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Risks, resilience and sustainability of plant-based protein chains in Europe: a stakeholder analysis

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Abstract

Purpose – As the global demand for alternative protein sources grows, understanding the perceptions of key stakeholders in the agri-food chain is critical to fostering sustainable and resilient food systems. This study investigates stakeholders' views on risk, resilience and sustainability within plant-based protein chains. It aims to cluster stakeholders based on these perceptions and identify the factors that influence cluster membership. **Design/methodology/approach** – A survey was conducted with participants including consumers, farmers, food industry professionals and policymakers across several European countries (n 5 482). Hierarchical and non-hierarchical cluster analyses were used to group stakeholders, while logistic regression identified factors influencing cluster membership. **Findings** – Stakeholders were segmented into two groups: optimistic advocates, who have a positive outlook on alternative protein chains, and cautious conventionalists, who remain sceptical. The analysis reveals that factors like familiarity with plant-based proteins, attitudinal certainty and stakeholder type significantly influence stakeholder perceptions. Respondents who are familiar with alternative proteins and respondents with higher attitudinal certainty are more likely to belong to the optimistic advocates cluster, while farmers are more likely to belong to the cautious conventionalists cluster compared to other stakeholders. **Originality/value** – This study is the first to evaluate and compare the risk, resilience and sustainability perceptions of multiple stakeholder categories towards plant-based protein chains. Additionally, this is the first study exploring resilience perceptions in an agri-food context, further contributing to the novelty.

Keywords: Stakeholder perceptions, Plant-based protein chain, Sustainability, Resilience, Risks, Europe

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1. Introduction

With increasing annual incomes, the worldwide meat consumption started to increase, while plant-based protein consumption decreased, resulting in negative effects on public health and the environment(Tilman andClark, 2014). This fact underscores the urgency for a dietary shift towards alternative protein sources, such as plant-based, algae, insects, cultured proteins and fungi (Aiking and de Boer, 2020). The alternative protein market is projected to reach $290 billion by 2035, with plant-based proteins valued at $44 billion in 2022 (Morach et al., 2021; Statista, 2024; Wood and Tavan, 2022). Globally, around 1,500 companies are producing plant-based alternatives, with around 500 companies located in Europe (GFI, n.d.). According to the Good Food Institute (GFI) Europe, the sales value of processed alternatives to animal derived products in 2022 reached 5.8 billion euro across 13 European countries, including Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Poland, Portugal, Romania, Spain, Sweden and the United Kingdom (GFI Europe, 2022). Within this market, plant-based dairy and meat substitutes represent the largest segments, with market values of 2.2 billion and 2.0 billion euro, respectively (GFI Europe, 2022). Notably, Germany leads in sales, with a total market value of 1.9 billion euro (GFI Europe, 2022). Despite economic challenges, plant-based food sales in Europe have continued to grow over recent years (GFI Europe, 2024). More data on European plant-based food sales collected in context of the Smart Protein project can be found on the Open Science Framework platform: https://osf.io/bwe42/. Despite the market potential for plant-based protein sources, the present state of protein-rich crop production in Europe is constrained, leading to substantial reliance on imports (European Commission, 2022) and exacerbating sustainability concerns in the exporting nations (Boerema et al., 2016). Key issues within the value chains of protein-rich crops in Europe include insufficient innovation and marketing efforts, as well as a restricted supply of locally grown crops (Schneider, 2002), highlighting the growing necessity for a robust, local, plant-based value chain. This need is also mentioned in the European Farm to Fork Strategy, in which the goal is to become more self-sufficient for feed materials by growing protein-rich crops and to partially shift from animal-derived protein consumption towards alternative protein sources (European Commission, 2020). This study will use the term "alternative protein scenario" to describe these goals.

Resilience and sustainability are considered necessary means to achieve food security (Berry et al., 2015; Boyacı-Gündüz et al., 2021). How these two concepts relate and differ from each other has been discussed extensively (Derissen et al., 2011; Marchese et al., 2018; Volkov et al., 2022), with one of the major differences being the more future-oriented nature of sustainability, focusing on the creation of desirable outcomes in the future, while resilience relates more to the current time, focusing on the protection of the chain against shocks now or in the near future (Marchese et al., 2018). In the context of agri-food chains, resilience is often characterized by flexibility, collaboration, agility and visibility (Stone and Rahimifard, 2018). On the other hand, the FAO defines a sustainable food value chain as one that integrates three core dimensions: economic, social and environmental sustainability (Neven, 2014). Given their sometimes conflicting

priorities, both resilience and sustainability must be considered when analysing food value chains (Warmbier et al., 2022).

All stakeholders involved in the agri-food chain, including consumers, farmers, food industry professionals, researchers and policymakers, play an important role in transitioning towards the alternative protein scenario. However, most research focuses on consumer attitudes towards alternative protein sources (Hartmann and Siegrist, 2017; Onwezen et al., 2021; Perez-Cueto et al., 2022), while other stakeholder groups are often overlooked. Consumer acceptance of alternative proteins is typically driven by product familiarity and the environmental and health benefits of the product (Estell et al., 2021; Laureati et al., 2024), while food neophobia and unpleasant sensory properties are identified as main barriers (Laureati et al., 2024). A recent review found that all stakeholders are positive about the effects of increased alternative protein consumption on animal welfare and food security, while mixed opinions exist about environmental and economic sustainability, as well as healthiness for consumers (Amato et al., 2023). Although sustainability perceptions heavily influence consumer and farmer decisions about purchasing or adopting protein-rich crops, foods and other sustainable practices(Degieter et al., 2023; Dessart et al., 2019; Jürkenbeck et al., 2019; Lizcano-Prada et al., 2024; Taillie et al., 2024). Yet, while stakeholder perceptions of BFJ sustainability have been explored in an agri-food context, resilience perceptions in context of alternative protein chains, or even agri-food chains in general, remain understudied.

According to the literature, consumers still underestimate the environmental impact of animal-derived food products (Lazzarini et al., 2016; Tobler et al., 2011). Sustainability perceptions are further influenced by the stakeholders' socio-demographics, such as age, gender and country of residence (Averbuch et al., 2022; Bloodhart and Swim, 2020; Degieter et al., 2023). Additionally, stakeholders with stronger, more certain attitudes are more likely to exhibit consistent behaviours, such as advocating for or adopting alternative proteins (Poortinga and Pidgeon, 2006). Those confident in their positive views may be more supportive of these products, while uncertainty or negative attitudes could lead to hesitancy or resistance (Poortinga et al., 2011; Tormala, 2016; Tormala and Rucker, 2007). This makes it essential to understand not only stakeholders' views but also the level of confidence behind them, as it impacts their likelihood of supporting or opposing alternative protein adoption. Finally, risk aversion is another important factor affecting adoption, especially among farmers (Degieter et al., 2023). In conclusion, it is evident that stakeholder perceptions of risks, sustainability and resilience of plant-based protein chains are important in shaping the future of alternative protein value chains.

Currently, no studies have explored the perceptions of different stakeholder groups regarding the risks, resilience and sustainability of plant-based protein chains. Hence, this study aims to (1) explore stakeholders' perceptions regarding plant-based protein chains, (2) cluster stakeholders based on these perceptions and (3) identify which factors, like stakeholder type, current engagement in plant-based protein chains and country of residence, affect cluster membership. Stakeholders considered in this study consist of consumers, farmers, professionals from the food and feed industry, researchers, policymakers, etc.

2. Methodology

2.1 Data collection

A mixed-methods approach was employed, starting with qualitative insights from a focus group discussion (FGD) and interviews to inform the survey design in the quantitative part of the study. A purposive sampling design was used, ensuring representation from key stakeholders across the plant-based protein value chain, including consumers, farmers, food industry professionals, researchers and policymakers. The FGD was organized in Belgium to get an idea about the strengths, weaknesses, opportunities and threats (SWOT) of novel alternative protein chains. Additionally, interested stakeholders who were not part of the FGD were interviewed separately. In total, 11 stakeholders from Belgium with different backgrounds (researchers, industry, farmer organizations, farmers with and without experience growing protein-rich crops) took part in this qualitative study. Two surveys were used for the larger, quantitative study, for which the SWOT analysis served as input to develop the risk-related constructs.

Two surveys to collect responses regarding the perceptions of alternative protein value chains were developed in Qualtrics (Qualtrics International Inc, United States): one for consumers and one for other stakeholders like food industry professionals, researchers and farmers. In the consumer survey, respondents were asked about their dietary lifestyle (Faber et al., 2024). The other stakeholders were asked about their involvement in the agri-food supply chain ("In which stage of the agri-food supply chain are you involved?") (Handford et al., 2015).

The second part of both surveys started by providing a definition of the conventional (or current) protein scenario, and the alternative protein scenario (see supplementary information S1), based on the Farm to Fork strategy (European Commission, 2020). Following these definitions, stakeholders were asked about their current involvement in the alternative protein scenario (yes/no). If the answer was "yes", they were asked in what way by providing them with multiple options (cultivation of protein-rich crops, processing of crops for food, processing of crops for feed, sales of (un)processed crops, research on the cultivation or processing, distribution of crops/foods, other) and how likely they are to continue being involved in the alternative protein scenario on a five-point scale, ranging from very unlikely to very likely. Stakeholders that were not yet involved in the alternative protein scenario, were asked about their likelihood to get involved in the coming years on a similar five-point scale, without defining a specific time.

The next sections on risk, sustainability and resilience perceptions of both surveys were identical for both the consumer and stakeholder surveys. Before each of these sections, respondents were able to see the definitions for the conventional and alternative protein scenarios again. Respondents were asked to evaluate the likelihood of 10 potential risks, derived from the FGD, for the alternative protein scenario in Europe on a five-point scale, ranging from very unlikely to very likely. Sustainability and resilience perceptions regarding the alternative protein scenario were measured in comparison to the conventional protein scenario ("Please indicate how you think the alternative protein scenario scores for the following sustainability/resilience indicators compared to the conventional protein scenario."), on a five-point scale (1 – alternative scenario scores much worse, 5 – alternative scenario scores much better). Sustainability constructs were based on the Sustainability Assessment of Food and Agriculture Systems (SAFA) indicators, developed by the FAO (Scialabba et al., 2013). Constructs were adapted and information was added to make sure that everything would be clear for respondents after consultations with sustainability experts. To measure resilience perceptions, constructs found in the literature for

agility (Li et al., 2009), flexibility (Richey et al., 2012), collaboration (Richey et al., 2012) and visibility (Sadeghi et al., 2023) were slightly adapted and used as indicators. All constructs and their statements that measure risk, sustainability and resilience perceptions are shown in supplementary information S2. Follow-up questions about the respondents' certainty of their answers regarding the sustainability and resilience questions, ranging from 0 (very unsure) to 10 (very sure), were asked (Blomquist et al., 2009).

After receiving positive advice for this study from the Ethics committee of the Faculty of Political and Social sciences of Ghent University, the two surveys were translated into nine languages and pilot-tested. Since this study was conducted in the context of a EC-H2020 project, project partners, including farmers' organizations and non-profits, helped to distribute the surveys across Europe in 2024. Additionally, a data agency was used to collect 50 farmer and 50 consumer responses in France, Poland and Romania. In total, a dataset of 482 responses was obtained after deleting surveys that were completed for less than 70%, under 4 min, or by people not residing or working (anymore) in Europe.

2.2 Data analysis

Data was analysed using IBM SPSS Statistics 28 and SmartPLS4 software. Since the risk items were based on results from the FGD, and not on existing constructs, a principal component analysis (PCA) was conducted to identify underlying factors (Hair et al., 2013). The KMO measure was higher than 0.05 and Bartlett's Test of Sphericity was significant, indicating that the items used for PCA were correlated. All items had communalities larger than 0.3. If a factor had an Eigenvalue higher than one (Kaiser criterion), it was retained (Hair et al., 2013). If an item loaded on more than one factor, it was deleted and the analysis was repeated. As a result, two risk factors were retained, one representing profitability-related risks, and one representing quality-related risks.

SmartPLS was used for confirmatory factor analysis (CFA) for the sustainability (environmental, economic and social dimensions) and resilience constructs to validate these constructs (Hair et al., 2013). All factor loadings exceeded 0.6, with composite reliability for all factors above 0.7, and the average variance extracted (AVE) by the factors close to or greater than 0.5. These results confirm that the items effectively represent their corresponding factors (Hair et al., 2013). Factors were also identified to be sufficiently distinctive, by evaluating the heterotrait-monotrait (HTMT) ratio of correlations (< 0,05, RMSEA0.9 (Tang et al., 2021; Wang et al., 2023)). All factors, with their corresponding items and Cronbach's alpha values, can be found in the supplementary information S2. Besides, a new variable regarding current adoption was computed. Non adopters consisted of consumers with an omnivore diet and other stakeholders that are not yet involved in the alternative protein scenario, while adopters consisted of consumers with another dietary lifestyle, such as vegan, vegetarian, pescatarian or flexitarian and other stakeholders already involved in the alternative protein scenario.

Since none of the factors follow a normal distribution, the Kruskal–Wallis H test and the Mann–Whitney U test were used to identify significant differences in mean ranks between stakeholder groups, and between adopters and non-adopters, respectively. Following this, a combination of hierarchical clustering (using Ward's method and Squared Euclidean Distance) and non-hierarchical K-means clustering was applied to determine the optimal number of clusters and to group respondents accordingly (Hair et al., 2013). Cluster analysis was applied in order to identify distinct respondent segments based on their risk, sustainability and resilience perceptions (Hair et al., 2013). The number of clusters was determined by analysing the dendrogram generated

from the hierarchical cluster analysis. The clusters identified through K-means clustering were then labelled based on the significant differences in their risk, sustainability and resilience perceptions scores. Finally, a binary logistic regression was performed to identify significant predictors of cluster membership (Hair et al., 2013). Multicollinearity was detected between two certainty-related questions, as indicated by a Variance Inflation Factor (VIF) greater than 2.5 (Senaviratna and Cooray, 2019). To address this issue, a principal component analysis (PCA) was performed, resulting in the creation of a new construct labelled "certainty," which demonstrated strong internal consistency (Cronbach's alpha 5 0.886). Additionally, the Box–Tidwell test was used to assess whether a linear relationship existed between the continuous independent variables and the log odds of the dependent variable, which is a key assumption for binary logistic regression. The test confirmed that this assumption was met. Throughout the analysis, a significance level of 5% was applied to all statistical tests, ensuring that the results were robust and reliable.

3. Results

3.1 Focus group discussion

Results from the SWOT analysis are shown in Figure 1. According to the participants of the FGD, alternative protein chains have several key strengths, particularly due to the beneficial characteristics of protein-rich crops and their positive environmental impacts. Other strengths include the nutritional value of alternative proteins, the improved public image of the sector and a better quality assurance due to the more local production of alternative protein products. The identified weaknesses include current chain uncertainties, low financial returns of protein rich crops, unstable yields of protein-rich crops due to climate variability and sensitivity to weeds and pests, inefficiencies within the chain due to small scale and lack of post-harvesting techniques and the price sensitivity of farmers and feed companies. Furthermore, the required extensive processing to produce end products is seen as a weakness. There are several promising opportunities for alternative protein sources including the capable research institutes that can provide valuable insights and advancements within the chain, the supportive policies within Europe, the increasing demand for alternative proteins and the European goal to become more self-sufficient in terms of plant proteins. Moreover, the high cost of fertilizers and the interest in nitrogen-fixing crops present further potential. Several threats could hinder the success of alternative protein chains. The affordability of alternative protein products, the competition for agricultural land with livestock and feed production, competition with non-European countries, the limited knowledge about cultivation techniques and pest management and new diseases and pests are considered as important threats by the FGD participants. Some participants are even sceptical about the local protein chain's potential to be more climate-friendly. Finally, additional threats that could affect the alternative protein market are negative consumer perceptions and potential allergens.

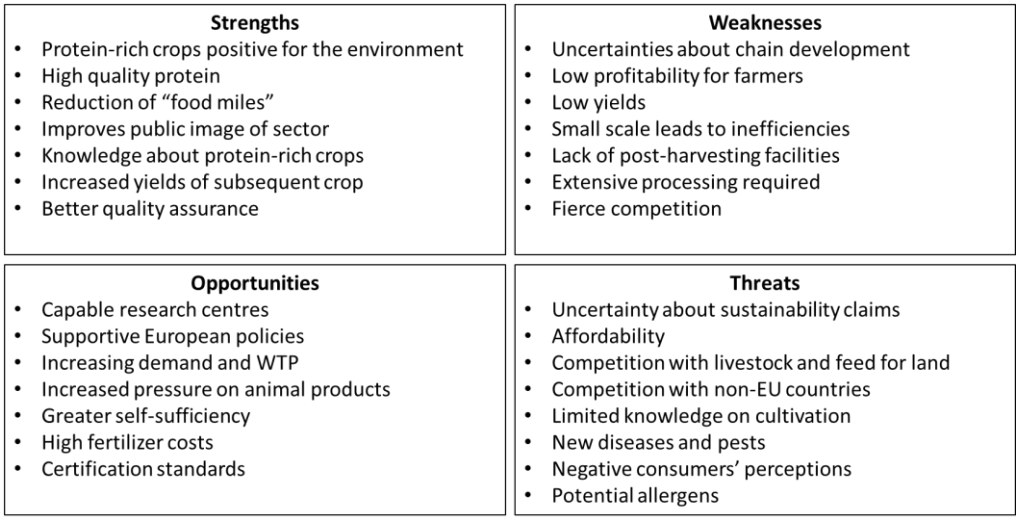

Figure 1: SWOT matrix of alternative protein chains in Europe

3.2 Respondents' characteristics

At the consumer level, a total of 252 survey responses were collected (Table 1). Most consumers are located in Poland, France, Romania or Belgium. As expected, most consumers are omnivores (or non-adopters), followed by pescatarians and flexitarians. The average age of consumers is 43 years. More females than males responded to the consumer survey. The group of other stakeholders mostly consisted of farmers. The other stakeholder categories consist of food or feed industry professionals, such as food/feed processors, distributors, wholesalers, retailers and people involved in marketing, researchers, people involved in monitoring or regulatory bodies, consultancy and non-profits. Some respondents belong to multiple categories, however, are considered in only one category for further data analysis. Farmers are sometimes involved in food/feed processing or research but are still considered as farmers. People involved in the R&D department of a food/feed company are still considered as food/feed industry professionals. Similar to consumers, most other stakeholders were working in Poland, France or Romania. The average age of the other stakeholders' group is 45. Again, females are slightly more represented in the sample in comparison to males.

Thirty-eight percent of all other stakeholders indicated that they are already involved in the alternative protein scenario. The majority (76%) is cultivating protein-rich crops, followed by stakeholders involved in processing protein-rich crops for human consumption (52%), processing of protein-rich crops for feed (47%), research regarding the cultivation and/or processing of protein-rich crops (47%), sales of processed and/or unprocessed protein-rich crops (37%), the distribution of protein-rich crops or foods (25%) and other types of involvement (e.g. promote the consumption of alternative proteins; 15%). Stakeholders already involved in alternative protein chains are likely to continue their involvement (mean = 3.91, SD = 1.40), while the stakeholders that are not involved yet are significantly less likely to become involved (mean = 2.56, SD = 1.13).

Table 1: Socio-demographics and company characteristics of respondents. Source: Authors own work.

Consumer characteristics (n = 252)	**% or mean**	**Stakeholder characteristics (n = 230)**	**% or mean**
Dietary lifestyle (%)		Stakeholder type (%)	
Vegan	2.8	Farmers	74.3

	Vegetarian	6.0		Food/Feed Industry	11.3
	Pescatarian	17.9		Researchers, policymakers, etc.	14.3
	Flexitarian	11.6			
	Omnivore	61.8			
Country (%)			Country (%)		
	Poland	24.3		Poland	24.7
	France	22.2		France	26.0
	Romania	22.2		Romania	23.8
	Belgium	17.1		Belgium	7.5
	Italy	5.2		Italy	2.2
	Other	9.0		Other	15.8
Mean age (SD)		42.9 (14.8)	Mean age (SD)		45.1 (13.8)
Gender (%)			Gender (%)		
	Male	38.9		Male	43.4
	Female	59.0		Female	54.8
	Other	2.1		Other	1.8

3.3 Risk, resilience and sustainability perceptions

The mean scores of risk, resilience and sustainability perceptions are shown in Table 2. Significant differences in mean ranks between stakeholder categories are identified for the variable quality-related risks, profitability-related risks, environmental sustainability and economic sustainability. In general, farmers perceive quality-related risks to be more likely to occur compared to other stakeholders, while they perceive profitability-related risks as being less likely. Farmers perceive the environmental sustainability of the alternative protein scenario as slightly better compared to the conventional protein scenario, however much less than all other stakeholder categories. Respondents from the industry, researchers, policymakers, consultants and non-profits, perceive the environmental benefits of the alternative protein scenario to be much higher in comparison to the other stakeholder categories. Consumers have the highest perception scores for the economic sustainability of alternative proteins compared to other stakeholders. Finally, standard deviations are on average smaller for the stakeholder groups industry and research, policy, etc., indicating that there is more agreement for these stakeholder categories.

Table 2: Mean perceived risk, resilience and sustainability. Source: Authors own work.

	Consumers (n = 252)	**Farmers (n = 171)**	**Industry (n = 26)**	**Research, policy, other (n = 33)**
Risks				
Quality-related risks	2.89 (0.80)[a,b]	3.32 (0.84)[a,c,d]	2.44 (0.63)[b,c]	2.61 (0.53)[d]
Profitability-related risks	3.58 (0.64)	3.51 (0.86)[a]	3.92 (0.45)[a]	3.83 (0.54)
Sustainability				
Environmental sustainability	3.53 (0.82)[a,b,c]	3.15 (0.85)[a,d,e]	4.00 (0.54)[b,d]	4.04 (0.57)[c,e]
Economic sustainability	3.31 (0.82)[a]	3.05 (0.91)[a]	3.27 (0.54)	3.19 (0.65)
Social sustainability	3.30 (0.84)	3.12 (0.90)	3.42 (0.51)	3.37 (0.51)

Resilience				
Agility	3.30 (0.83)	3.24 (0.91)	3.06 (0.76)	3.32 (0.60)
Flexibility	3.23 (0.87)	3.16 (0.96)	3.36 (0.57)	3.16 (0.63)
Collaboration	3.40 (0.90)	3.33 (0.94)	3.43 (0.70)	3.55 (0.77)
Visibility	3.36 (0.94)	3.18 (0.93)	3.44 (0.79)	3.34 (0.82)

[A,b,c,d,e]Indicate significant differences (adjusted p<0.05) in mean rank scores based on Dunn's test. P-values adjusted with Bonferroni correction.

Besides comparing the scores for all stakeholder groups, the perceptions of adopters and non-adopters are compared (Table 3). Adopters have a significantly lower mean rank score for quality-related risks. Furthermore, adopters have a significantly higher mean rank score for all three sustainability factors. Finally, adopting consumers have a significantly higher mean rank score for all resilience factors than the non-adopters, while adopting stakeholders only have a higher mean rank score for collaboration and visibility.

Table 3: Mean perceived risk, resilience and sustainability for adopters and non-adopters. Source: Authors own work.

	Consumers		**Other stakeholders**	
	Adopters	**Non-adopters**	**Adopters**	**Non-adopters**
Risks				
Quality-related risks	2.66 (0.85)*	3.00 (0.75)*	2.68 (0.80)*	3.39 (0.78)*
Profitability-related risks	3.59 (0.65)	3.58 (0.64)	3.53 (0.90)	3.64 (0.73)
Sustainability				
Environmental sustainability	3.85 (0.87)*	3.37 (0.75)*	3.64 (0.86)*	3.21 (0.83)*
Economic sustainability	3.54 (0.77)*	3.20 (0.82)*	3.25 (0.78)*	3.00 (0.87)*
Social sustainability	3.47 (0.85)*	3.22 (0.82)*	3.31 (0.78)*	3.11 (0.84)*
Resilience				
Agility	3.55 (0.81)*	3.18 (0.81)*	3.34 (0.83)	3.16 (0.88)
Flexibility	3.47 (0.84)*	3.12 (0.86)*	3.24 (0.87)	3.14 (0.89)
Collaboration	3.67 (0.85)*	3.27 (0.90)*	3.55 (0.86)*	3.26 (0.90)*
Visibility	3.60 (0.92)*	3.25 (0.93)*	3.41 (0.91)*	3.12 (0.89)*

**Indicates significant differences (p<0.05) in mean rank scores based on the Mann-Whitney U test*

3.4 Segmentation analysis and determinants of cluster membership

The cluster analyses identified two clusters (Table 4), namely (1) the "optimistic advocates", and (2) the "cautious conventionalists". Both clusters contain almost the same number of respondents. The cautious conventionalists have a lower mean score for all sustainability and resilience factors compared to the optimistic advocates. Optimistic advocates perceive the alternative protein scenario as more sustainable and resilient than the conventional protein scenario. Cautious conventionalists perceive the quality-related risks of the alternative protein scenario to be higher than the members of the other cluster, while optimistic advocates score the profitability-related risks slightly higher. However, the profitability-related risk factor is the only factor that is not significantly different for both clusters.

Table 4: Results from cluster analysis based on risk, sustainability and resilience perceptions. Source: Authors own work.

Factors	Mean (SD)	
	Optimistic advocates (n = 237)	**Cautious conventionalists (n = 225)**
Risks		
Quality-related risks	2.88 (0.85)*	3.17 (0.79)*
Profitability-related risks	3.62 (0.68)	3.57 (0.77)
Sustainability		
Environmental sustainability	3.86 (0.70)*	2.96 (0.73)*
Economic sustainability	3.73 (0.65)*	2.65 (0.67)*
Social sustainability	3.77 (0.64)*	2.68 (0.64)*
Resilience		
Agility	3.79 (0.63)*	2.72 (0.67)*
Flexibility	3.74 (0.65)*	2.64 (0.72)*
Collaboration	3.96 (0.61)*	2.78 (0.75)*
Visibility	3.88 (0.68)*	2.68 (0.73)*

**Indicates significant differences (p<0.05) in mean rank scores based on the Mann-Whitney U test*

The binary logistic regression model demonstrates a good fit, as indicated by the significant chi-square statistics ($p < 0.001$) from the Omnibus Tests of Model Coefficients and the insignificant chi-square statistic ($p = 0.552$) from the Hosmer and Lemeshow Test. The dependent variables country, adopter, age, certainty, gender and stakeholder are included in the regression, and three variables are identified as significantly affecting cluster membership. The Nagelkerke R^2 value of 0.144 suggests that the model explains 14.4% of the variation in cluster membership. The results of all variables are depicted in Table 5. Adopters are significantly less likely to belong to cluster 2 (cautious conventionalists). Respondents with higher certainty regarding their answers to sustainability and resilience questions are also less likely to be members of cluster 2. Additionally, stakeholder type has a significant impact. Farmers are significantly more likely to belong to cluster 2 compared to consumers.

Table 5: Factors affecting cluster membership, identified by binary logistic regression. Source: Authors own work.

Variables	B	S.E.	Wald	*p*	Exp(B)
Country (1 = SE)	0.367	0.216	2.876	0.090	1.443
Adopter (1 = yes)	-0.919	0.230	15.966	**<0.001**	0.399
Age	-0.002	0.007	0.0085	0.771	0.998
Certainty	-0.203	0.051	15.915	**<0.001**	0.816
Gender (1 = female)	-0.162	0.208	0.608	0.435	0.850
Stakeholder (1 = farmer)	0.492	0.217	5.133	**0.023**	1.635
Stakeholder (1 = Other)	0.021	0.378	0.003	0.955	1.021
Constant	1.261	0.510	6.108	**0.013**	3.531

Clusters (dependent variable): optimistic advocates as benchmark (0), cautious conventionalists = 1; Country: NW (Northern or Western Europe) as benchmark (0), SE (Southern or Eastern Europe) = 1; Adopter: 0 = no, 1 = yes; gender: 0 = male, 1 = female; stakeholder: Benchmark = consumers

4. Discussion

4.1 Stakeholders' perceptions regarding the alternative protein scenario

In this study, risk, resilience and sustainability factors effectively divided respondents into two clusters, highlighting their relevance. Furthermore, factors affecting cluster membership were identified. The proportion of consumers following a non-omnivorous diet is consistent with findings from a previous large-scale European study (Perez-Cueto et al., 2022). Around 40% of the surveyed farmers are already cultivating protein-rich crops for food or feed, a figure consistent with previous research (Degieter et al., 2023). Due to the smaller sample size of other stakeholder categories in this study, their involvement in the alternative protein sector was not compared to existing literature.

This study found that consumers with dietary lifestyles different from omnivores(adopters) generally have higher sustainability perceptions regarding the alternative protein scenario. While age and gender did not significantly impact cluster membership in this study, the literature suggests that younger and male consumers are more likely to accept alternative protein foods (Laureati et al., 2024). The country of residence did not influence cluster membership, contrasting with earlier findings that consumers from Northern and Western European countries have more positive attitudes towards alternative protein foods compared to those from Eastern and Southern European countries (Zaleskiewicz et al., 2024). Consumers with an omnivore diet perceive quality-related risks, such as low protein content and health risks, as more likely than those with alternative diets. However, previous research has indicated that health concerns can be a significant factor for consumers to adopt alternative diets (Fehér et al., 2020).

Like omnivores, farmers also perceive quality-related risks as more likely than other stakeholders. In line with this study's results, previous research found that farmers are less positive towards alternative proteins compared to consumers (Crawshaw and Piazza, 2023). Livestock farmers, in particular, have expressed concerns about the threat to their livelihoods posed by alternative proteins (Crawshaw and Piazza, 2023). This study showed that farmers perceive the risks related to profitability as moderate, however, lower than other stakeholder categories. Furthermore, farmers perceive the social sustainability of the alternative protein scenario to be comparable to the conventional scenario. The lower concern of farmers regarding the livelihood of farmers in comparison to previous research might be because not all farmers in this study were livestock farmers. In addition, the definition of the alternative protein scenario given to all respondents might also have resulted in a lower concern by farmers, since it indicated that a higher amount of protein-rich crops should be produced by local farmers and that livestock production should decrease but not disappear.

While Estell et al. (2021) found that Australian nutrition professionals express more concern than consumers about alternative protein quality compared to meat, this study's findings reveal that food industry stakeholders, policymakers and researchers are generally more optimistic about alternative proteins, particularly regarding environmental sustainability and quality-related risks. Furthermore, the study from Blanco-Gutiérrez et al. (2020) found that stakeholders involved in the production of food, like industry professionals, farmers and distributors, tend to be less positive towards plant-based alternatives than consumers, policymakers, NGOs and researchers. While these findings partially align with those of this study, food industry professionals were identified as among the most positive stakeholders here. Additionally,

consumer perceptions were more favourable than those of farmers, but less positive compared to policymakers, industry professionals and researchers.

Adopters have a lower chance of belonging to the cautious conventionalists cluster. This may be due to their familiarity with alternative proteins, which previously has been identified to drive the acceptance of alternative proteins (Siddiqui et al., 2022). In summary, enhancing stakeholder familiarity and knowledge about alternative proteins is pivotal for fostering positive perceptions and greater involvement in alternative protein chains. Besides the variable "stakeholder type" and "adopter", the certainty of respondents regarding their answers to the sustainability and resilience questions was also found to have a significant impact on cluster membership. Respondents who are more certain of their answers have a lower chance of being members of the cautious conventionalists, while farmers have a higher chance of belonging to this cluster. Previous research regarding the influence of certainty on consumers' or other stakeholders' perceptions in an agri-food context is scarce. However, a previous study showed that certainty has an impact on consumers' attitudes, with consumers who are more certain regarding their feelings having stronger opinions, either positive or negative (Poortinga and Pidgeon, 2006). This is in line with the results from this study since the group of optimistic advocates have a slightly stronger opinion compared to the cautious conventionalists who have average scores closer to 3 (neither likely nor unlikely).

4.2 Implications, limitations and future research

This research highlights the positive attitudes within the industry towards the future of alternative protein chains, marking a significant departure from earlier works that focused primarily on consumer acceptance. This study therefore contributes novel insights into how different stakeholders perceive the risks, sustainability and resilience of alternative protein chains. In addition, this is the first study measuring resilience perceptions in relation to a food system, thus contributing to the scientific value. Unlike previous studies that measure subjective resilience by asking respondents to self-evaluate (Jones and d'Errico, 2019), this study asks respondents to assess the resilience of a value chain in which they might not be directly involved at the moment. Furthermore, this study identified the important factors for improving stakeholder perceptions regarding alternative protein chains and potentially their engagement in alternative protein chains. These results can have implications for policymakers since they can try to promote the consumption and production of alternative proteins.

The certainty of stakeholders regarding sustainability-related questions significantly predicts cluster membership, with more certain respondents having a lower chance of belonging to the cautious conventionalists cluster. Therefore, increasing stakeholders' certainty about the sustainability of alternative proteins could lead to more positive perceptions and a higher likelihood of their involvement in alternative protein chains. Certainty could potentially be increased by having more direct experiences and social consensus(Tormala and Rucker, 2007). Farmers, who are more likely to belong to the cautious conventionalists cluster, should be engaged through knowledge-sharing programs, on-farm trials and financial incentives (e.g. subsidies) to support local protein-rich crop cultivation. Since the agricultural sector is still of high importance in Europe, aligning farmer views with those of other stakeholders is essential. Policymakers could further try to increase social consensus among consumers by providing more education and knowledge regarding the quality, sustainability and resilience of alternative protein foods. In addition, expanding plant-based product availability in mainstream retail could increase familiarity and reduce scepticism. The food industry, which exhibited a more positive outlook,

could play a key role in mainstreaming alternative proteins through innovation in product development, improving sensory characteristics and further improving supply chain resilience.

One of the limitations of this study is the small number of stakeholders that are neither consumers nor farmers. Although consumers and farmers are very important for the protein transition, the food/feed industry, researchers and policymakers play a crucial role as well (Aiking and de Boer, 2020; Vila-Clara et al., 2024). Furthermore, this study only looked at stakeholders in Europe. Future research could compare European stakeholders' perceptions with those in other parts of the world, for example, countries where meat consumption is strongly associated with culture and tradition like Brazil (Veiga et al., 2023). Another potential shortcoming of this study is the difficulty for some stakeholders to assess the risks, sustainability and resilience of alternative protein chains. However, for comparability among different stakeholders, it was decided that all stakeholders would receive the same main questions. Future research should further assess the impact of other factors, next to the risks, sustainability and resilience perceptions, on different stakeholders' willingness to get involved in the alternative protein chain. Since ultra-processed alternative protein foods are not necessarily more sustainable compared to their animal-based counterparts (van der Weele et al., 2019), future research could differentiate between unprocessed, processed and ultra-processed food products when assessing stakeholders' perceptions.

5. Conclusion

This study provides critical insights into the perceptions of various stakeholders regarding alternative protein chains in Europe, with a particular focus on risks, sustainability and resilience. By segmenting stakeholders into distinct clusters, the research highlights the diverse perceptions across the chain. These findings underscore the importance of stakeholder familiarity and certainty in shaping positive perceptions and promoting engagement with alternative protein sources. The study also emphasizes the role of farmers, whose cautious stance towards alternative proteins suggests a need for targeted educational and policy interventions to align their views with those of other stakeholders. The implications of these findings are significant for policymakers, who must address the identified differences between stakeholders and improve perceptions overall. Increasing certainty about the benefits of alternative proteins through direct experience and enhanced social consensus could shift perceptions and behaviours in favour of these emerging food sources. Future studies should explore global comparisons and assess additional factors that influence stakeholders' willingness to engage in the alternative protein chain. By doing so, a more comprehensive understanding of the potential for alternative proteins to contribute to food security and sustainability can be developed.

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