions of alternative protein consumption, we tested if perceptions of possible futures vary across socio-demographic groups. The data did not fit the requirements for a one-way ANOVA; therefore, Kruskal–Wallis tests were conducted as a non-parametric alternative for each alternative protein. For dichotomous variables Welch's t-test was used. If applicable, post-hoc Conover tests with Bonferroni correction were performed. Furthermore, Wilcoxon effect sizes (r) were computed to assess the magnitude of the differences.

4. Results

4.1. Participants

In total, the sample counted 682 participants, whereby 474 participants were considered for this study. Data were excluded if, for example, only questions on personal characteristics were filled in, comments indicated that the answers were not serious or the response time was too short.

The sample is described in Table 1. Of the respondents, 56.1% were below 40 years old, 66.5% identified as female, 31.9% as male and 1.5% as diverse. The majority of the participants lived in cities (big city: 57.6% and city: 15.0%). Compared to the German population, the sample was not representative as it contained an overrepresentation of younger people, people who identify with the female gender and people with a higher level of education [68]. Additionally, the respondents lived disproportionately in larger cities [69].

Table 1. Personal characteristics of participants.

Personal Characteristic	N	%	German Population [1]
Age			
20–39	266	56.1	30.0
40–59	162	34.2	34.2
≥60	46	9.7	35.8
Gender			
female	315	66.5	50.7
male	151	31.9	49.3
diverse	7	1.5	-

Table 1. *Cont.*

Personal Characteristic	N	%	German Population [1]
Education			
low level	12	2.5	22.3
intermediate level	78	16.5	50.4
high level	384	81.0	27.1
Location			
small place	57	12.0	-
town	73	15.4	-
city	71	15.0	-
big city	273	57.6	-
Food habits			
traditional	85	17.9	-
adventurous	389	82.1	-

[1] Census data based on the Database of the Federal Statistical Office of Germany (Table 12411-0041 and Table 12211-0102) [68,69]. Please note, the percentages refer to our target population (people living in Germany in the age range from 20 to ≥60 years).

4.2. Possible and Probable Futures for Alternative Protein Sources

The overall pattern was that the possibility and probability of eating algae in the future were perceived most positively, followed by crickets and jellyfish, as shown in Figure 1 (see also descriptive statistics (Table S2) and Spearman's correlations (Table S3) of study variables in the Supplementary Materials). The Friedman test revealed a significant effect of the alternative protein source for the perceptions of possible futures ($\chi^2(2) = 411.65$, $p < 0.001$) and probable futures ($\chi^2(2) = 386.45$, $p < 0.001$).

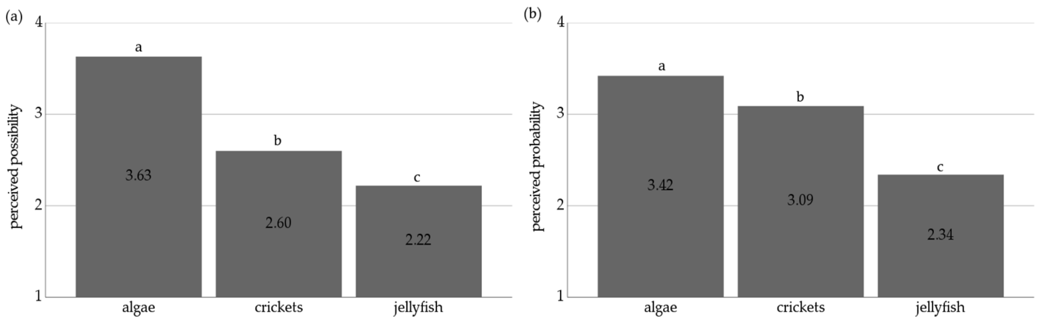

Figure 1. (**a**) Comparison of alternative protein sources as possible futures (algae, crickets, jellyfish). Means are displayed. Different letters indicate a significant difference between the means (Wilcoxon rank-sum test with Bonferroni correction, $p < 0.001$). (**b**) Comparison of alternative protein sources as probable futures (algae, crickets, jellyfish). Means are displayed. Different letters indicate a significant difference between the means (Wilcoxon rank-sum test with Bonferroni correction, $p < 0.001$).

Pairwise comparisons indicated significant differences for both variables between all factor pairs ($p < 0.001$). For the possible futures, two comparisons showed a large effect size (algae–crickets: $r = 0.63$, algae–jellyfish: $r = 0.80$) and one comparison showed a moderate effect size (crickets–jellyfish: $r = 0.32$). For the probable futures, two effect sizes were large (algae–jellyfish: $r = 0.78$; crickets–jellyfish: $r = 0.63$) and the comparison of algae and crickets had a moderate effect size (algae–crickets: $r = 0.33$).

Furthermore, crickets and jellyfish were perceived by respondents as significantly more probable alternative protein sources for the society at large than as possible for their own future diets ($p < 0.01$). In contrast, the possibility of consuming algae oneself was perceived significantly higher than the probability that it will become part of the normal diet ($p < 0.001$). The effect size was small for jellyfish ($r = 0.15$) and moderate for crickets ($r = 0.42$) and algae ($r = 0.30$).

4.3. Probable Futures for Alternative Protein Sources under Non-Specific and Extreme Scenarios

When asked to imagine that an extreme future scenario of 'no land' or 'no trade' comes true, participants assessed the probability of the future consumption of algae most positively, followed by crickets and jellyfish, as shown in Figure 2. A Friedman test revealed a significant difference in perceived probability between the alternative protein sources in the presence of an extreme scenario ($\chi^2(2) = 283.47$, $p < 0.001$). Pairwise comparisons indicated significant differences between all factor pairs ($p < 0.001$). The comparisons between algae and jellyfish ($r = 0.70$), as well as crickets and jellyfish ($r = 0.56$), showed a large effect size and the comparison between algae and crickets showed a small one ($r = 0.18$).

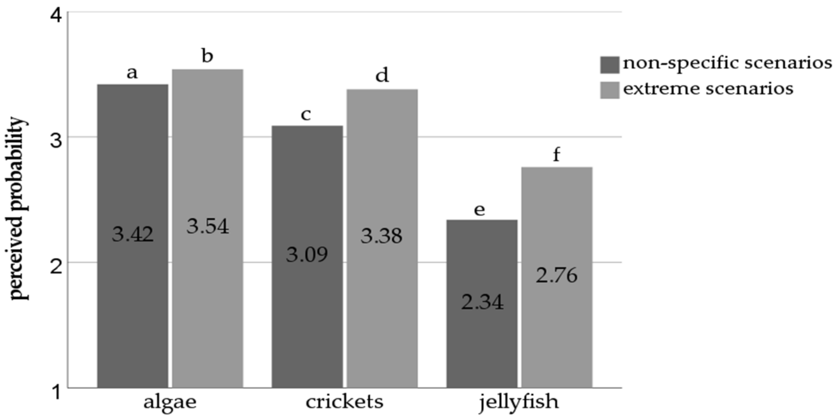

Figure 2. Comparison of alternative protein sources as probable futures (algae, crickets, jellyfish) under non-specific and extreme scenarios. Means are displayed. Different letters indicate a significant difference between the means (Wilcoxon rank-sum test with Bonferroni correction, $p < 0.001$).

Comparing the perceived probability under non-specific scenarios versus the perceived probability under extreme scenarios, the consumption of each alternative protein source was perceived as significantly more probable in the presence of the extreme future scenario, as can also be seen in Figure 2. The comparison between perceived probability under non-specific and extreme scenarios for algae showed a small effect size ($r = 0.17$), while for crickets ($r = 0.41$) and jellyfish ($r = 0.48$) the effect sizes were moderate.

4.4. Possible Futures and Personal Characteristics

To better understand how inclusive the future vision of consuming each alternative protein is, we examined if the extent to which people see it as possible to include each alternative protein source in their diet varied across social groups. Please note that Spearman's correlations of the personal characteristics variables can be found in Table S4 in the Supplementary Materials. Some significant but relatively small correlations (all < 0.20) were observed between various personal characteristics within our sample. Older participants tended to be more frequently male, generally possessed a lower level of education, lived in smaller locations, and exhibited more traditional food habits. Additionally, participants residing in bigger locations were more likely to be male and had a higher level of education.

Age. Only the test for jellyfish was significant ($\chi^2(2) = 18.98$, $p < 0.001$). The post-hoc Conover test revealed a significant difference between the age groups 20–39 and $\geq$60 years (small effect $r = 0.22$) and 20–39 and 40–59 years (small effect $r = 0.13$). In both cases, the older group had a more positive perception of eating jellyfish compared to the younger group.

Gender. For the analysis regarding gender differences, only participants were included who identified themselves as female or male ($n = 467$) because only seven participants identified themselves as diverse and thus formed a group too small for any robust statistical comparisons. None of the variables were normally distributed, but given the sample size, a standard t-test was thought to be suitable [69,70]. Thus, a Welch's t-test was conducted for each alternative hypothesis discussed in Section 3. As expected, male participants saw the possibility of eating crickets in the future more positively (M = 2.84) than female participants (M = 2.49, $t(271.77) = 2.95$, $p < 0.01$). This was only a small effect (Cohen's d = 0.30, 95% CI [0.11 0.50]). Moreover, the possible future consumption of jellyfish was seen more positively by men (M = 2.46) than women (M = 2.11, $t(288.19) = 3.33$, $p < 0.001$), but with only a small effect size (Cohen's d = 0.33, 95% CI [0.14 0.53]). The perceptions of algae did not differ significantly by gender.

Education. None of the Kruskal–Wallis tests were significant.

Location. Only the Kruskal–Wallis tests for algae revealed a significant effect of location ($\chi^2(3) = 11.97$, $p < 0.01$). A post-hoc Conover test showed that participants from a big city perceived the possibility of eating algae more positively compared to people from a smaller place (small effect r = 0.16).

Food habits. In order to examine the importance of food habits, the sample was split into two groups, one containing participants with traditional or rather traditional food habits (n = 85) and the other with adventurous or rather adventurous food habits (n = 389). The Welch's t-test was calculated for each alternative protein source. Interestingly, only algae showed a significant difference between the two groups, where the more adventurous group (M = 3.70) saw the possibility of eating algae more positively than the group with more traditional food habits (M = 3.34, $t(102.61) = -3.39$, $p < 0.01$). The effect size was medium (Cohen's d = 0.51, 95% CI [0.27 0.75]).

5. Discussion

Transforming the agrifood system is an urgent global challenge that requires a responsible approach, taking into account the public's views on future protein consumption [12]. To contribute to identifying responsible pathways for protein transitions, the present study examined the public perceptions of three alternative protein sources—algae, crickets and jellyfish. In this discussion, we reflect on how inclusive each vision of future protein consumption is and their implications for responsible innovation and transformation of the agrifood system. Specifically, for each transition pathway we reflect if it should be developed and, if so, how to proceed responsibly.

Our study found that the future consumption of algae-based proteins is seen by respondents as possible, and more probable than the consumption of animal-based protein from sources such as crickets and jellyfish. The pattern differed slightly from that found in Italy, where current consumer acceptance is highest for seaweed, followed by jellyfish and insects [61]. The probability that crickets and jellyfish become part of normal diets is seen more positively than the possibility of eating them oneself. The opposite is observed for algae, which is in line with past studies showing that the general public in Germany [42] and experts in Denmark [19] consider algae as possible but not feasible for the future. When extreme future scenarios are assumed, the consumption of all protein sources is perceived as significantly more feasible for all three protein sources and the comparative pattern stayed the same.

The future consumption of algae was seen as possible and probable by most respondents, suggesting that this vision of the future is fairly inclusive. However, concerns exist with regard to the possible exclusion of those living outside large cities and having less adventurous eating habits, which were already raised by [25] and [17], respectively. Overall, it is advisable to further develop this transition pathway and to make it more inclusive. To prevent exclusions, it is advisable to develop targeted education and communication strategies to inform the public about the diverse range of algae protein options [70] and to ensure accessibility outside urban areas.

The possibility and probability of consuming crickets in the future are seen on average as mildly positive, which suggests that this future vision for proteins is moderately inclusive at present. In line with past findings [27–30], male respondents assessed this possibility as greater than females, which implies that women could be excluded from consumption. It is therefore important to ask if this pathway should be further developed and, if so, how could it be carried out in a responsible and inclusive way? Further research is needed to better understand the rejection of cricket-containing products by women and take evidence-based responsive actions.

The public views on the consumption of jellyfish in the future were visibly split and on average less positive than for the other two alternative protein sources. Older and male respondents perceived the possibility of eating jellyfish in the future more positively than their counterparts. These results suggest that the visions of future jellyfish consumption are not inclusive at present. In this context, it would be responsible to explore the benefits and risks of further development before investing in advancing this pathway further.

5.1. Limitations and Future Research

The design of our study and the sample have affected the results in the following ways: First, the presentation of 'extreme scenarios' at the beginning of the survey biased the responses and could have induced more positive perceptions of novel foods (cf. 'adaptation' by Gifford et al. [71]). Second, the perceptions of alternative proteins among respondents in our sample, in which young and highly educated people were overrepresented, may have been more positive than in the general population in Germany as these groups are environmentally conscious [72]. A similar effect could have had the high proportion of people with adventurous eating habits in our sample. Future studies based on representative samples are still needed. Third, the personal characteristics variables showed significant correlations, particularly for age (see Table S4 in Supplementary Materials). These correlations were relatively small but it is important to note that due to the highly skewed distribution across the groups of personal characteristics, it is likely that we did not have sufficient statistical power to fully elucidate the true nature of these intercorrelations within the target population. Thus, the magnitude of the effects related to personal characteristics might be mitigated by intercorrelations between the personal characteristics themselves. Fourth, as this study wanted to enable broad participation of the lay public and not experts, no questions were asked about prior relevant expertise. However, prior knowledge of alternative proteins may affect the responses [24,73] and, therefore, this variable should be included in future surveys. Fifth, this study did not distinguish between macro- and microalgae (in line with Mellor et al. [36]), which undermines the robustness of our results given the significant differences between these species [34]. Consequently, there is a need for future studies that examine each type separately.

5.2. Conclusions

In summary, the present study gives three substantial key contributions: (1) the first indications of the public opinion in Germany on the vision of consuming algae, crickets and jellyfish in the future; (2) a reflection on how inclusive each vision is and a discussion about if and how the transition pathways should be further developed; and (3) recommendations for action were derived on how to innovate responsibly to facilitate responsible protein transitions.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16020566/s1, Table S1: Personal characteristics variables; Table S2: Descriptive statistics of study variables; Table S3: Spearman's correlations of study variables; Table S4: Spearman's correlations of personal characteristics variables.

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