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Exploring consumers' willingness to adopt climate-friendly diets

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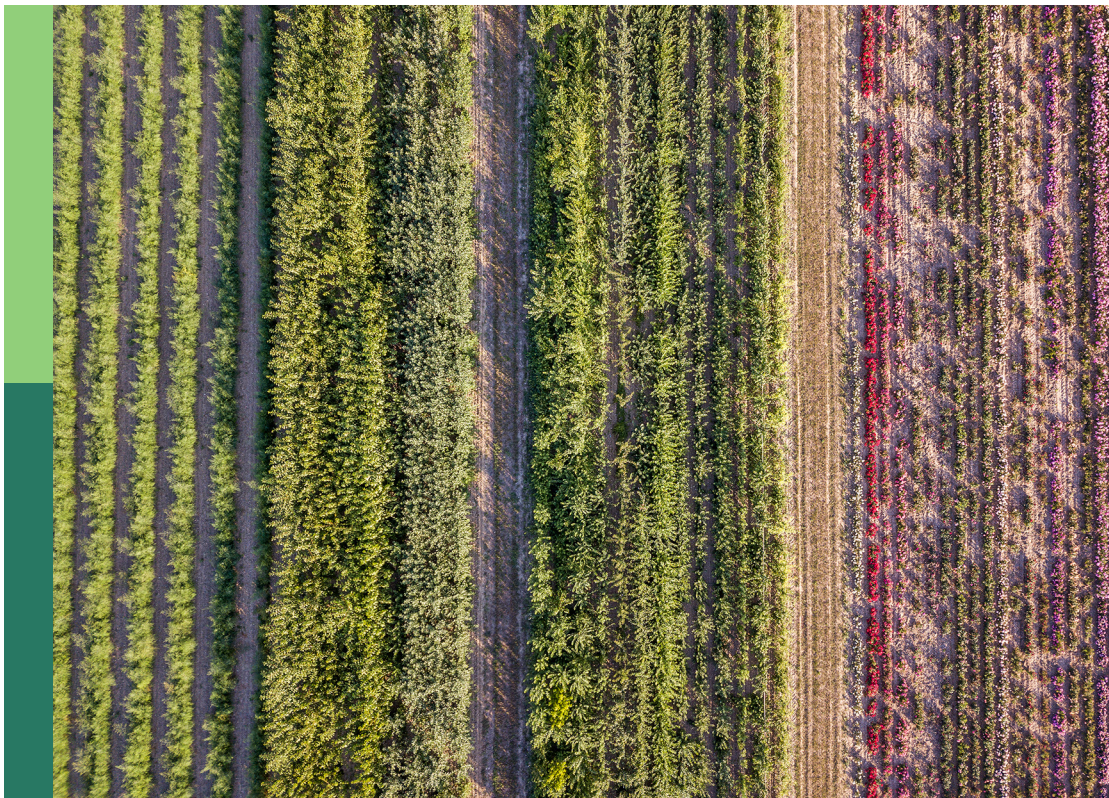

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Exploring consumers' willingness to adopt climate-friendly diets

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Editorial: Exploring consumers' willingness to adopt climate-friendly diets

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Editorial on the Research Topic
Exploring consumers' willingness to adopt climate-friendly diets

The urgency to mitigate climate change has propelled dietary shifts to the forefront of global sustainability efforts. Climate-friendly diets, characterized by reduced meat consumption, increased plant-based foods, and sustainable agricultural practices, present a significant opportunity for reducing greenhouse gas emissions. This Research Topic, "*Exploring consumers' willingness to adopt climate-friendly diets*," aggregates a diverse range of studies that collectively advance our understanding of the factors influencing consumer behaviors toward sustainable food consumption. By examining these various dimensions, the contributing articles offer valuable insights into the multifaceted nature of dietary transitions and their broader implications.

The scoping review by Srinivasan et al., on the factors that facilitate consumer uptake of sustainable dietary patterns in Western countries provides a comprehensive overview of the existing literature. This foundational piece identifies key motivators and barriers, such as environmental awareness, health benefits, and socio-economic influences. The review underscores the complexity of dietary behavior change, highlighting that a confluence of individual, social, and structural factors is essential to promote sustainable consumption effectively.

In examining the intersection of economic variables and dietary habits, several studies shed light on how broader economic contexts influence consumer behavior. The simulation study focusing on Ukraine by Shpak et al., evaluate the impact of production and export changes on national food security. This analysis reveals how macroeconomic factors and policy decisions can either support or hinder sustainable dietary practices. Similarly, the investigation into the global economic crisis's impact on organic food consumption in the Czech Republic by Majerova and Cizkova, illustrate the vulnerability of sustainable food markets to economic downturns, stressing the need for resilient food systems.

Cultural narratives and social movements play pivotal roles in shaping consumer attitudes toward climate-friendly diets. The historical exploration of the Meatless Monday movement by Semba et al., trace its origins and growth, demonstrating how grassroots initiatives can galvanize public interest and participation in sustainable eating practices. This cultural shift is further exemplified in the study from China by Chen et al., which

identify drivers of consumers' intentions to adopt sustainable healthy dietary patterns, revealing the influence of cultural norms and government policies.

Effective communication strategies are critical for fostering dietary shifts toward sustainability. The cross-national study on communicating dietary shifts associated with a 1.5°C climate scenario for Brazil, China, Sweden, and the UK by Lee et al. underscore the importance of tailored messages that resonate with diverse cultural contexts. Furthermore, the exploration of perceived determinants of food purchasing behavior by Pšurný et al. highlight the potential for targeted behavioral change interventions to promote sustainable consumption.

Consumer perceptions significantly impact the adoption of climate-friendly diets. The study on food producer labels by Zhu and Jin investigate whether food produced by farmers is perceived as healthier and more natural, and its influence on consumer choices. These findings suggest that labeling can play a crucial role in guiding consumer preferences toward sustainable options. Similarly, the research on the ambivalence and willingness to pay for suboptimal fruits and vegetables among organic consumers in Germany by Puteri et al. address the potential for reducing food waste through informed consumer decisions.

Innovative approaches to promoting sustainable diets are explored in several contributions. The study on adherence to the Mediterranean Diet through a bio-psycho-social and sociotype approach by Donini and Berry present an integrative model that incorporates psychological and social factors, offering a holistic perspective on dietary adherence. The investigation into vegetarian and vegan private label products in Slovakia by Košičiarová et al. identify emerging trends and challenges in sustainable food consumption, reflecting shifting consumer preferences.

Emerging technologies and novel food sources also feature prominently in this Research Topic. The study on cultured proteins in Nordic countries by Klöckner et al. examine consumer attitudes toward lab-grown meat, milk, and fish, highlighting the attributes that could make these products attractive to different demographic groups. This research underscores the potential of alternative proteins to contribute to sustainable food systems.

The influence of retail environments on consumer behavior is explored in the study on supermarket consumers' intentions toward climate-friendly food consumption by Emberger-Klein et al.. This research emphasizes the role of supermarkets in shaping consumer choices through product availability, marketing, and normative influences. The findings suggest that supermarkets can act as critical nodes.

Collectively, the articles in this Research Topic provide a nuanced understanding of the various factors influencing the adoption of climate-friendly diets. They highlight the interplay between individual choices, economic conditions, cultural narratives, and structural enablers. The insights gained from these studies are invaluable for policymakers, marketers, and advocates aiming to promote sustainable dietary practices.

In a broader context, these findings align with global sustainability goals, such as those outlined in the United Nations' Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). By fostering a deeper understanding of the drivers and barriers to sustainable food consumption, this research contributes to the development of effective strategies for achieving these goals.

The transition to climate-friendly diets is a complex but necessary endeavor for addressing the global climate crisis. The diverse perspectives and insights presented in this Research Topic underscore the importance of a multi-faceted approach that considers economic, cultural, social, and psychological dimensions. As we continue to explore and understand the factors influencing consumer behavior, we can better design interventions and policies that support sustainable dietary transitions and ultimately contribute to a more sustainable and resilient food system.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The Influence of Climate Attitudes and Subjective and Social Norms on Supermarket Consumers' Intention Toward Climate-Friendly Food Consumption

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Consumers can reduce greenhouse gas (GHG) emissions by changing their individual diets. Moreover, several studies showed that a positive intention to make climate-friendly food choices can be found among private consumers. Accordingly, the aim of this study was to analyze the factors, which influence supermarket consumers' behavioral intentions toward climate-friendly food consumption. For the analysis data from a face-to-face in-store survey in the southern Germany was used. The study was able to verify a large positive effect of Climate Attitudes and a medium positive effect of Subjective and social Norms on consumers' behavioral intention toward climate-friendly food consumption using an extended model of the Theory of Reasoned Action and structural equation modeling to analyze the data. However, the presumed direct effect of Perceived Behavioral Competency on this issue could not be proven. Based on the results strategies for the enhancement of climate-friendly food consumption are suggested.

Keywords: food consumption, GHG emissions, consumer, theory of reasoned action, structural equation modeling

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INTRODUCTION

In 2021 almost one fifth of European citizens evaluates climate change as the most serious problem in the world, just ahead of poverty, hunger and lack of drinking water as well as the spread of infectious diseases. Most of the participants of the Eurobarometer-study perceive actions against climate change to be the responsibility of national governments. However, more than 40% of the participants believe in personal responsibility with regard to climate change-related activities (European Union, 2021). On the individual level personal actions in the area of food, mobility and housing are useful, since these fields significantly impact the emissions of greenhouse gas (GHG) emissions (Faber et al., 2012). Behavioral change options in the food domain are e.g., to eat more local food, to reduce imported food, to reduce food waste, to eat healthy or to change to a vegetarian diet (Faber et al., 2012). Eating more locally-produced food has positive impacts on transportation emissions. Considering the change to a vegetarian diet, Scarborough et al. (2014) showed that the mean GHG emissions per 2,000 kcal diet of heavy consumers of meat are almost twice as high as those of vegetarians. Green et al. (2015) found that a reduction of up to 40% of CO_2

emissions can be reached by switching to a diet which contains e.g., fewer animal products and more fruit, vegetables and cereals. According to these authors, higher reductions are also possible. However, this would require radically altered and narrow diets (Green et al., 2015). Thus, these studies and others (e.g., Hedenus et al., 2014) show that alternative personal diets can reduce a serious amount of GHG emissions. Nevertheless, Mäkiniemi and Vainio (2013) point out that climate-friendly food consumption seems to be challenging for consumers due to aspects like a lack of consumers' awareness of their environmental impact, a lack of willingness to reduce meat consumption or a perceived difficulty to follow a plant-based diet. Faber et al. (2012) summarize that knowledge-based barriers, unconscious behavior, structural and physical, and cultural barriers exist for climate-friendly food consumption. In spite of these barriers different studies documented a positive intention of consumers to make climate-friendly food choices (e.g., eat local, eat seasonal or reduce meat consumption) (Tobler et al., 2012; Mäkiniemi and Vainio, 2013; Sundblad et al., 2014; van der Linden, 2014).

Given the described mitigation potential of personal diets and the described positive intention to act, it is important to know the factors which influence the intention toward climate-friendly food consumption. Knowing these factors it is possible to derive measures for behavioral change. This is possible since different well-established social psychology theories [e.g., Theory of Reasoned Action (Fishbein and Ajzen, 1975); Theory of Planned Behavior (Ajzen, 1985)] show that intention is a direct predictor of behavior. When analyzing intention influencing factors it is especially desirable to follow a theory-driven approach, since research in this area has often been rather descriptive or explanatory (Tikir and Lehmann, 2011; van der Linden, 2014). While there are studies using established social psychology theories to explain climate-friendly behavior in other fields (e.g., transportation) (Bamberg et al., 2007; Tikir and Lehmann, 2011), such studies are lacking in the area of food consumption. Thus, the aim of this study was to analyze the factors, which influence supermarket consumers' behavioral intentions toward climate-friendly food consumption using a theory-driven approach, namely an extended model of the Theory of Reasoned Action (TRA). TRA was used, because strong predictive utility of the model was proven for various fields of human behavior (Sheppard et al., 1988). Structural equation modeling was used to analyze data from a face-to-face, in-shop consumer study conducted in southern Germany. Within the survey, we were especially interested in the consumption of fruit and vegetables, since substituting fruit and vegetables for animal products can save substantial amounts of GHG emissions (Scarborough et al., 2014; Green et al., 2015).

The remainder of this study is structured as follows: In the next section a model explaining climate-friendly food consumption is developed on the basis of relevant literature and theory. This is followed by a description of the used methodology and a presentation of the results. The manuscript ends with a discussion of the results as well as the major conclusions.

THEORETICAL BACKGROUND AND HYPOTHESES

Since the 1970s environmental psychologists have tried to detect the factors which predict environment-related behavior, which is closely related to climate-friendly behavior (R. Gifford et al., 2011). One important theory in this respect is the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), which assumes a person's intention to perform or not perform a specific behavior as the direct determinant of the behavior (see **Figure 1**).

TRA consists of two determinants of intention: attitude toward the behavior and subjective norm. Attitude is personal in nature, while subjective norm reflects the social influence. Thus, individuals intend to behave in a certain way when they positively appraise the behavior and when they think that people who are important to them believe they should behave in this way (Fishbein, 1979). The adequacy of the TRA to explain environment-related behavior has been proven empirically in different fields, like e.g., purchase intention for green or energy-efficient products (Ha and Janda, 2012; Paul et al., 2016), use of green information technology (Mishra et al., 2014) or intention to conserve water in lodging context (Untaru et al., 2016). In this respect all the mentioned studies as well as others (e.g., Tikir and Lehmann, 2011) found a positive effect of attitude and subjective norm on the respective intention to behave environmentally friendly (Ha and Janda, 2012; Paul et al., 2016; Untaru et al., 2016). Additionally, especially for Germany Dirks et al. (2010) showed that general social norms have a strong correlation with the intention of climate-friendly behavior.

Thus, following the TRA-model and the described empirical findings for Germany, the following hypotheses are formulated regarding the influence of *Subjective and social Norms* and *Climate Attitudes* on the intention of climate-friendly food consumption behavior (see also **Figure 2**):

- The stronger the *Subjective and social Norms* regarding climate-friendly food consumption the higher the intention of climate-friendly food consumption (H1).
- The more positive the *Climate Attitudes*, the higher the intention of climate-friendly food consumption (H2).

Due to the mitigation potential of substituting fruit and vegetables for animal products this study is especially interested in the consumption of fruit and vegetables. However, the actual reduction potential of groceries is effected by the substituted

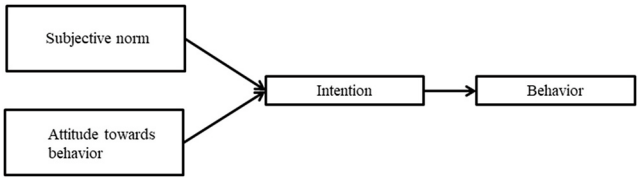

FIGURE 1 | Theory of reasoned action. Source: Modified according to Fishbein (1979).

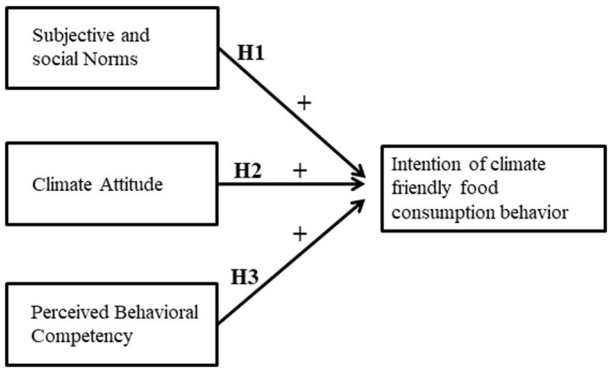

FIGURE 2 | Developed model for the Intention of climate-friendly food consumption behavior.

products, since large variations exist in the GHG intensity per unit of animal and vegetable food products (Hedenus et al., 2014). In the case of fruit and vegetables the variation in CO_2-emissions e. g between different production systems, seasons, places of production or distribution systems could be shown by different authors (e.g., Theurl, 2008; Kögl and Tietze, 2010; British Standards Institution, 2012; Soode et al., 2015). However, for many consumers it is difficult to identify high and low carbon-emitting groceries (Sharp and Wheeler, 2013). Given this fact, we argue that behavioral competency regarding the identification of climate-friendly food, especially fruit and vegetables, can directly affect the intention to consume climate-friendly food. We base this assumption on different studies which indicate a positive influence of competency on environmentally responsible behavior. For example, Corral-Verdugo (1997) reported that re-using and recycling competencies can successfully predict observed re-use/recycling behavior; De Young (1988) could show that procedural-knowledge is helpful in differentiating observed recyclers from non-recyclers and Aitken et al. (2016) found that perceived environmental competency directly influences frequency of difficult pro-environmental behaviors. Following Ajzen (1991)'s request for model extension and in analogy to other studies (e.g., Untaru et al., 2016) an extended version of the pure TRA-model is evaluated in this study. The following hypotheses regarding the influence of behavioral competency on the intention toward climate-friendly food consumption behavior is assessed (see also **Figure 2**):

- The higher the *Perceived Behavioral Competency* regarding the identification of climate-friendly fruits and vegetables, the higher the intention of climate-friendly food consumption (H3).

MATERIALS AND METHODS

Procedure

The analysis is based on data from a quantitative consumer study conducted in the spring of 2014 ($n = 413$). The survey dealt with the topic "Consumption of fruit and vegetables" and had a special focus on apples and tomatoes. The target group consisted of individuals age 16 and older, who are the grocery shoppers for their household and who at least occasionally buy apples and tomatoes. Data was collected by means of computer assisted personal interviews, which took place in four cities with differing numbers of inhabitants (Reutlingen $n = 106$, Pfullendorf $n = 99$, Stuttgart-Vaihingen $n = 108$, Weil der Stadt $n = 100$) in southern Germany using convenience sampling. The interviews were carried out by the first author plus seven instructed and mostly in interviewing very experienced students in four supermarkets and convenience stores belonging to the biggest German food retailer, the EDEKA group. To include all types of shopping behavior and households in the survey, the interviews were spread over all possible shopping days of one week (Monday to Saturday) and the different times of the day. The interviews lasted on average 20.7 min and took place within the supermarkets or near the checkout area. Before the interviews, respondents were informed about the content of the survey and that the interviews will be kept strictly confidential and will not be used for any purpose other than the scientific project. Upon completion of the survey, respondents received a voucher of a local bookstore (worth 10 €) as incentive.

Measures

Table 1 summarizes the wording of the items, their labels and their sources, which were used to operationalize the theoretical constructs of this survey. All items were rated on a five-point Likert-like Scale from *I absolutely agree* (=1) to *I do not agree* (=5). The *Intention of climate-friendly food consumption behavior* (short: *Intention*) was operationalized using two items. One of them describes the personal importance of contributing to climate protection (intent_importance). The second emphasizes that consumers strongly aim to contribute more to climate protection in the future (intent_future). *Subjective and social Norm (SN)* was measured with two items (norm_all, norm_close). All of the described items originated from the study of Dirks et al. (2010) and were formulated with a focus on food consumption. Dirks et al. (2010) found in a representative study ($n = 3.284$) that the item sets used are robust and very well-suited for application in studies on climate-friendly consumer behavior in German. They also recommended modifying the developed items according to the subject of the study at hand. The four items regarding *Climate Attitude (CA)* are a modified and shortened version of the Green Consumption Values developed by Haws et al. (2014) (attitude_importance, attitude_decision, attitude_purchasehabit, attitude_concern). The selection of the four items from the original six items was based on the data of an online study [$n = 71$, Kainz et al. (2014)], in which the original items of Haws et al. (2014) were used and reliability analysis was performed. To adapt the items of the original scale to the context of the climate-friendly food consumption behavior, we replaced the term "environment" with "climate" in the following three items: attitude_importance, attitude_decision, attitude_purchasehabit. Items for the *Perceived Behavioral Competency (PBC)* construct were developed based on the study of Mäkiniemi and Vainio (2013). In their survey the authors identified six climate-friendly

TABLE 1 | Operationalization of the constructs in the survey.

Construct	Indicator (wording of item)	Indicator label	Source
Intention of climate-friendly food consumption behavior	It is important for me, to contribute as a consumer to climate protection by means of my nutrition and my food consumption.	intent_importance	Modified according to Dirks et al. (2010)
	I as a consumer strongly aim at contributing more to climate protection by means of my nutrition and food consumption in the future.	intent_future	
Subjective and social norm (SN)	All consumers should contribute to climate protection via their nutrition and food consumption.	norm_all	
	My close friends and family find it important to contribute to climate protection as a consumer by means of their own nutrition and food consumption.	norm_close	
Climate attitude (CA)	It is important to me that the products I use do not harm the climate.	attitude_importance	Modified according to Haws et al. (2014)
	I consider the potential climate impact of my actions when making decisions.	attitude_decision	
	My purchase habits are affected by my concern for the climate.	attitude_purchasehabit	
	I am concerned about wasting the resources of our planet.	attitude_concern	
Perceived behavioral competency (PBC)	Fruit and vegetables from my region are easy to identify when purchasing food.	pbc_local	Developed based on Mäkiniemi and Vainio (2013)
	I know which fruit and vegetables have a negative effect on the climate.	pbc_effect	
	I know at which time of the year given fruit and vegetables are in season.	pbc_season	
	I know measures to reduce food waste.	pbc_reducewaste	
	It is easy for me to identify fruit and vegetables which were imported by plane.	pbc_planeimport	

Source: own depiction.

food choices using a literature review. On the basis of five of these strategies, items were formulated which express the PBC to choose climate-friendly produce (see **Table 1**) (pbc_local, pbc_effect, pbc_season, pbc_reducewaste, pbc_planeimport).

Data Analysis

In this study structural equation modeling was used. This method is currently seen as a standard for simultaneously exploring complex causal connections between latent, exogenous or endogenous variables (Huber et al., 2007). The partial least squares (PLS) approach was chosen for this study because it is able to represent formative as well as reflexive constructs. Therewith, key driver constructs can be identified and PLS does not postulate normally distributed data (Hair et al., 2017). SmartPLS Version 3 Software (Ringle et al., 2015) was used for data analysis.

While the inner path model represents the causal connections between latent variables in a path diagram, the outer exogenous model illustrates the connections between manifest indicators which determine independent latent variables. The outer endogenous model displays the connections between manifest indicators that fix dependent latent variables (Nitzl, 2010). Multiple causal connections between variables can thus be designed and tested empirically by using structural equation modeling (Boßow-Thies and Panten, 2009).

According to Henseler et al. (2009), the PLS Algorithm can be seen as a sequence of regressions in terms of weighted vectors. Weights are used as auxiliary variables in order to fix estimation parameters. Within an iterative process (least squares method), precise values can be determined for latent variables (Huber et al., 2007). As a first step, construct values for each latent variable are identified. Dependent on a reflexive or formative operationalization of the construct, the correlation value or regression coefficient is used as a weighting factor for proximate latent variables within the path weighting scheme. Second, the construct value for latent variables within the inner model is calculated. Subsequently, the outer weights are estimated. While a principal component analysis is run for reflexive constructs, a multiple regression analysis is calculated for formative constructs. The algorithm is completed with the outer approach of the latent variable values. The path coefficients can then be calculated creating mean values (Henseler et al., 2009).

RESULTS

Description of the Variables

Table 2 shows the key socio-demographic (SOD) characteristics of the sample, and for the purpose of comparison it also includes information on the relevant population (householder). Approximately two thirds of the respondents were female, which corresponds to the fact that in Germany women are still the primary purchasers of household goods (Verbraucheranalyse, 2012). The share of young people (<30 years) and larger households (3+ individuals) was higher in the sample than in the relevant population. Additionally, there is an overrepresentation of people with higher education and higher occupation groups (e.g., senior executives/chief officers).

The results of the items, which operationalized the intention of climate-friendly food consumption, are summarized in **Table 3** (total) and **Table 4** (by socio-demographics).

In total, consumers show a high *Intention* to behave climate-friendly regarding food consumption according to this study. 76.8%, respectively, 68.3% (absolutely) agree with the *Intention*-statements. However, there are also statistically significant differences between some SOD groups: Women have a higher *Intention* of climate-friendly food consumption

than men. The same is true for older (30+ years) compared to younger (<30 years) consumers. In tendency there are also differences for at least one *Intention*-item between the occupation and education groups: By trend, is the importance to contribute to climate protection lowest for people who have never been employed and highest for senior executive/chief officers. Additionally, the aim to contribute more to climate protection in future is highest for people with a medium level of education.

Table 5 shows the frequency distribution and means of all statements which operationalise the three exogenous variables as well as their correlations with both *Intention*-items. We find a high agreement with the *Subjective and social Norm*-item that all consumers should contribute to climate protection as well as to two C*limate Attitude*-items (attitude_importance, attitude_concern). Thus, for most consumers it is important to use products which do not harm the climate and the majority of

TABLE 2 | Socio-demographic characteristics of the sample and the population.

		Sample	Householder[a]
n		413	
Gender (%)	Female	69.0	67.3
	Male	31.0	32.7
Age (%)	16–29 years	24.7	11.2
	30–49 years	31.2	34.5
	50+ years	44.1	54.3
Size of household (%)	1 Individual	13.3	26.3
	2 Individuals	39.5	38.1
	3+ Individuals	47.2	35.6
Education[b] (%)	Low	3.4	11.9
	Medium	65.9	70.8
	High	30.8	17.3
Occupation (%)	Self-employed/freelancer/agriculturalist	13.1	8.6
	Senior executive/chief officer	15.0	8.2
	White-collar worker/public officer	47.2	57.5
	Skilled worker/unskilled worker	10.4	20.9
	Never been employed	14.3	4.8

[a]*Individuals 16+ years from Baden-Württemberg who are the purchaser of household goods and who bought food from EDEKA during the last months (Source: Verbraucheranalyse, 2012);* [b]*Low: no/does not yet have a certificate of graduation, Certificate of Secondary Education (CES) without apprenticeship; Medium: CES with apprenticeship, secondary school, higher education entrance qualification; High: higher education.*

Source: Emberger-Klein et al. (2015).

TABLE 4 | *Intention* by sociodemographic variables ($n = 413$).

		Intent_importance		Intent_future	
		m[c]	sd	m[c]	sd
Sex[a]	Female	1.8***	0.8	1.8***	0.8
	Male	2.2***	0.9	2.2***	0.9
Age[b]	16–29 years	2.3***	0.9	2.4***	0.9
	30–49 years	1.8***	0.8	2.0***	0.9
	50+ years	1.8***	0.9	2.0***	0.9
Household size[b]	1 Person	2.0	1.1	2.1	1.0
	2 Persons	1.9	0.9	2.1	0.9
	3+ Persons	1.8	0.8	2.1	0.9
Education[b]	Low	1.9	0.8	2.1$	0.8
	Medium	1.9	0.9	2.0$	0.9
	High	1.9	0.9	2.2$	0.9
Occupation[b]	Self-employed/freelancer/agriculturalist	1.9$	0.9	2.2	1.0
	Senior executive/chief officer	1.7$	0.7	2.0	0.9
	White-collar worker/public officer	1.8$	0.9	2.0	0.9
	Skilled worker/blue collar worker	1.9$	0.9	2.1	0.9
	Never been employed	2.2$	0.9	2.3	0.9

m, mean; sd, standard deviation.

$*p < 0.1$.

$*p < 0.05$.

$**p < 0.01$.

$***p < 0.001$.

[a]*Wilcoxon rank-sum (Mann-Whitney) test.*

[b]*Kruskal-Wallis equality-of-populations rank test.*

[c]*I absolutely agree (=1) to I do not agree (=5).*

Source: own data set and calculations.

TABLE 3 | Description of the variable *Intention* (frequencies-agreement in %, $n = 413$).

	Agreement[a]	Indifference[b]	No agreement[c]	m	sd
It is important for me, to contribute as a consumer to climate protection by means of my nutrition and my food consumption (intent_importance).	76.8	19.1	4.1	1.9	0.9
I as a consumer strongly aim at contributing more to climate protection by means of my nutrition and food consumption in the future (intent_future).	68.3	24.7	7.0	2.1	0.9

m, mean; sd, standard deviation.

[a]*I (absolutely) agree (= 1 or 2).*

[b]*Neither agree nor disagree (=3).*

[c]*I (somewhat) do not agree (= 4 or 5).*

Source: own data and calculations.

TABLE 5 | Description of all items which operationalize the exogenous variables and correlation of the variables with *Intention* (Frequencies-agreement in %, $n = 413$).

	Agree-ment[a]	In-difference[b]	No agreement[c]	m	sd	Pearson correlation with Intent_importance	Pearson correlation with intent_future
norm_all	86.0	11.9	2.2	1.6	0.8	0.54	0.55
norm_close	55.2	29.3	15.5	2.4	1.1	0.40	0.41
attitude_importance	70.7	23.2	6.1	2.0	0.9	0.57	0.51
attitude_decision[d]	43.1	36.6	20.3	2.7	1.0	0.51	0.52
attitude_purchasehabit[d]	41.9	34.1	24.0	2.7	1.1	0.53	0.56
attitude_concern	85.2	11.4	3.4	1.6	0.8	0.44	0.38
pbc_local	52.8	31.5	15.7	2.5	1.1	0.16	0.16
pbc_effect[d]	33.2	33.4	33.4	3.0	1.2	0.26	0.31
pbc_season	86.7	10.7	2.7	1.5	0.8	0.16	0.25
pbc_reducewaste	83.3	11.4	5.3	1.7	0.9	0.20	0.30
pbc_planeimport[d]	28.1	25.2	46.7	3.3	1.3	0.20	0.15

m, mean; sd, standard deviation.
[a]I (absolutely) agree (=1 or 2).
[b]Neither agree nor disagree (3).
[c]I (rather) not agree (4 or 5).
[d]Data follows a normal distribution (Shapiro-Wilks test).
Source: own data set and calculations.

consumers are concerned about wasting our planet's resources. In contrast, the agreement with the statements dealing with the consideration of potential climate impacts as well as purchase habits is much lower. The correlations of all *Attitude*- or *Subjective and social Norm*-related statements with the *Intention*-items are medium to large. Consumers state a high *Perceived Behavioral Competence* regarding the growing season of different produce as well as regarding measures to reduce food waste. However, they feel less qualified to identify locally produced food or produce imported by plane as well as regarding the effect of different fruit and vegetables on the climate. The correlations of these statements with the *Intention*-items are small to medium. Additionally, **Table 5** shows that the distribution of most of the items does not follow normality.

Results of the Structural Equation Modeling

Evaluation of the Measurement Model

To evaluate the measurement model the reflective construct *Intention* and the formative constructs *Subjective and social Norms, Climate Attitudes and Perceived Behavioral Competency* were separately assessed following the recommendations of Hair et al. (2017).

To evaluate the reflective construct *Intention* internal consistency and convergent validity was checked. Assessed criteria as well as desired values are summarized in **Table 6**. An evaluation of discriminant validity was not applicable, since we have only one reflective construct. Internal consistency was proven due to a Cronbach's alpha value of 0.806, respectively, composite reliability value of 0.911. Convergent validity, which describes the extent to which a measure correlates positively with alternative measures of the same construct, was assessed using indicator reliability by observing the outer loadings as well as the average variance extracted (AVE) (Hair et al., 2017). Both outer loadings (0.916, 0.915) are above the desired value of 0.7, which documents sufficient levels of indicator reliability. In addition, the AVE-value of 0.837 confirms convergent validity.

TABLE 6 | Evaluation of reflective construct*: Intention*.

	Evaluation criteria	Estimated parameters
Internal consistency reliability	Cronbach's alpha: desired value: >0.7	0.806
	Composite reliability: desired value: >0.6 and <0.95	0.911
Convergent validity	Indicator reliability: outer loadings (m, sd, *p*-value); desired value >0.7	
	- intent_importance	0.916 (0.915, 0.010, $p < 0.000$)[a]
	- intent_future	0.915 (0.914, 0.010, $p < 0.000$)[a]
	Average variance extracted (AVE): desired value >0.5	0.837

m, mean; sd, standard deviation.
[a]Complete bootstrapping option: no significant sign changes, 5,000 samples.
Source: own data and calculations.

To assess the parameter estimates related to the three formative constructs *Subjective and social Norm, Climate Attitude,* and *Perceived Behavioral Competency* presence of collinearity among indicators using variance inflation factor (VIF) and significance of relevant indicator weights was checked. Results are summarized in **Table 7**. Since all VIF values are smaller than a threshold of 5, collinearity is not at a critical level. Complete bootstrapping (method: no significant sign changes, 5,000 samples) was used to determine if outer weights are significantly different from zero. All *Subjective and*

TABLE 7 | Evaluation of the formative constructs.

Construct	Indicator	Outer weight	m[a]	sd[a]	*p*-value[a]	Confidence interval[a,b] (2.5%; 97.5%)	VIF	Outer loading
	Desired value	**>0.1**					**<5**	
Subjective and social norm (SN)	norm_all	0.781	0.779	0.050	0.000	(0.671; 0.867)	1.1	0.924
	norm_close	0.407	0.407	0.067	0.000	(0.278; 0.538)	1.1	0.684
Climate attitude (CA)	attitude_importance	0.443	0.442	0.069	0.000	(0.304; 0.578)	1.4	0.817
	attitude_decision	0.291	0.288	0.060	0.000	(0.179; 0.413)	2.0	0.783
	attitude_purchasehabit	0.330	0.329	0.066	0.000	(0.203; 0.458)	2.1	0.828
	attitude_concern	0.220	0.222	0.062	0.000	(0.091; 0.339)	1.3	0.620
Perceived behavioral competency (PBC)	pbc_reducewaste	0.430	0.418	0.11	0.000	(0.198; 0.632)	1.2	0.698
	pbc_effect	0.536	0.524	0.10	0.000	(0.326; 0.729)	1.2	0.787
	pbc_local[c]	0.184	0.178	0.12	0.124	(−0.051; 0.414)	1.1	0.446
	pbc_planeimport[d]	0.134	0.130	0.13	0.298	(−0.115; 0.389)	1.2	0.487
	pbc_season	0.230	0.226	0.13	0.079	(−0.020; 0.494)	1.2	0.566

m, mean; sd, standard deviation.
[a]Complete bootstrapping (option: no significant sign changes, 5.000 samples).
[b]Method: bias-corrected and accelerated Bootstrap.
[c]Outer loading, mean: 0.433 (p-value: 0.000).
[d]Outer loading, mean: 0.473 (p-value: 0.000).
Source: own data and calculations.

social Norm and C*limate Attitude* indicator weights as well as pbc_reducewaste and pbc_effect are significant at a level of 0.1%. In contrast, pbc_season is only significant at a 10% significance level. Thus, all these indicators contribute to forming the constructs. Since the weights are standardized, the outer weights express each indicators relative contribution to the construct. Thus, norm_all has the highest relative importance in forming the construct *Subjective and social Norm*, and attitude_importance in constructing *Climate Attitudes*. The outer weights of the indicators pbc_local and pbc_planeimport are not significant. In the case of non-significant indicator weights Hair et al. (2017) recommend to not automatically interpret this outcome as indicative of poor measurement model quality. Instead, the indicators absolute contribution to its construct should be considered by analyzing the formative indicator's outer loadings and its significance. If an outer loading is smaller than 0.5 it should be considered to remove it from the model. Although the outer loadings of both indicators are slightly below 0.5 (0.433/0.473), we kept them in the model since the outer loadings are highly significant ($p < 0.000$) and the variables are assumed to be relevant for the *PBC*-construct.

Evaluation of the Structural Model

Since the examined reflective and formative constructs show satisfactory levels of quality, the measurement model is evaluated in the next step. Therefore, presence of collinearity, significance of path coefficients, R2, effect size (f2) and predictive relevance (Stone-Geisser's Q2) are assessed and the results are summarized in **Table 8** and **Figure 3**. Since the VIF values of all exogenous variables are smaller than a critical level of 5, there is no indication of collinearity among the predictors.

The path coefficients of *Subjective and social Norm* and *Climate Attitude* are highly significant ($p < 0.000$) and consequently have a significant influence on *Intention* of climate-friendly food consumption behavior. This is also proven by the confidence intervals, which do not inlcude zero. For both variables the effect is positive. In the case of *Climate Attitude* a one-unit increase of this latent variable increases intention by 0.501 *ceteris paribus*. Accordingly, this variable also has the strongest effect, followed by the construct *Subjective and social Norm* (0.356). The coefficient of *PBC* is significant at a 10% level. Thus, this construct has a tendency to have a small and positive influence on intention (0.074).

In total, the three exogenous constructs *Subjective Norm, Climate Attitudes and Perceived Behavioral Competency* explain $R^2 = 62.1\%$ of the variance of the endogenous construct *Intention,* indicating good explanatory power of the model. Addtionally, the f^2 effect size can be used to evaluate whether a specified exogenous variable has a substantive effect on the *Intention*-model by observing the change in the R^2 value when the respective construct is excluded from the model. The effect size of *Climate Attitude* can be considered as large ($f^2_{CA} = 0.423$) and the effect size of *Subjective and social Norm*s as medium ($f^2_{SN} = 0.238$). However, since f^2 of *Perceived Behavioral Competency* (0.012) is smaller than 0.02, we found no substantive impact of this construct on the endogenous variable. Finally, predictive relevance was checked using Stone-Geisser's Q^2. Since this value is larger than zero, the path model's predictive relevance for the reflective, endogenous construct *Intention* can be confirmed.

On the basis of the described results we can confirm H1 and H2, since we found that the stronger the *Subjective and social Norm* and the more positive the *Climate Attitudes* are, the greater the *Intention* to consume climate-friendly food. However, we have to reject H3 since we could not find a substantive effect of the construct *Perceived Behavioral Competency* on *Intention*.

Addtionally, to check if data is homogenous with respect to different socio-demographic groups multigroup analysis for sex

TABLE 8 | Results of the structural model.

Exogenous construct Desired value	Path coefficient	m[a]	sd[a]	*p*-value[a]	Confidence interval[a,b] (2.5%; 97.5%)	Effect size f^2 Min. >0.02	VIF <5
Subjective and social norm	0.356	0.355	0.043	0.000	(0.277; 0.446)	0.238	1.4
Climate attitude	0.501	0.502	0.039	0.000	(0.425; 0.579)	0.423	1.6
Perceived behavioral competency	0.074	0.080	0.038	0.051	(−0.007; 0.141)	0.012	1.2
R^2 = 0.621, Stone-Geisser's Q^2-value = 0.512 (desired value >0)							

m, mean; sd, standard deviation.
[a]Complete bootstrapping (option: no significant sign changes, 5,000 samples).
[b]Method: bias-corrected and accelerated Bootstrap.
Source: own data set and calculations.

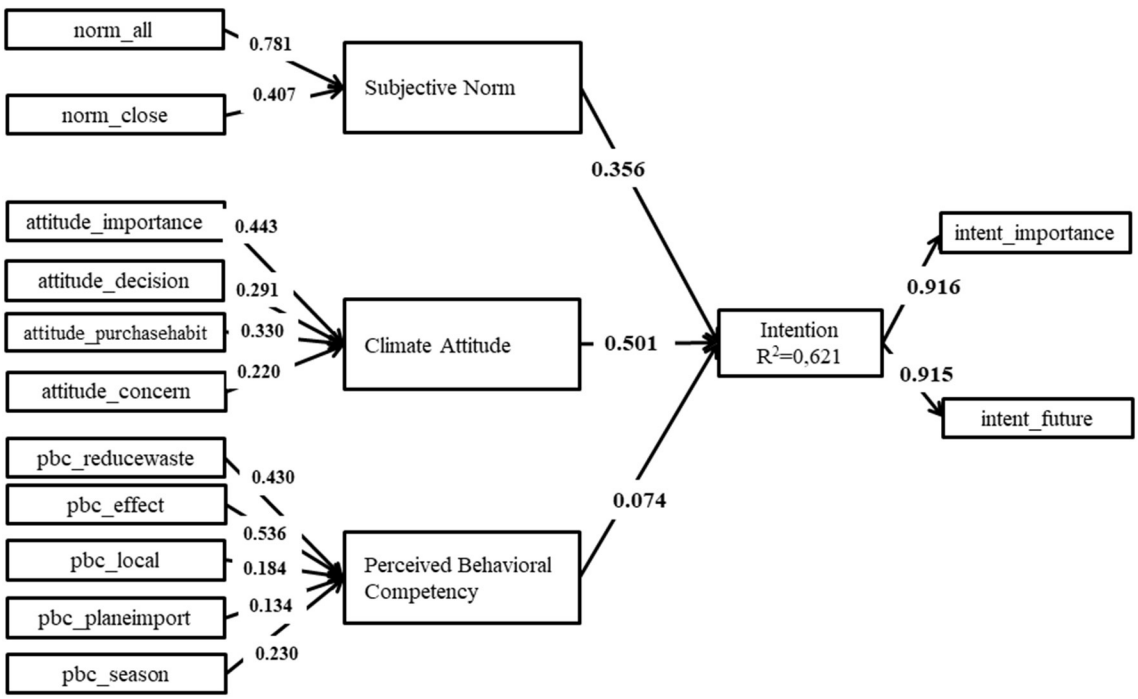

FIGURE 3 | PLS model for Intention of climate-friendly food consumption behavior.

and age groups was conducted. The method makes it possible to check if the specified data groups have significant differences in their group-specific parameter estimates (Hair et al., 2017). However, we did not find any clear differences between the different groups.

DISCUSSION

Motivated by a proven mitigation potential of changing personal diets and a reported positive intention of consumers to act, the aim of this study was, to analyze the factors which influence consumers' behavioral intentions toward climate-friendly food consumption. Using an extended model of the Theory of Reasoned Action a large positive effect of *Climate Attitudes* and a medium positive effect of *Subjective and social Norm* on consumers' behavioral intention toward climate-friendly food consumption was proven. Similar results have been also described in other environment-related fields like the intention toward the purchase or use of green or energy-efficient products or technologies or transportation (Tikir and Lehmann, 2011; Ha and Janda, 2012; Mishra et al., 2014; Paul et al., 2016; Nguyen et al., 2018; Rahimah et al., 2018). Thus, this study showed that in the case of food consumption, individuals intend to behave environmental friendly when they positively appraise this behavior and when they think that people who are important to them believe they should behave in this way. Fishbein (1979) points out the relative importance of the influence of attitude and Subjective and social Norm depends in part on the intention under investigation. In this respect studies from other environment-related fields often found a higher influence of attitude toward the intention compared to the influence of

Subjective and social Norms (e.g., Tikir and Lehmann, 2011; Mishra et al., 2014; Paul et al., 2016). This was also the case in this study. To further induce climate-friendly food consumption behavior, it is particularly important to point out the positive sides of climate-friendly food consumption, for example in the public debate about climate change. In this respect it is especially important to sensitize consumers to the link between personal diets and climate change so people can connect their own food consumption behavior with their personal GHG mitigation potential. For this purpose, the introduction of carbon labels on food products could be beneficial, since they are able to help consumers to identify climate-friendly food products (Emberger-Klein et al., 2015).

Given the medium high influence of *Subjective and social Norm*, other strategies in this context are working with peer groups (Tikir and Lehmann, 2011) or using consumer-based incentives which reward beneficial behaviors instead of sanctioning disadvantageous behavior (Liverani, 2009; Tikir and Lehmann, 2011). Specifically in the field of food consumption behavior, there are additionally several studies which investigated the effect of social-norm-based-messages [for a review see Robinson (2015)]. These are messages which provide subjects with information proposing that other individuals eat e.g., a healthy diet. These studies can help researchers understand whether such messages affect real behavior, how long potential effects may last, and whether these kinds of messages are more efficient than simple reminders to consume healthy foods (Robinson, 2015). Even though the results of interventional studies testing such messages in the field of eating behavior are mixed (Robinson, 2015), evaluating the effect of social-norm-based messages can be an interesting research target for future studies in the field of climate-friendly food consumption. Especially, as healthy and climate-friendly food consumption often go hand-in-hand (e.g., eating more fruit and vegetables saves GHG emissions and is healthy) studies testing the combined effect of both arguments may be worthwhile. Therefore, laboratory experiments and longitudinal studies, as Robinson (2015) suggests for the field of eating behavior, are an interesting methodological approach.

Additionally, in the present study a direct effect of *Perceived Behavioral Competency* regarding the identification of climate-friendly food on the intention to consume climate-friendly food was proposed. The hypothesis was based on different studies which indicate a positive influence of behavioral competency on environmentally responsible behavior (e.g., De Young, 1988; Corral-Verdugo, 1997; Aitken et al., 2016). However, in this study only a small positive, but not substantial influence of the *PBC*-construct on intention toward climate-friendly food consumption was found. There could be several reasons for this: To begin with, the items measuring *Perceived Behavioral Competency* had a strong focus on fruit and vegetables, since these are integral components of a climate-friendly diet. However, procedural knowledge on wider or further aspects of climate-friendly food consumption (e.g., meat or dairy products reduction) may better predict *Intention*. Additionally, Aitken et al. (2016) found that perceived competency directly influences environmentally responsible behavior only in the case of difficult behavior, but not in the case of easy behavior. Due to the results of the descriptive statistics it may be assumed that climate-friendly food consumption was not perceived as very difficult behavior by the respondents. In this case it might be worthwhile to test whether there is an indirect effect of *Perceived Behavioral Competency*, which is mediated through autonomous and controlled motivation, as Aitken et al. (2016) showed in their study.

Besides these main findings, we showed that *Intention* toward climate-friendly food consumption varies between different socio-demographic groups, for example between men and women or individuals of different age groups. These results are consistent with other studies dealing with aspects of climate-friendly food consumption (e.g., Gifford and Comeau, 2011; Gifford and Chen, 2017). Due to these variations it would be useful to follow the suggestion of Gifford and Comeau (2011). They recommended incorporating messages which include elements designed to enhance the intentions of individuals to engage in climate-friendly actions especially in media which are heavily used by groups with low intention levels (e.g., men and younger people). Such messages could e.g., point out the positive aspects of climate-friendly food consumption or use norm-based-strategies. Following the suggestion of Untaru et al. (2016) we included socio-demographic variables in our theoretical framework by investigating if pre-defined socio-demographic groups have significant differences in their group-specific PLS parameter estimates. However, we did not find any clear differences in the parameter estimates of the factors which influence *Intention* between the different socio-demographic groups using multigroup analysis.

Limitations in this study indicate the need for further research: first, in this work individuals' *Intention* of climate-friendly food consumption was analyzed instead of real behavior. However, intention does not always lead to actual behavior (Davies et al., 2002). Thus, future studies could include individuals' actual food consumption behavior to test the full TRA framework. Given the complexity of personal diets as well as the variation of GHG emissions in food products (Hedenus et al., 2014), this target is difficult to achieve, especially when an individual's entire diet is under consideration. In this case large nutritional studies like the National Food Consumption Study (Nationale Verzehrsstudie) in Germany can serve as guides for designing future studies [Max Rubner Insitut (MRI), 2008]. To reduce the complexity of the task, researchers could focus on specific components of personal diets which are known to have large climate impacts (e.g., meat or dairy products consumption). Further, social desirability might play a role in our results (Randall and Fernandes, 1991; Untaru et al., 2016), since we used a self-report survey to investigate individuals' intention within a face-to-face survey. This implies direct contact between a respondent and the interviewer. Thus, future studies could use survey forms which allow more anonymity like e.g., an online survey. This could at least partly reduce the social desirability bias. Finally, our model accounted for 62% of the explained variance in *Intention* of climate-friendly food consumption. Even though this indicates good explanatory power of the model, it seems necessary to detect further variables which affect *Intention* and include them in the TRA framework. This can help to further enhance climate-friendly food consumption behavior and exhaust the

mitigation potential of personal diets. Suggestions for further important antecedents of climate-friendly food consumption can be found in studies dealing with environmental- or climate-related behavior. For example, Untaru et al. (2016) showed that by expanding the proposed TRA model incorporating the variables: environmental concern and doing the activity in daily life, can enhance the predictive power of the proposed TRA model. Also the study by Gifford and Chen (2017) gives valuables insights concerning further antecedents of climate-friendly food consumption *Intentions.* They found: Denial, Conflicting goals, Aspirations, and Tokenism to be significantly correlated with mitigate food choice intentions. Another limitation of the study lies in the operationalization of *Climate Attitudes.* To measure *Climate Attitudes* a shortened version of the Green Consumption Values developed by Haws et al. (2014) was used and the wording of the items was adapted to the focus of this study. While the original scale by Haws et al. (2014) is a validated scale, the changes have not been validated yet. Adapting existing scales to the focus of a study has been realized in previous studies on climate attitudes (e.g., Tobler et al., 2012). Additionally—and most importantly—according to Fishbein and Ajzen (1975)—behavior-specific attitudes are more predictive of intention, than are generic attitudes (Gifford et al., 2011). Thus, a clear reference to "climate" in the formulation of the items used in the study on hand does follow these recommendations. Nevertheless, it is advisable to use validated scales from other studies to measure climate attitudes (e.g., Tobler et al., 2012) in future studies or to validate the adaption of existing scales before carrying out the main survey.

Nevertheless, by using a theory-driven approach our study could point out important factors which influence the Intention toward climate-friendly food consumption. Knowing that *Climate Attitudes* and *Subjective and social Norms* are able to explain a large portion of variance in Intention, it is possible to derive measures for behavioral change with respect to food consumption. Promising measures are for example to sensitize consumers to the link between personal diets and climate change e.g., by introducing carbon labels, by giving targeted information to groups with low intention levels, by working with peer-groups or by using social-norm based information strategies. Given the mitigation potential of personal diets and the described positive intention of individuals to act, future actions in this direction of all responsible actors in food-related value chains are very valuable.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

AE-K and KM contributed to the development of the ideas and the design of the study. AE-K collected the data and performed the data analysis. AE-K and JS wrote the manuscript, which was revised by KM. All authors have read and approved the final manuscript.

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Vegetarian and Vegan Private Label Products as a Challenging Trend in Addressing the Customers Within Sustainable Food Consumption—A Case Study of Slovakia

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The meat consumption at the current level is highly unsustainable. Because of the problems that meat production causes to the environment, it is considered as one of the main problems. Vegetarian and vegan private label products represent a new challenging trend in addressing the customers within sustainable food consumption at affordable prices. The submitted paper aimed to find out whether Slovak consumers know and subsequently buy products of the private brand targeted on vegans and vegetarians, in which product categories they do so, how they perceive them and what attracts and discourages them. The research was carried out in the period from September to December 2020, when a total of 2,011 respondents from all over Slovakia took part. As we have focused only on consumers who know the product line of private labels targeted on vegans and vegetarians (product line of vegan and vegetarian products), we have further analyzed and interpreted only the answers of 978 respondents. For the need to obtain the main aim of the research, we have formulated four theoretical assumptions and five hypotheses, whose veracity was verified with the use of selected statistical methods and techniques processed out at statistical programs XL Stat, SAS Enterprise Guide 7.1. and SAS 9.4. The key finding of our research is, that even if it could be assumed that the products of this specific private label will be bought only by respondents from the vegan or vegetarian category, the opposite is true—the private label is known and bought by the respondents from the category "I eat everything," which means that it is necessary to think about this product line, to wider it and continue in the improvement of its quality as this is what the customers want.

Keywords: private label, vegan, vegetarian, consumer behavior, sustainable food consumption

INTRODUCTION

The meat industry is facing some major sustainability problems. Animal livestock uses a disproportionally large amount of land and the meat industry is also a major source of environmental damage, with the UN describing animal agriculture as "one of the most significant contributors to the most serious environmental problems, at every scale from local to global." Whilst many of the problems associated with animal agriculture could be solved by large percentages of the world's population giving up meat, this seems extremely unlikely, regardless of environmental or ethical reasons. As such, there is a large opportunity for any company that can create a realistic substitute for meat products (Dent, 2020).

How does the market reflect on this challenging trend in sustainable food consumption? Could be also taken into consideration a requirement of many customers for the affordable price of vegan and vegetarian products? The answer comes with the private label vegetarian and vegan product lines.

Marques et al. (2020) stated that private labels have had several different definitions over the years, however, they are commonly known as super and hypermarkets' brands and products, sold exclusively on their stores, alongside other brands (Sutton-Brady et al., 2017).

As Gil-Cordero et al. (2020) state, in general terms, private labels are brands that can be manufactured by the distributor or a manufacturer, managed and marketed by the distributor under the name of the ensign or its brand, and that can be distributed in the ensign's establishments or those of other chains (Lybeck et al., 2006). Private labels represent a significant threat to their national label competitors (Hoch and Banerji, 1993; Anesbury et al., 2020; Bronnenberg et al., 2020; Marques et al., 2020; Pinar and Tulay, 2020). With the development of private labels, individual retailers now play an active role in producing final products. These products, which represent between 10 and 40% of food retail sales in the different countries of the European Union, are a strategic tool used by retailers to increase profits (Gil-Cordero and Cabrera-Sánchez, 2020; Gil-Cordero et al., 2020). It is not surprising that private labels provide additional market power to retailers (Bontemps et al., 2008).

As it was pointed out in several studies (Chan and Coughlan, 2006; Košičiarová and Nagyová, 2014; Lim et al., 2019; Kádeková et al., 2020a; Košičiarová et al., 2020a,b,etc.), one of the characteristic features and at the same time key strategies of retail chains and companies is to address as many customers as possible and, if it is possible, all customer groups, i.e., focus not only on price-sensitive customers but also those who seek for the quality. These realities have to be satisfied by the products or services we have researched, which are collectively referred to as private labels, whose share in Europe, especially in Slovakia, is constantly growing.

The growing market share of private brands began many years before the global economic recession of 2008 (Cuneo et al., 2012). In these receptions, some authors investigated how different macroeconomic variables affected private brand share (Samit and Cazacu, 2016; Gil-Cordero et al., 2020). In this sense and the different receptions, the growth of private labels in Europe and the USA in recent years has been extraordinary, since in the last decade they have become present in more than 90% of the categories of products packaged for the final consumer (Kumar, 2007).

Private labels become not just a source of competitive advantage, but especially a means of building customer loyalty and thus the overall corporate image, which cannot be (by the quality of private labels) only significantly improved but also worsen (Kádeková et al., 2020a). It can be stated that while in Austria the share of private labels (in household expenditure) still represents a level above 40%, in the case of the V4 countries this level is above 30% and it has mostly increased in the case of the Czech Republic, by 1%. Interestingly, while in France private labels represent 1/3 of the sold products, in Switzerland and Spain it is up to ½ products (PLMA, 2020).

However, in according to the results of research by Gfk in 2021, private labels are gaining increasing share in expenses for fast-moving goods. They currently represent a quarter of the market value (25.5%; Mediaguru, 2021).

As Li et al. (2021) explained, that some studies have also focused on the private-brand quality-positioning problem (Chung and Lee, 2017; Nalca et al., 2018). Wang et al. (2021) suggested that the retailer should lower the quality of the store brand to reduce competition intensity with the manufacturer.

It can be said that most chains continue to develop and evolve their brands in response to changing market conditions, the development of science and technology, as well as the customers' needs (Kádeková et al., 2020a,b).

In the case of 2018 and 2020, further positive activities in the area can be observed, as several retail chains (especially Kaufland and Lidl) have introduced new private label product lines focused not only on domestic products and their producers, but also on the development and expansion of the range of foods aimed at people with food intolerances and specific needs when they introduced new categories of private labels such as "K-take it veggie," "K-bio," "K-free," or "Vegan friendly," "Free from"etc.

Although the popularity of vegetarian diets has varied over the centuries, the prevalence of vegetarianism is currently high (Amato and Partridge, 2008; Timko et al., 2012), which can also contribute to sustainable consumption, agriculture, and the economy. The research studies by Segovia-Siapco and Sabaté (2019) and Sanchez-Sabate et al. (2019) mention that in countries like the United States or the UK, vegetarians account for <5% of their respective populations. According to a News Gallup (2020), 5% of U.S. adults consider themselves to be vegetarian and the US vegan population is 3% of adults (News Gallup, 2020). Recognizing the difference between what people eat and what they think they are can explain the inconsistency between the lack of an increase in the number of people who identify as vegetarians and reports of reductions in the consumption of meat (Šimčikas, 2018).

The current position is that the number of people who maintain a vegetarian or vegan diet 100% of the time holds at 3% of the population and still increases. Interest in veganism has reached an all-time high in 2020, based on the data from Google Trends (Google Trends, 2020). It reflects the notable rise

in popularity of plant-based diets and vegan lifestyles around the world (Ho, 2021).

"Vegetarianism" refers to a spectrum of inter-related food selection and food avoidance patterns (Beardsworth and Keil, 1993). Technically, ovo-vegetarians include eggs but no dairy products in their diet, Lacto-vegetarians include dairy products but exclude eggs, and Lacto-ovo vegetarians include both eggs and dairy products in their diet (Messina and Burke, 1997; Trautman et al., 2008). Semi-vegetarians restrict the type of meat they consume only to a certain extent, with some consuming only fish (Pesco-vegetarian), some only poultry (Pollo-vegetarian), and some consuming both fish and poultry (Pesco Pollo vegetarians). Finally, individuals who adhere to a vegan diet exclude all red meat, fish, poultry, dairy, and other animal-origin foods such as eggs from their diets, and generally also avoid non-edible animal products such as leather (Vegan Official Labels, 2020).

Šedík et al. (2017) have pointed out, that hypermarket Kaufland responded to changing trend in food consumption by creating its private label brand "K-take it veggie." All these products are offered to consumers with conscious consumption (Kaufland.sk, 2021).

In a new retail landscape, retailers have realized that the most important engine to drive both growth and profitability is strategically building private labels (Gangwani et al., 2020).

The submitted contribution is focused on the issue of specific categories of private labels, specifically private labels designed primarily for vegans and vegetarians, where we try to prove and find out whether these products have their place in the private label market, whether they have found their customer and whether this customer is just a vegan/vegetarian.

MATERIALS AND METHODS

The submitted contribution intended to point out the fact that Slovak consumers are starting to focus on new categories of private labels, specifically on vegan/vegetarian products, which are still just looking for their regular consumers. For this reason, the main aim of our research was to find out whether Slovak consumers know and subsequently buy products of the private brand targeted on vegans and vegetarians, in which product categories they do so, how they perceive them and what attracts and discourages them.

The research was carried out in the period from September to December 2020, when a total of 2,011 respondents took part in it (based on the mentioned, our sample can be considered reliable, as $n \geq 1{,}849$ at a 99% confidence level and 3% margin of tolerable mistakes).

As we have focused (in the research) only on consumers who know the product line of private labels targeted on vegans and vegetarians (product line of vegan and vegetarian products), we have further analyzed and interpreted only the answers of these respondents and thus their final number was 978 (the sample is reliable at 99% confidence and 5% margin of tolerable mistakes, as $n \geq 665.64$). The specific representation of respondents can be seen in **Table 1**.

For the needs of fulfilling the main aim of the research, we have formulated the following theoretical assumptions, which we wanted to confirm, or refute by the research:

- Assumption 1—we assume that the private label targeted on vegans and vegetarians is bought only by vegans, resp. vegetarians,
- Assumption 2—the most frequently purchased food under the private label targeted on vegans and vegetarians is tofu,
- Assumption 3—the quality of products labeled with private brands targeted at vegans and vegetarians is comparable to the quality of similar products of traditional brands,
- Assumption 4—respondents from the selected aspects of products under the private label targeted on vegans and vegetarians evaluate as the best their quality level.

Subsequently, we have formulated the following statistical hypotheses:

- H1 there is no dependence between the consent to the statement and the form of the respondent's diet,
- H2 there is no dependence between the purchase of the private label targeted on vegans and vegetarians and the form of the respondent's diet,
- H3 there is no dependence between the consumption of specific products of the private label targeted on vegans and vegetarians and the respondent's sex,
- H4 there is no dependence between the perception of the quality of products labeled with the private label targeted on vegans and vegetarians and the preference for their purchase,
- H5 there is no dependence between the preference of products labeled with the private label targeted on vegans and vegetarians and the comparability of the quality of its products,

whose veracity was verified with the help of selected statistical methods and techniques. We have tested the above-mentioned hypotheses with the help of statistical programs XL Stat, SAS Enterprise Guide 7.1. and SAS 9.4, where we have used the statistical methods, techniques and tests such as:

- Pearson's Chi-square goodness of fit test—which is a statistical test applied to sets of categorical data to evaluate how likely it is that any observed difference between the sets arose by chance (Pearson, 1900),
- Cramer's contingency coefficient—which is a measure of association between two nominal variables, giving a value between 0 and +1 (inclusive). It is based on Pearson's chi-squared statistic and was published by Cramer (1946),
- Pearson's correlation coefficient—is a measure of linear correlation between two sets of data. It is the ratio between the covariance of two variables and the product of their standard deviations; thus it is essentially a normalized measurement of the covariance, such that the result always has a value between −1 and 1 (University Libraries, 2022),
- Phi coefficient—is a measure of association for two binary variables. In machine learning, it is known as the Matthews correlation coefficient (MCC) and it is used as a measure of the

TABLE 1 | Characteristics of respondents.

Category of respondents	Number	Net monthly income of the household	Number
Men	223	Up to 500 €	74
Women	755	501–800 €	106
The age structure of respondents		801–1,100 €	191
<17 years	42	1,101–1,500 €	245
17–20 years	136	Over 1,501 €	362
21–30 years	644	**Number of household members**	
31–40 years	101	One member	93
41–50 years	37	Two members	309
51–60 years	11	Three members	221
61–70 years	3	Four members	289
Over 70 years	4	Other	66
The educational structure of respondents		**Place of residence of the respondents**	
Primary education	62	A city with a population of over 100,000	207
Secondary education without GCSE	39	City with population from 10,000 to 19,999	32
Secondary education with GCSE	397	A city with a population from 2,000 to 4,999	87
Higher education I. degree	256	A city with a population from 20,000 to 49,999	190
Higher education II. degree	208	A city with a population from 5,000 to 9,999	113
Other	16	City with population from 50,000 to 99,999	132
The economic activity of respondents		A town/village with a population of up to 999	108
Student	448	A town / village with population from 1,000 to 1,999	109
Employed	379	**Region of**	
Unemployed	26	Banská Bystrica	66
Self-employed person	69	Bratislava	238
Maternity leave	33	Košice	43
Retired	9	Nitra	298
Other	14	Prešov	43
		Trenčín	125
		Trnava	93
		Žilina	72
Total number of respondents			**978**

Source: Results of the questionnaire survey.

quality of binary classifications (Matthews, 1975). Introduced by Karl Pearson (Cramér, 1976) and also known as the Yule phi coefficient from its introduction by Yule (1912) this measure is similar to the Pearson correlation coefficient in its interpretation—Pearson correlation coefficient estimated for two binary variables will return the phi coefficient (Guilford, 1936). The phi coefficient is related to the chi-squared statistic for a 2×2 contingency table,

- Friedman's test—is a non-parametric statistical test developed by Friedman (1937) and it is used to detect differences in treatments across multiple test attempts. The procedure involves ranking each row (or block) together, then considering the values of ranks by columns (Friedman, 1940),
- Kruskal-Wallis—is a non-parametric method for testing whether samples originate from the same distribution. It is used for comparing two or more independent samples of equal or different sample sizes. It extends the Mann–Whitney *U*-test, which is used for comparing only two groups (Kruskal, 1952),
- the Correspondence analysis—is a multivariate statistical technique, which offers a visual understanding of relationships between qualitative (i.e., categorical) variables. Correspondence analysis is a method for visualizing the rows and columns of a table of non-negative data as points in a map, with a specific spatial interpretation. Data are usually counts in a cross-tabulation, although the method has been extended to many other types of data using appropriate data transformations (Greenacre, 2001), and
- Categorical principal component analysis (CATPCA) with Varimax rotation and Kaiser normalization—which is appropriate for data reduction when variables are categorical (e.g., ordinal) and the researcher is concerned with identifying the underlying components of a set of variables (or items) while maximizing the amount of variance accounted for in those items (by the principal components; Data Science and Analytics, 2022). This method has shown a great potential when applying for validation of questionnaire especially for Likert scale or different measures due to optimal scaling.

Furthermore, it explains higher variance in comparison to FA or PCA (Campos et al., 2020). CATPCA was applied for ordinal data obtained from respondents who evaluated selected aspects regarding vegetarian and vegan private label products (5-points scale was applied).

RESULTS AND DISCUSSION

Based on results of research by Dodds et al. (1991), Sweeney and Soutar (2001), Flavián et al. (2006), Vahie and Paswan (2006), Liljander et al. (2009), Beneke et al. (2013), Diallo (2012), Diallo et al. (2013), Beneke and Carter (2015), and Gfk (2021) and many others can be concluded the private labels have found their important place worldwide. Also in Slovakia, the Slovak consumers recognize and purchase private label products more often, which was proved by the research agencies such as IRI, Nielsen, Gfk Slovakia, TNS Slovakia, etc. This fact was supported also by findings and results of our research, which we have been conducting since 2014 when we recorded the major shifts in the perception and evaluation of private labels by Slovak consumers.

As for the specific interest of Slovaks in the private labels, it can be said that as in the case of retail chains and customers, their interest in them is constantly growing—this is confirmed not only by the representatives of the most important retail chains operating in Slovakia but also by the results of research by Nielsen (2019) that found out that revenues from private labels exceeded 4 billion EURO in 2018, which means that they have increased by 0.5% year-on-year (the share of private labels on the Slovak market accounts for more than 1/5 of the total turnover of fast-moving products and maintains approximately the same level).

Nielson's Report (2018) that "The largest markets for private-label products are found primarily in the more mature European retail markets." Regarding the exposure of private labels, we can also talk about a significant shift, as the results of research conducted by Go4insight (conducted for the Slovak Food Chamber in 2019; Tovarandpredaj, 2017) show that while in 2013 the share of private labels was longer at the level of 20%, in 2019 it was found that this share increased by 1.3% (compared to the previous year) and it has reached a level of more than 25%. Most private labels are represented on the shelves of retail chains Lidl (56%), followed by Kaufland and Coop Jednota (23%) and the lowest share is held by the CBA chain at 13%. Interesting findings of the mentioned research are that private labels in Slovakia have the largest representation in the category of food in discount stores and warehouses, where their share is up to 50%; the share of private labels on store shelves in Slovakia is as follows—milk (68%), canned products (40%), packaged meat products (42%), pasta (39%), natural cheeses (37%), other dairy products (35%), oils (34%), packaged long-life bread (31%), soft drinks (29%), processed products (27%), water and mineral water (24%), chocolate confectionery (22%), non-chocolate confectionery (12%) spirits (9%), beer (9%), and wine (6%); the share of private labels is 25%, with 18% representing foreign production and the remaining 7% domestic, Slovak. At the same time, most foreign private labels are displayed in the Lidl chain, up to 51% (Kádeková et al., 2020a). Unfortunately, as far as the vegan product category is concerned, there is no detailed database yet that can be used as a basis for evaluating how many of these products are represented in the private label category. However, this is a modern trend and it is therefore highly likely that the number/share of the products in question will continue to increase over time.

Muruganantham and Priyadharshini (2017) pointed out that the highest number of research studies were carried out in the food and grocery product category as a leading private label's research area. In terms of the percentage of private labels in individual product categories, it can be said that in Europe, private labels are currently mostly represented in the category of frozen and chilled foods, or detergents, animal feed and consumer food (IRI, 2018; **Figure 1**); or to the fact that according to the results of research carried out by IRI in 2017, household cleaners (36.2%), personal care products (34.2%) and hygiene products (36.4%), resp. alcoholic beverages (26%), frozen meals (24.8%) and ready meals (22.2%) are the most preferred product lines in Greece. The results of Nielsen's research from the same year carried out in the Czech Republic show that Czechs prefer private milk and dairy products (average 31.25%), cooking oils (36%), canned food (average 34%), salty snacks (29%), packaged bread (27%), or sweet packaged pastries (25%) and juices (22%).

As far as customers themselves and thus consumers are concerned, a significant shift in the perception and purchase of private labels can be also observed. While the results of research carried out by the GfK Slovakia in 2010 show, that every Slovak household has popular brands in its usual and regular purchases, which it prefers, while in some categories of goods there is a stronger preference for brands, resp. while in the case of long-life milk, "less prestigious" private labels account for almost 80% of total consumption (TASR, 2010); thus, the results of a survey conducted by TNS Slovakia in June 2012 clearly stated that the most popular private labels are TESCO brands (49% of respondents), COOP Jednota (44% of respondents), Kaufland (32% of respondents), Billa (23% of respondents), and CBA (21% of respondents); and that products sold under the private labels of the COOP Jednota and TESCO are bought by women rather than by men (Fedorková, 2012). These then underline and supplement our findings in the given area, when in 2014 we found out, that of a total of 644 respondents, up to 57% of respondents purchase the private labels regularly, up to 17% explicitly prefer them over traditional brands (especially in the case of the TESCO retail chain), and that the most frequently purchased categories of private labels include milk and dairy products, salty snacks and water, lemonades and juices (Nagyová and Košičiarová, 2014). In the case of our further research, we have gradually recorded a slight shift in the area, as in 2020 we have found out, that of the total number of 1,190 respondents, up to 81.26% buy private labels (of which 28.49% buy them regularly and 52.77% buy them sporadically); furthermore, up to 30.17% explicitly prefer them in their purchases over traditional brands; up to 39.83% buy mainly classic private labels; and that as far as specific product categories are concerned, private labels are most often purchased in the product categories milk and dairy products, then mineral waters, lemonades and juices, salty

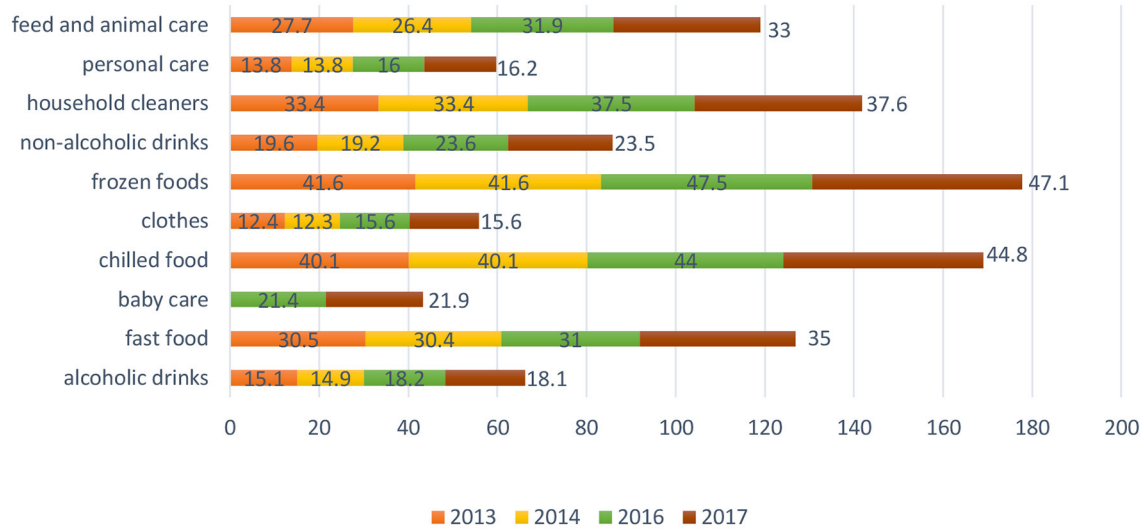

FIGURE 1 | Percentage of private labels in individual product categories in Europe (2013 and 2014, resp. 2016 and 2017). Source: own processing according to available sources.

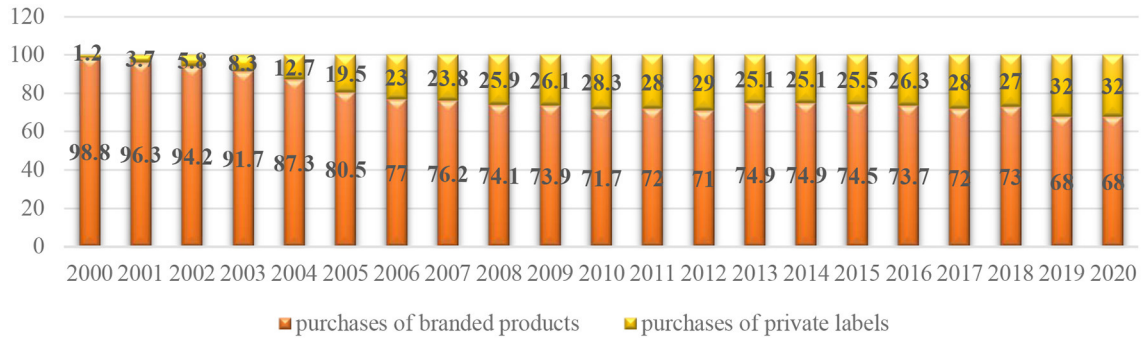

FIGURE 2 | Percentage share of purchases of branded products and products sold under private labels in Slovakia. Source: own processing according to available sources.

delicacies, confectionery, delicacies and preserves, frozen semi-finished products, meat and fish, respectively coffee and tea and at least in product categories ready meals and alcoholic beverages (Košičiarová, 2020).

According to Yang (2012), the perceived quality disparities amongst private label brands and national brands are an important determining of intention to purchase. Private labels perceived quality directly affects the purchase intent of consumers toward private labels brands (Liljander et al., 2009; Yan et al., 2019). The findings of such studies conclude that the higher the strength or the more favorable the perception, the more likely the consumer will purchase the private labels and develop patronage toward them. Therefore, it can be assumed that private labels perceived quality has a positive effect on the consumer's private labels purchase intention (Gangwani et al., 2020).

Based on the results in **Figure 2**, it can be said that purchasing or the preference of private labels by the Slovak consumers has an increasing tendency, which is largely caused not only by the lower price of the products but also by higher confidence in them, respectively their ever-increasing quality, which in many cases becomes not only comparable but also higher compared to traditional brands.

As we have in 2020 also focused on the research on how Slovak respondents perceive private labels, whether they are their end-users and whether they also buy them in new and specific categories of private labels (a total of 1,120 respondents participated in the given research)—when our results show that Slovaks buy private labels not only in the food segment, but also in the category of cosmetics and cleaning products, where they buy them every month, or in the category of clothing, which they buy mainly depending on the current offer; further that up to 45.45% of respondents buy also specific types of private labels, such as e.g., organic assortment, gluten-free assortment, low-fat assortment, etc., and they buy them mainly due to a healthy lifestyle (36.45% of respondents); respectively that

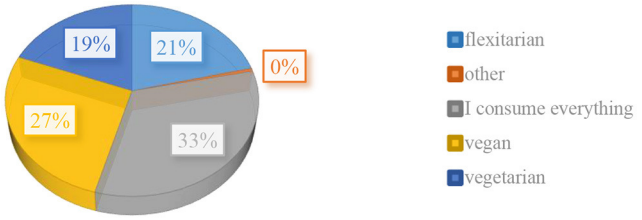

FIGURE 3 | Form of diet (in %). Source: Results of the questionnaire survey.

they are also the end-users of private label products (61.52% of respondents; Kádeková et al., 2020a,b). Perceived value is revealed to absolute influence consumer willingness to buy a product (Sweeney and Soutar, 2001). Furthermore, price-quality linkages significantly influence private labels purchase, especially in a category that consumers perceive as riskier (Sinha and Batra, 1999). Consumer's perceived value is debatably the most decisive determinant factor of purchase intention (Gangwani et al., 2020).

The submitted research paper focuses on those private labels, which aim to address customers with specific needs and requirements. As we have pointed out in the Material and Methods Section, the main aim of our research was to find out whether Slovak consumers know and subsequently buy products of the private brand targeted on vegans and vegetarians, in which product categories they do so, how they perceive them and what attracts and discourages them.

A total of 2,011 respondents participated in the research, of which up to 978 respondents (i.e., 48.67%) know, and 709 respondents (i.e., 35.26%) regularly buy products of the given private label, i.e., vegan products. The specific representation of respondents can be seen in **Table 1**, from which it is clear that in the case of our research the most represented were women (77.2%), respondents aged from 21 to 30 years (65.85%), respondents with secondary education (40.59%), students, respectively employed people (45.81 and 38.75%), households with two members (31.6%) and net monthly family income over 1,501 € (37.01%), respondents from a city with a population over 100,000 (21.17%) and respondents from Nitra and Bratislava region (30.47 and 24.34%).

At the same time, our results bring many interesting findings, especially the fact that even if it could be assumed that the given products are known and bought only by vegans, resp. vegetarians, it is not quite so—from the above sample of respondents (i.e., 978) up to 32.72% stated that in terms of consumption/their diet they fall into the category "I eat everything" (**Figure 3**; assumption 1 was not confirmed).

Nezlek and Forestell (2020) stated that not enough attention has been paid to possible differences among types of vegetarians, including differences in why people are vegetarians. Some research suggests that vegans are meaningfully different from other types of vegetarians (Matta et al., 2018; Nezlek et al., 2018; Rosenfeld, 2019), but more attention needs to be paid to possible differences between vegetarians who have similar eating habits but different reasons for being vegetarians. As noted by Rosenfeld (2018) as well as by Nezlek and Forestell (2020), the recent research converges to suggest that the three most common motivations among vegetarians are concerns about animals, health, and the environment. It is important to note that these motives are not mutually exclusive. Most vegetarians report being motivated by a combination of motives to adopt a vegetarian diet (Janssen et al., 2016; Rosenfeld and Burrow, 2017a,b; Armstrong Soule and Sekhon, 2019). Finally, some people may be motivated to adopt a plant-based diet by the appeal of the "idea" of being vegetarian. This is referred to as social identity motivation and reflects the desire to identify with a social group because of its perceived positivity and potential benefits for one's self-esteem (Plante et al., 2019).

In our research, we were interested in the respondents' opinions on individual statements about veganism and vegetarianism, in the questionnaire survey we have also formulated certain statements to which the respondents had to react in the range of answers, i.e., on a scale from 1 to 5, where 1 meant I disagree at all and 5 I strongly agree. We have then looked at the answers not only in terms of which statement the respondents agree with the most and with which the least, but also whether there is a dependence between agreeing with the statement and the form of the respondent's diet.

As it can be seen from **Tables 2**, **3**, our respondents mostly agree with the statement *"Vegetarianism means the exclusion of any food from animals—meat, fish, eggs, milk, and insects"* and the least with the statement *"I was a vegetarian, but I returned to classic diet for health reasons"* (so we have the least respondents of this category), respectively it can be seen that there are indeed dependencies between the level of agreement with the statement in the form of the respondent's diet, where these dependencies indicate higher levels of agreement between respondents from the vegan and vegetarian categories (**Table 3**, highlighted in yellow).

As our research further shows, up to 45.81% of respondents buy a given private label sporadically and another 26.69% buy it regularly, while we have shown a clear relationship between buying the given private label and the form of respondent's diet (p-value was at the level of significance $\alpha \leq 0.001$, the value of the Phi coefficient was equal to 0.5747 and the value of the Cramer's coefficient was 0.4064, which indicates a mean and at the same time statistically significant dependence). As we were interested, how often do the respondents buy or consume the researched private label products, we have focused on the given questions in the questionnaire survey. The results of our research show, that our respondents most often consume and at the same time buy tofu, vegetable cream and soy yogurt (almost daily; assumption 2 was confirmed). The least purchased foods in a given range of private labels are lasagne, vegetarian candies, vegetarian bullets and burger pancakes, which are bought and consumed only occasionally, or not at all. From the point of view of statistical evaluation of the obtained data, it proved to us that again it is true that the given products are rather bought and consumed by vegans and vegetarians, respectively, by women rather than men, where the preference was found for products such as tofu, lasagne, vegetable cream and soy yogurt (**Table 4**).

Subsequently, we have focused on the perception of the range of private labels in terms of their quality level, comparability

TABLE 2 | Results of the Friedman's test (statements).

Friedman's test:	
Q (Observed value)	5,542.221
Q (Critical value)	33.924
DF	22
p-value (Two-tailed)	<0.0001
alpha	0.05

Sample	Frequency	Sum of ranks	Mean of ranks	Groups
I have been a vegetarian/vegan, but I have returned to the classic diet (because of health reasons).	978	4,599.5	4.703	A
Vegetarianism is not natural for humans and that is why I do not support it.	978	6,533	6.680	B
I prefer Vegetarianism /Veganism because my health, indulgence and love for animals are secondary to me.	978	7,784	7.960	C
There are plenty of Vegan products on the market.	978	8,403	8.592	C D
I have my favorite brand of veggie products.	978	9,390	9.601	D E
A vegetarian diet is not more expensive than a conventional type of diet.	978	9,967	10.191	E F
I'm not a vegetarian/vegan and I still like to buy vegetarian/vegan products. They are a healthy and tasty alternative to my diet.	978	9,972	10.196	E F
Thanks to the transition to vegetarianism/veganism, I feel happy.	978	10,718	10.959	F G
There are plenty of vegetarian products on the market.	978	11,331	11.586	G H
I buy various brands of veggie products.	978	11,513.5	11.772	G H
Vegetarianism carries certain risks that one may or not cope with, such as vitamin B12 deficiency.	978	11,691.5	11.954	G H
Vegans live longer on average, suffer much less from heart disease and cancer, have more energy and are less obese.	978	11,788	12.053	G H I
Veganism is a lifestyle, a belief that is for the whole life.	978	11,994.5	12.264	H I
Vegetarian/Vegan products are produced socially responsibly and in accordance with the environment.	978	12,092	12.364	H I
Vegetarianism allows us to make the world a better day every day.	978	12,816	13.104	I J
The food menu for vegans could be more varied.	978	13,493.5	13.797	J K
Vegetarianism includes a very wide range of eating styles. The general principle is to partially or completely limit the consumption of animal products.	978	13,502	13.806	J K
Consumption of animal products and animal husbandry results in huge pollution and associated environmental problems.	978	14,206.5	14.526	K L
Vegetarianism/Veganism is a health care that represents a certain lifestyle, a philosophy of life, based on respect for animals and their rights, protection of nature.	978	14,674	15.004	L M
Vegetarianism/Veganism is a personal belief.	978	14,736	15.067	L M
I do not agree with the industrial processing of meat and the breeding of animals in undignified conditions.	978	15,460	15.808	M N
Veganism is different from vegetarianism. Not all vegans are vegetarians, but all vegans are vegetarians.	978	16,520	16.892	N O
Veganism means the exclusion of any food from animals - meat, fish, eggs, milk and insects.	978	16,742.5	17.119	O

Source: Results of the questionnaire survey, output of the XL Stat program.

of quality and subsequent preference for purchase by our respondents. The results of our research show that the respondents are generally satisfied with the range of these private labels-−79.27% of respondents perceive the quality level of private labels targeted on vegans and vegetarians as good or appropriate; in terms of quality comparability 48.8%, respectively, 22.28% of respondents think that it is rather, respectively, certainly comparable to the quality of similar products of traditional brands; in 79.27% of respondents the given private label evokes adequate quality at a reasonable price and up to 31.59% of respondents prefer the products of the given private label to traditional brand products in their purchase (12.13% explicitly prefer them; assumption 3 was confirmed). From the point of view of the results of the correspondence analysis, which is also called as a reciprocal averaging, and which is a useful data science visualization technique for finding out and

TABLE 3 | Results of the Kruskal–Wallis Test (dependence between agreement with the statement and the form of the respondent's diet).

Variable/Test	Kruskal–Wallis
Vegetarian / Vegan products are produced socially responsibly and in accordance with the environment.	**<0.0001**
Veganism means the exclusion of any food from animals - meat, fish, eggs, milk and insects.	**<0.0001**
Veganism is different from vegetarianism. Not all vegans are vegetarians, but all vegans are vegetarians.	**<0.0001**
Vegetarianism includes a very wide range of eating styles. The general principle is to partially or completely limit the consumption of animal products.	0.315
Vegetarianism carries certain risks that one may or not cope with, such as vitamin B12 deficiency.	0.116
Vegans live longer on average, suffer much less from heart disease and cancer, have more energy and are less obese.	**<0.0001**
Vegetarianism allows us to make the world a better day every day.	**<0.0001**
Veganism is a lifestyle, a belief that is for the whole life.	**<0.0001**
A vegetarian diet is not more expensive than a conventional type of diet.	**<0.0001**
I buy various brands of veggie products.	**<0.0001**
Thanks to the transition to vegetarianism/veganism, I feel happy.	**<0.0001**
The food menu for vegans could be more varied.	**<0.0001**
Vegetarianism/Veganism is a personal belief.	**<0.0001**
I prefer Vegetarianism/Veganism because my health, indulgence and love for animals are secondary to me.	**<0.0001**
There are plenty of vegan products on the market.	0.182
There are plenty of vegetarian products on the market.	**<0.0001**
Vegetarianism is not natural for humans and that is why I do not support it.	**<0.0001**
I do not agree with the industrial processing of meat and the breeding of animals in undignified conditions.	**<0.0001**
I'm not a vegetarian/vegan and I still like to buy vegetarian/vegan products. They are a healthy and tasty alternative to my diet.	**<0.0001**
Consumption of animal products and animal husbandry results in huge pollution and associated environmental problems.	**<0.0001**
Vegetarianism/Veganism is a health care that represents a certain lifestyle, a philosophy of life, based on respect for animals and their rights, protection of nature.	**<0.0001**
I have my favorite brand of veggie products.	**<0.0001**
I have been a vegetarian/vegan, but I have returned to the classic diet (because of health reasons).	**<0.0001**

Source: Results of the questionnaire survey, output of the XL Stat program.

displaying the relationship between categories (Tibco.com, 2022; **Figure 4**), it can be said that it applies that those respondents who perceive the quality of the private label and its products as good and high also think that it is comparable to the quality of traditional brand products and they have a fundamental preference for the given private label.

The above-mentioned dependence between the preference of the products of the private label targeted on vegans and vegetarians and the perception of the quality of its products, resp. the dependence between the preference for products labeled with the private label targeted on vegans and vegetarians and the comparability of their quality is confirmed by the results obtained from SAS Enterprise Guide 7.1, which show a statistically significant dependence, but this dependence is perceived as small rather than medium (p-value was in both cases at the significance level $\alpha \leq 0.001$, the value of the Phi coefficient was equal to 0.4434 in the case of H4 and the value of the Cramer coefficient of 0.2217 and in the case of H5 0.3676 and 0.1838, which indicates a weak and statistically significant dependence).

The last questions we have focused on in our questionnaire survey are the questions:

- concerning the evaluation of selected aspects of vegan products of the private label targeted at vegans and vegetarians, where the respondents had on the scale of 1–5, where 1 meant very low and 5 very high, to evaluate aspects such as the level of promotion, price level, breadth of assortment, the attractiveness of design/packaging, level of quality, and overall acceptability of products; and
- regarding the decisive factors in the purchase of a given private label and the disincentives to purchase it.

The results of our research declare that in terms of perception, resp. evaluations of selected aspects are rated as the best acceptability of products and their quality level, as in these aspects the respondents gave the highest ratings (**Appendix A**; assumption 4 was confirmed), in terms of decisive factors "playing" in favor of purchasing private label products are the good previous experience and reasonable price and quality (**Appendix B**) and the factor that mainly discourages from the purchase of these products is their taste (**Appendix C**).

In addition, by applying CATPCA on selected aspects of the private label targeted on vegans and vegetarians we obtained a deeper insight into respondents' evaluations. Test explained 62.8 of variance and identified two latent factors based on component loading (**Figure 5**). The first latent component includes price and quality level. The second component involves promotion level, assortment width, attractiveness packaging, and product's overall acceptability.

Marangon et al. (2016) also examined consumers' awareness of vegan food, to investigate the consumers' attitudes and preferences toward vegan food products. Factors related to the country of origin were found to be critical in the purchasing process. Assortment width and quality belong to one of the most important factors when purchasing vegetarian/vegan food products, however, the results suggested that only 8% of customers are willing to pay a premium price. Based on results by Kapoor and Kumar (2019) and Underwood and Klein (2002), Yildirim et al. (2017), the attractiveness of products packaging is important especial for young people. For customers older than 25 is much more important the information provided by the producer on the packaging. Consumers tend to search for a vegan indicator and use their brand beliefs to give the conclusion of whether the product is vegetarian/vegan suitable. The result

TABLE 4 | Results of the Kruskal–Wallis test (dependence between the consumption of specific products of the researched private label and the respondent's sex).

Variable/Test	Kruskal–Wallis
[Vegetable milk— soybean]	0.129
[Vegetable milk—almond]	0.573
[Vegetable milk—rice]	0.451
[Vegetable milk—oats]	0.573
[Tofu]	**0.035**
[Lasagne]	**<0.0001**
[Falafel]	0.662
[Vegetarian nuggets]	0.745
[Burger pancakes]	0.251
[Vegetarian steak]	0.697
[Vegetarian bullets]	0.780
[Vegetable cream]	**0.010**
[Soy yogurt]	**0.024**
[Vegetarian ham]	0.484
[Vegetarian ice cream]	0.073
[Vegetarian candies]	0.586

Source: Results of the questionnaire survey, output of the XL Stat program.

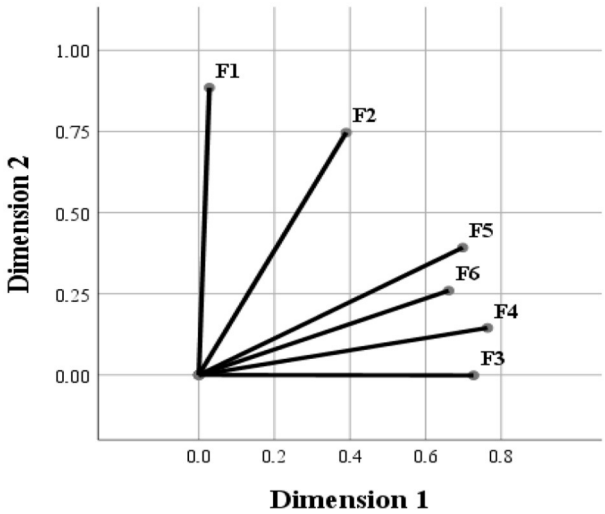

FIGURE 5 | Purchasing factors analyzed by CATPCA. Source: Results of the questionnaire survey, output of the SPSS version 25. F1- price level, F2- quality level, F3- promotion level, F4- assortment width, F5- product's overall acceptability, F6- attractiveness of packaging.

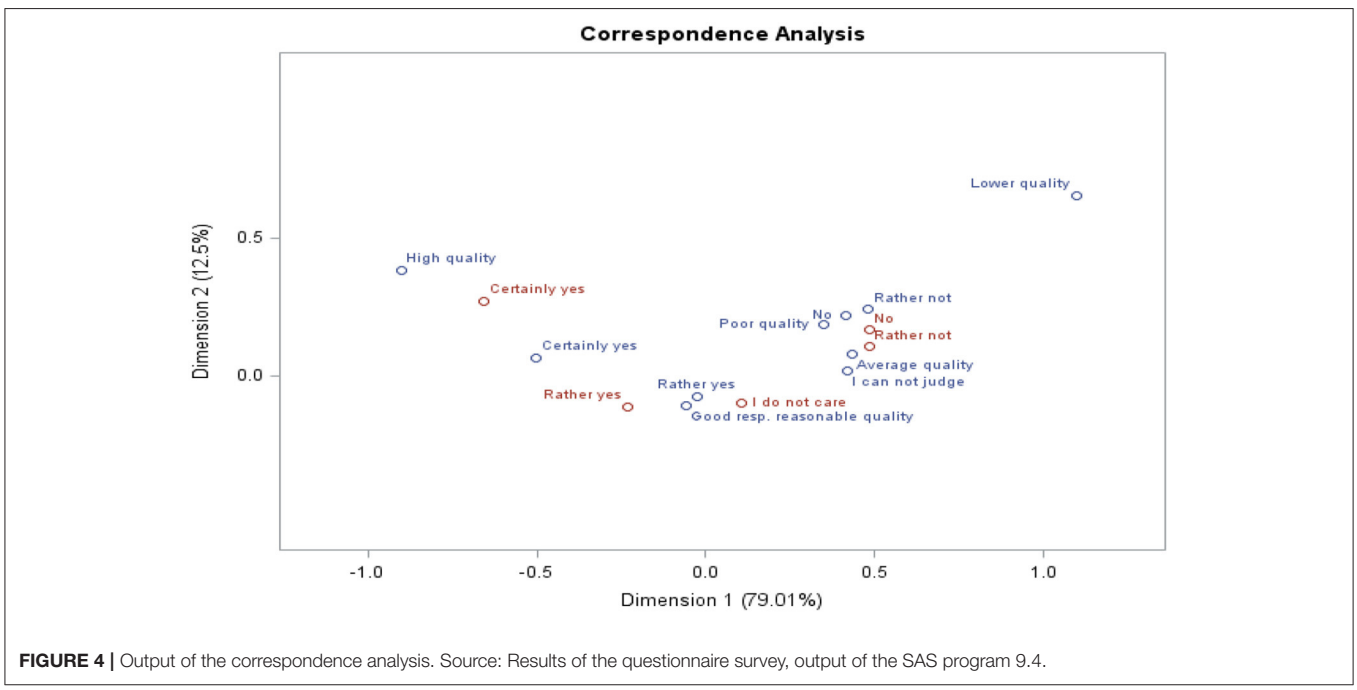

FIGURE 4 | Output of the correspondence analysis. Source: Results of the questionnaire survey, output of the SAS program 9.4.

shows the role of the vegan indicator in the vegan product label. In this context can be concluded that the promotion level of vegetarian/vegan products belongs to the least important factors influencing the purchasing behavior of the customers worldwide.

CONCLUSION

Purchasing affordable vegetarian and vegan products could be a solution to the problem regarding the sustainability of meat production and its consumption and also a new challenging trend. The submitted contribution intended to point out the fact that Slovak consumers are starting to focus on new categories of private labels, specifically on vegan/vegetarian products, which are still just looking for their regular consumers. For this reason, the main aim of our research was to find out whether Slovak consumers know and subsequently buy products of the private label targeted on vegans and vegetarians, in which product categories they do so, how they perceive them and what attracts and discourages them. The research was carried out on a sample of 2,011 respondents, where it was found that even though up to 48.67% of respondents know the given private label, only 35.26% of our respondents are its real consumers and users, so, indeed, the private label is still looking for its customers. However, our results point to another interesting finding, and therefore that even if it could be assumed that the products of this private label will be bought only by respondents from the vegan or vegetarian category, the opposite is true—the private label is known and bought by a respondent from the category "I eat everything." To fulfill the main aim of the article, we have formulated a total of four theoretical assumptions and five statistical hypotheses, based on the evaluation which we can say that three theoretical assumptions were confirmed and all examined dependencies were proved, although in some cases it can be said that they are weak rather than moderate addictions.

The importance of submitted research is highlighted by the fact that private labels have been growing. However, we realize that our research has also some limitations and barriers. We focused just to the limited area of Slovakia. There is also a fact that solved problem is evolving over time and situation described in the submitted paper may change in close future. This is the point from which further possibilities and trends for future research can arise. In terms of our recommendations for practice and possible limits of the research can be said unequivocally that we are aware that this research is unique and specific and therefore it is not possible to provide a thorough discussion of our findings—the area of private labels is largely researched by us, as far as new and specific categories of these brands are concerned, there are still large gaps and reserves in the market. Therefore, we perceive this contribution as original and unique in the subject area and it can therefore serve as a guide for further similar research, whether in this area or even from managerial, economic or marketing point of view. Results of our research could be also used in the practice by food companies and sellers. As our results show that these products are also bought by omnivorous consumers, it is clear that chains should focus on the better promotion of these products, as it is still true that several respondents are unaware of this type of private label and therefore they do not buy me. In terms of the quality level of these products, our respondents are generally satisfied, but the possibilities for improvement can be still found and the customer regularly asks for them. It is questionable whether the chain wants to go into a "bigger" fight for a potential customer, but since it is still true that private labels are a source of competitive advantage and a means of building a positive corporate image (Košičiarová, 2020), we think it will pay off.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

IK, ZK, PS, and LS contributed to all steps of research (concept, questionnaire, data collecting), database and manuscript as well as a literature review. IK, ZK, and PS did statistical evaluation. All authors contributed to manuscript revision, read, and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.858048/full#supplementary-material

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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

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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.

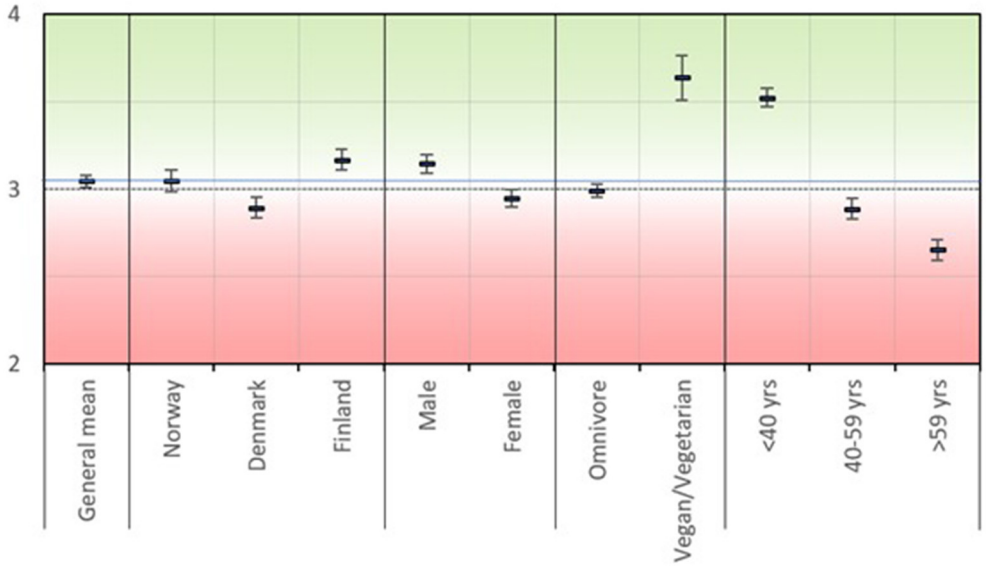

FIGURE 1 | Mean ratings of the general attitude of cultured protein by consumers. The thin blue line represents the general mean across all respondents. The error bars represent 95% credibility intervals.

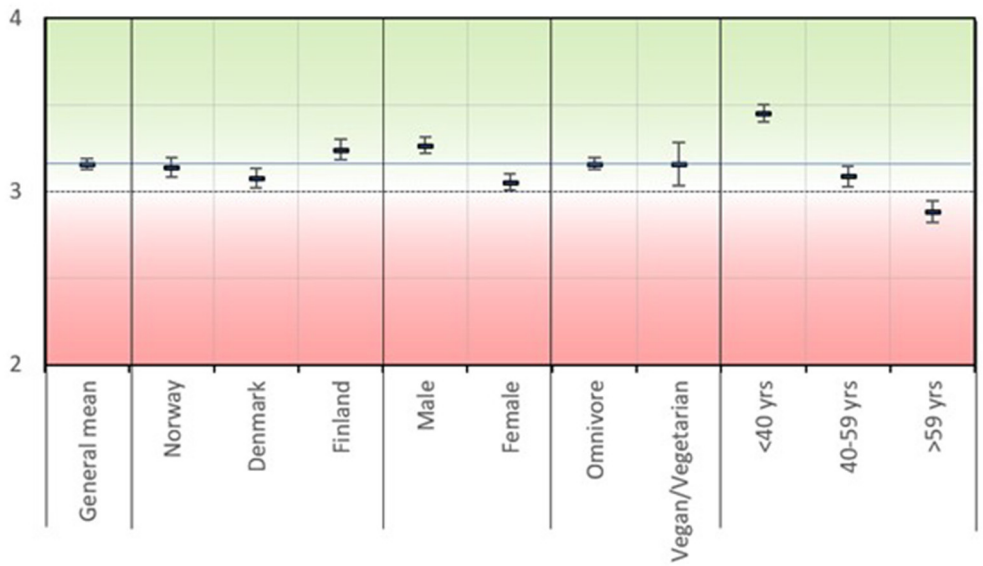

FIGURE 2 | Mean ratings of the intention to consume cultured protein. The thin blue line represents the general mean across all respondents. The error bars represent 95% credibility intervals.

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

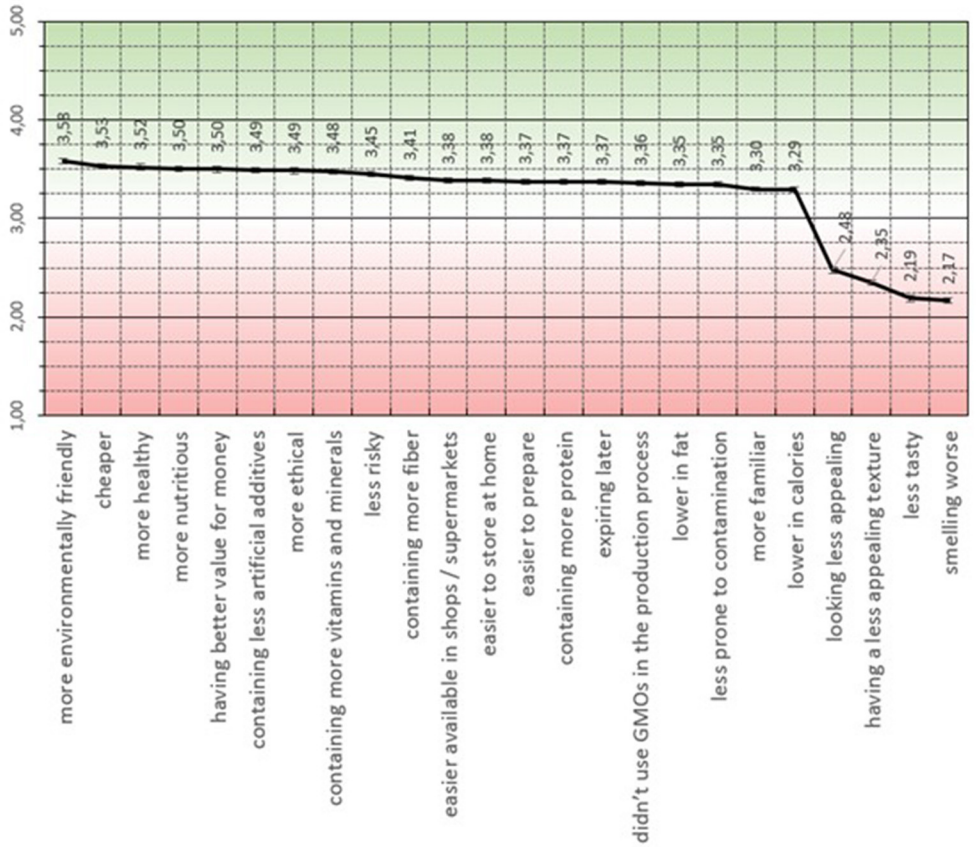

FIGURE 3 | Mean ratings of how much the attitude toward synthetic protein would become more positive or negative if synthetic protein was more of the aspect (e.g., more environmentally friendly) than farmed protein. The error bars represent 95% credibility intervals estimated with Bayesian estimation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

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.

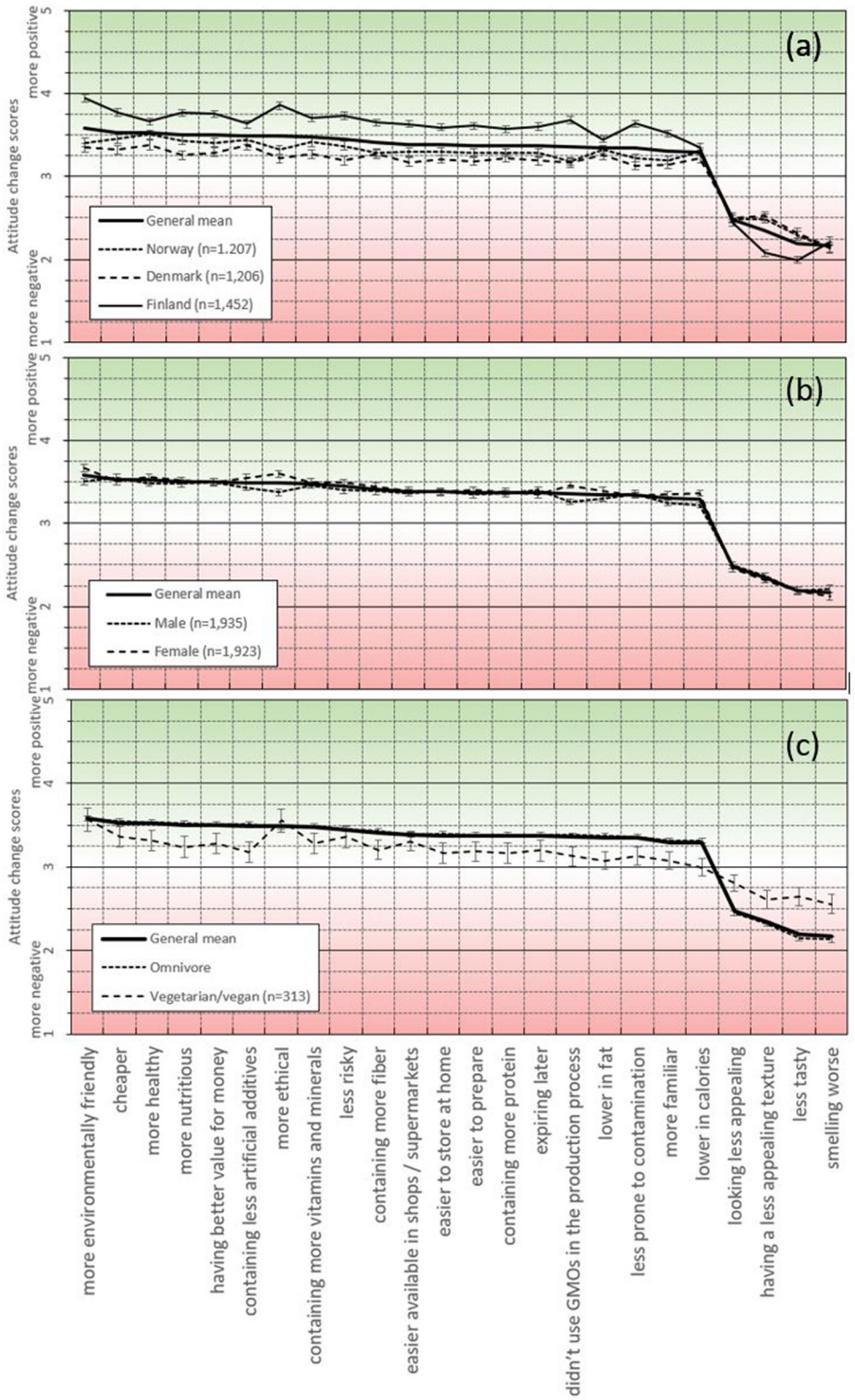

FIGURE 4 | Differences between countries **(a)**, gender **(b)**, and diet **(c)**. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

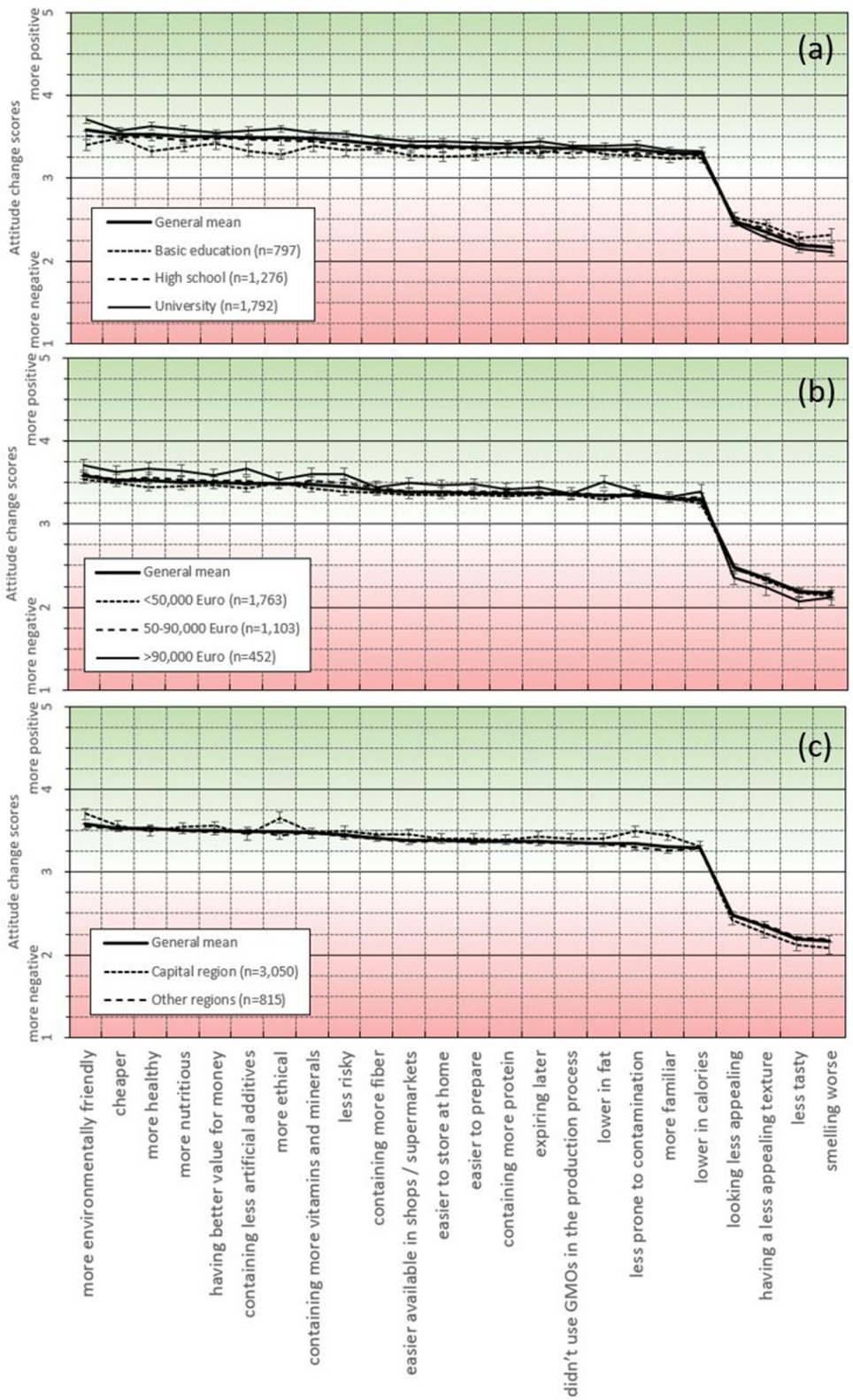

FIGURE 5 | Differences between education **(a)**, income **(b)**, and the capital vs. other regions **(c)**. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

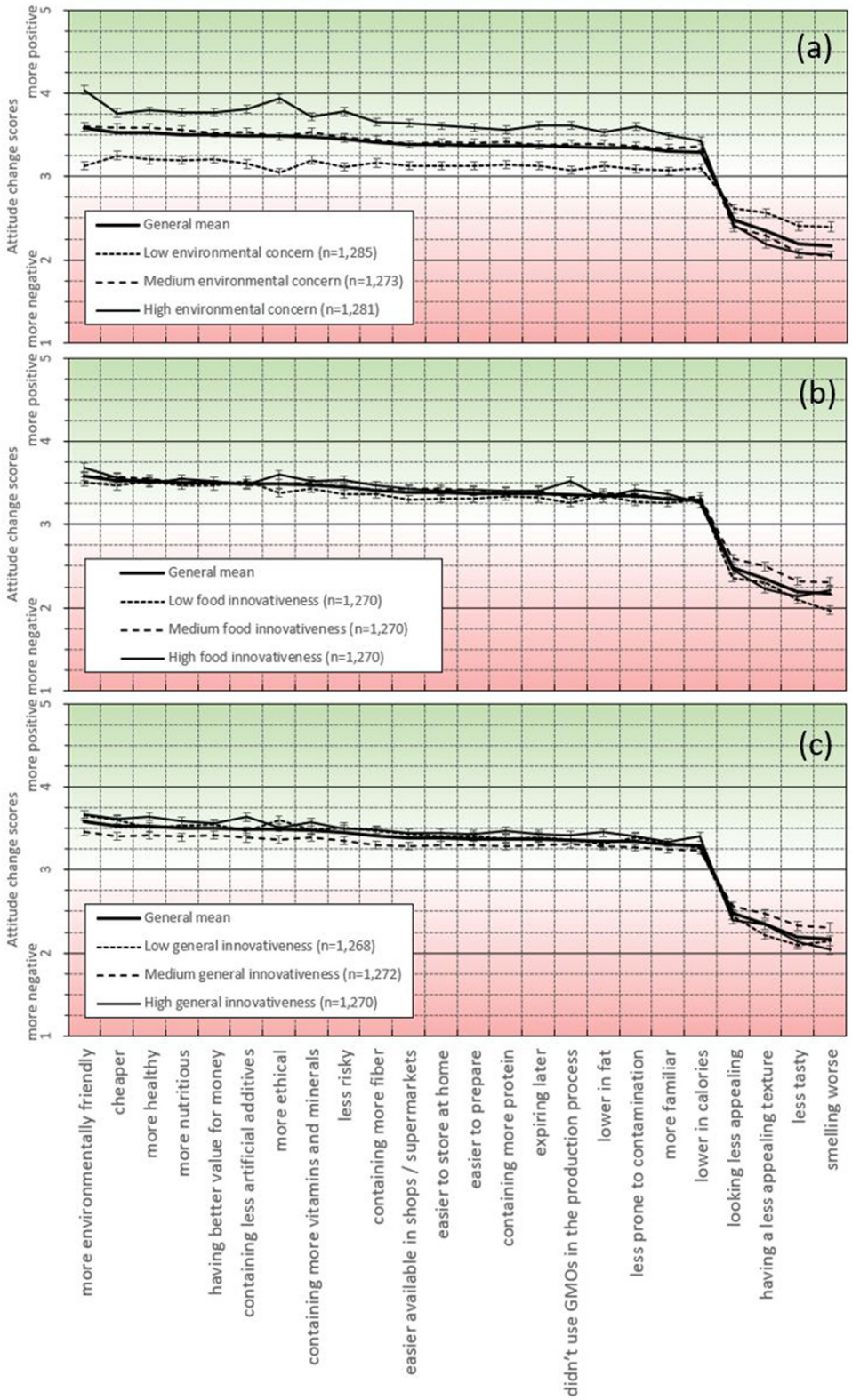

FIGURE 6 | Differences between NEP levels **(a)**, food innovativeness **(b)**, and general innovativeness **(c)**. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

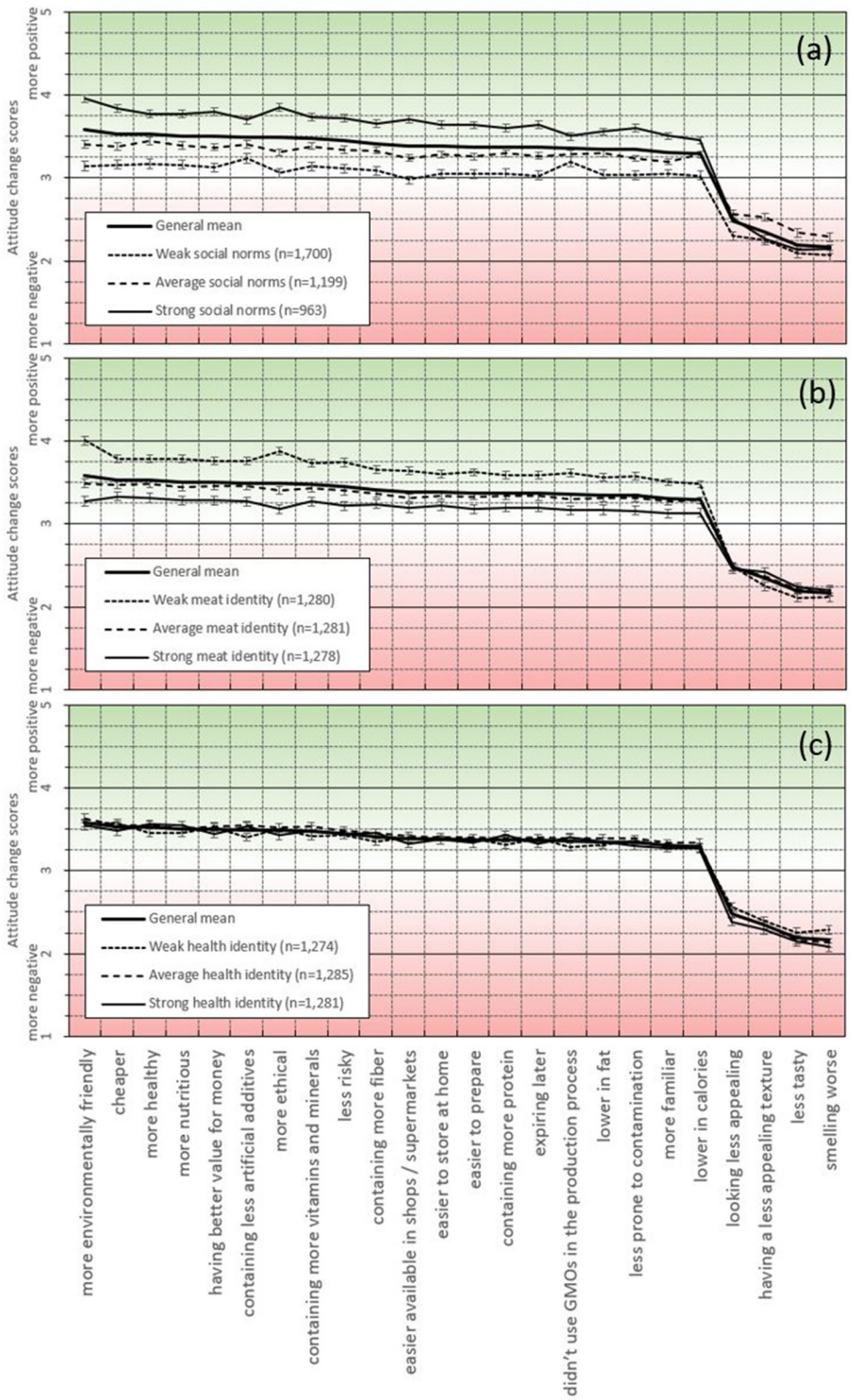

FIGURE 7 | Differences between social norm levels **(a)**, meat identity **(b)**, and health identity **(c)**. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

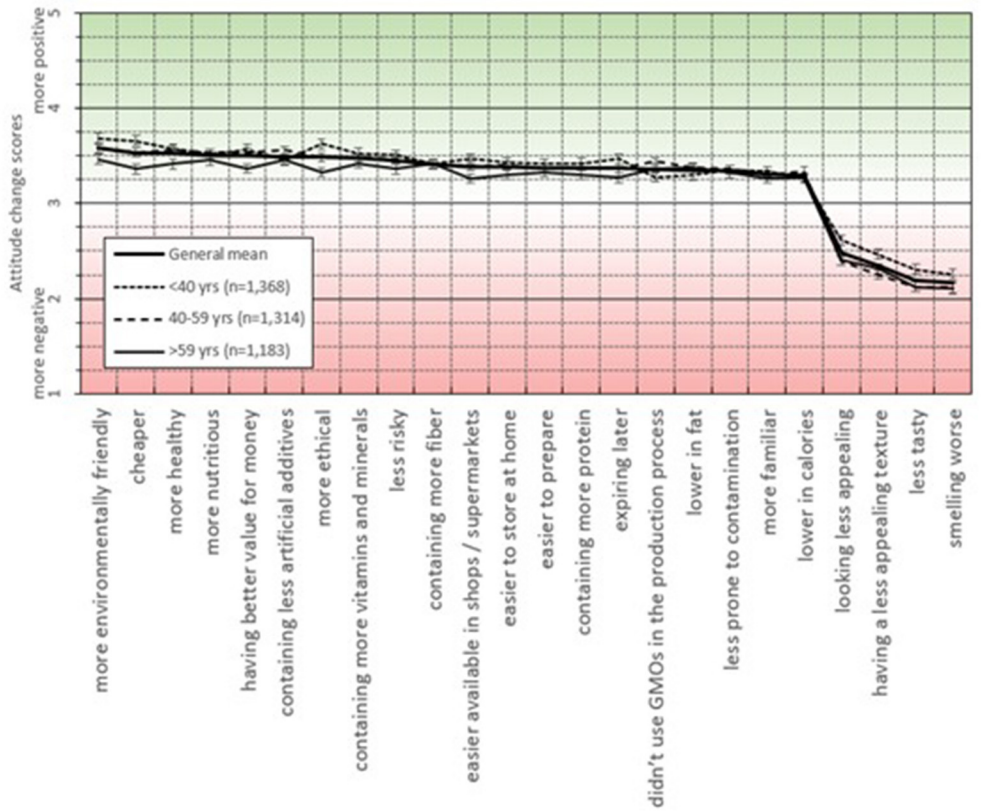

FIGURE 8 | Differences between age groups. The error bars represent 95% credibility intervals estimated with Bayesian estimation.

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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Take it or leave it? Investigating the ambivalence and willingness to pay for suboptimal fruits and vegetables among organic consumers in Germany

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Organic fruits and vegetables are often visually "suboptimal" because organic farming uses neither pesticides nor synthetic fertilisers to improve the cosmetic appearance of the produce. Despite the organic sector's natural and sustainable image, such foods often never reach the market or are left on the shelf, greatly increasing food waste. The current work hypothesised that an important factor in the rejection of suboptimal food is consumers' experience of ambivalence regarding these products. Data were collected through an online survey of (occasional) organic consumers in Germany (n = 493), including an online mouse-tracking experiment. We investigated the interplay of ambivalence with environmental concerns and attitudes towards suboptimal food that influence people's willingness to pay (WTP) for suboptimal fruits and vegetables. Our findings suggest that environmentally concerned consumers have more favourable attitudes and experience less ambivalence towards suboptimal food. Only subjective ambivalence was found to be directly associated with consumers' WTP, however, while attitudes were not. Based on these results, we propose measures for policymakers and food retailers to reduce such ambivalence and thus increase organic consumers' acceptance for suboptimal food.

KEYWORDS

ambivalence, attitude, food waste, mouse-tracking experiment, organic consumers, suboptimal food, willingness to pay, environmental concerns

Introduction

Although so-called "suboptimal" foods with an abnormal appearance in terms of weight, size or shape are safe to consume, these products are often wasted throughout the supply chain (Aschemann-Witzel et al., 2015). Around 30% of fruits and vegetables in Europe are wasted for cosmetic reasons (de Hooge et al., 2018; European Commission, 2021). This waste is not based on any objective product criteria such as nutritional and bacterial qualities identified by food safety authorities but on the subjective perceptions of retailers and consumers of what constitutes "optimal" appearance (Aschemann-Witzel et al., 2018).

On the one hand, consumers' perceptions of "acceptable" food and their purchasing behaviour determine the food standards applied by food retailers which then affect all actors in the entire food supply chain (de Hooge et al., 2018; Aschemann-Witzel et al., 2020a; Pfeiffer et al., 2021). On the other hand, retailers have long applied cosmetic standards that exceed the legal requirements to "prove" the premium quality of the foods they sell, especially in the case of fresh fruits and vegetables (de Hooge et al., 2018; Herzberg et al., 2022). This in turn shapes consumer perceptions of how "optimal" foods should look (Aschemann-Witzel et al., 2015, 2022). From this it follows that changes in the supply and marketing communications of retailers could positively influence consumer attitudes to suboptimal foods (Aschemann-Witzel et al., 2022). While several studies have explored the marketing of suboptimal food, important knowledge gaps still exist regarding the key factors determining the success of marketing measures applied by policymakers and food retailers.

The association between consumers' positive attitudes and reported purchase intentions has been confirmed by numerous studies (e.g., Barbe et al., 2017; Adel et al., 2021; Stöckli and Dorn, 2021). Research has also identified environmental concerns and food waste awareness as the most important drivers for consumers to purchase suboptimal food (de Hooge et al., 2017; Stöckli and Dorn, 2021). These conclusions have mainly been based on data from consumers in general, however, who differ from organic consumers in their altruistic values, food preferences and food involvement (Hamm et al., 2012). A study by Hermsdorf et al. (2017) with food retailers has shown that organic consumers are more likely to accept suboptimal fruits and vegetables because they mostly know that naturally produced foods vary in shape and size and that these variations do not affect taste. Because organic consumers are often found more willing to contribute to environmentally friendly behaviour (Hamm et al., 2012; Lord et al., 2021), we argue that they are an important target group for suboptimal fruits and vegetables. This is supported by a study by Stangherlin et al. (2019), which found that environmentally conscious consumers are inclined to accept suboptimal fruits and vegetables because they associate suboptimal appearance with organic qualities. Considering the promising opportunities for these products in the organic market, we found no study targeting organic consumers in previous reviews on suboptimal food (Stangherlin and Barcellos, 2018; Hartmann et al., 2021). Consequently, we still have limited information on the determinants of suboptimal food purchases among organic consumers, which is thus the focus of our present study.

We investigate the psychological factors that explain why people do (not) accept and buy fruits and vegetables with suboptimal appearance. In particular, we look at the factor of the psychological state known as subjective ambivalence, i.e., consumers' experiences of conflict between opposing evaluations (van Harreveld et al., 2015). This ambivalence arises, for example, when a person's desire to contribute to the environment pulls them towards choosing a suboptimal food such as crooked cucumbers displayed in a store alongside "perfect" cucumbers while at the same time their perception that "what is beautiful is good" (Dion et al., 1972, p. 289) pulls them towards purchasing the perfect cucumbers. In this way consumers can often be torn as to whether it is good or bad to buy suboptimal food. Investigating this state of ambivalence might help further our understanding of the inconsistencies between consumers' attitudes and behaviour when making purchase decisions for or against suboptimal food.

Following the recommendations of Hartmann et al. (2021) and the Federal Environment Agency (UBA, 2020), the present study brings together consumer research and psychological perspectives to investigate the purchasing barriers and drivers of organic consumers for the willingness to pay (WTP) for suboptimal food. This includes factors such as subjective ambivalence, environmental concerns, food waste awareness and moral norms regarding food waste reduction. We then discuss the theoretical and practical implications of our findings that could influence consumers' acceptance of suboptimal food.

Theoretical framework

Ambivalence

Ambivalence is defined as the simultaneous presence of positive and negative evaluations concerning an attitude object (van Harreveld et al., 2015). Psychological research further distinguishes between objective and subjective ambivalence. Objective ambivalence refers to the extent to which positive and negative associations towards an attitude object are similar in strength with each other, whereas subjective or "felt" ambivalence refers to people's meta-cognitive experience of this evaluative conflict (van Harreveld et al., 2015). This distinction implies that people can hold both positive and negative attitudes at the same time (objective ambivalence) without consciously experiencing conflict (subjective ambivalence), since ambivalent attitudes only become conflicting when people become conscious of the two opposing sides of an object. Such conflict typically arises when one has to decide how to act based on opposing, i.e., ambivalent, attitudes. Importantly, however, it is only the realisation of this conflict (subjective ambivalence) that has been shown to induce feelings of discomfort and can thus influence people's affect, cognition and behaviour (van Harreveld et al., 2015).

To investigate organic consumers' subjective ambivalence towards suboptimal fruits and vegetables, we asked our study participants to decide between opposing evaluations (positive vs. negative) of suboptimal and optimal products while measuring their mouse-trajectories (Mathur and Reichling, 2019). Mouse-tracking as an implicit measure enables researchers to evaluate

people's experience of ambivalence by capturing the dynamic aspect of ambivalence that unfolds during their evaluation processes. This method contrasts with self-reporting that only assesses the evaluation itself. Mouse-tracking circumvents biased answers in self-reports that might arise due to social desirability or to people's inability to report their own feelings and thoughts. The results of such tracking can nonetheless be related and compared to (explicit) self-reported measures of subjective ambivalence (Schneider et al., 2015). Mouse-tracking is thus particularly helpful when investigating consumers' unconscious motives and behavioural patterns because it can capture spontaneous motor reactions to a stimulus that cannot be captured through questionnaires. However, Bolos et al. (2019) have also demonstrated, both implicit and explicit measures of attitudes towards suboptimal food can effectively predict purchase intentions. In order to assess people's subjective ambivalence, therefore, we implemented both an explicit measure (self-report) and a more implicit measure (mouse-tracking).[1]

Ambivalence towards suboptimal food

Fruits and vegetables with suboptimal appearance have been found to trigger both positive and negative attitudes among consumers (Bolos et al., 2019; Aschemann-Witzel et al., 2020b). For example, many consumers have positive associations with suboptimal food because its purchase reduces food waste and thus benefits the environment (Barbe et al., 2017; Stöckli and Dorn, 2021). Suboptimal foods are also perceived as more natural than optimal foods and are sometimes considered as organically produced precisely on this account (Hermsdorf et al., 2017; Stangherlin et al., 2019; van Giesen and de Hooge, 2019). At the same time, however, negative perceptions can arise from the abnormal appearance of suboptimal food. For example, externally deviated fruits and vegetables are often seen by consumers as not being prototypical (Hingston and Noseworthy, 2020; Barone et al., 2021) and thus as less nutritious, fresh, attractive and tasty than optimal looking products, sometimes even being viewed with disgust and regarded as risky to consume (Jaeger et al., 2018; Loebnitz and Grunert, 2018; Cooremans and Geuens, 2019; Schifferstein et al., 2019; Hingston and Noseworthy, 2020; Pfeiffer et al., 2021).

Research has shown that considering ambivalence is useful for understanding consumers' attitudes and their purchase intentions for suboptimal food (e.g., in the case of visually non-normative apples: Bolos et al., 2019). Studies have also indicated that ambivalence plays an important role in consumers' WTP for food that is past its best-before date and their premeditated waste of such suboptimal products. Using the mouse-tracking measure, Buttlar et al. (2021) have demonstrated that consumers evaluate food with expired best-before dates not only as less favourable but also experience more ambivalence towards such food compared to non-expired products, with participants reporting they were more likely to waste food past its best-before date and would pay less for such products.

Importantly, however, these studies by Bolos et al. (2019) and Buttlar et al. (2021) relied on data from conventional consumers who are often found to have negative perceptions of suboptimal food (Aschemann-Witzel et al., 2020b; Giménez et al., 2021). By contrast, organic consumers may be more prone to experience higher levels of ambivalence. This is because subjective ambivalence becomes more pronounced when people have to make decisions on personally relevant topics to which they hold ambivalent attitudes (van Harreveld et al., 2015). From this it can be assumed that decisions about whether to buy suboptimal food are especially important for organic consumers due to their higher environmentally friendly motivation (Hamm et al., 2012), hence our following hypothesis for organic consumers:

Hypothesis (H1): suboptimal food elicits a higher degree of subjective ambivalence in comparison to optimal food.

Drivers and barriers influencing consumers' attitudes to and WTP for suboptimal food

Organic consumers are often found to value environmental-related attributes in their decisions regarding food purchase and management (Hamm et al., 2012; McCarthy and Liu, 2017). For instance, McCarthy and Liu (2017) reported that organic consumers demonstrated greater awareness than non-organic consumers of the waste of resources involved in throwing away edible foods and were thus more willing to reduce the amount of food waste. Such interindividual differences in environmental concerns and food waste awareness seem to be highly influential on consumers' attitudes towards suboptimal fruits and vegetables (Loebnitz et al., 2015; de Hooge et al., 2017; van Giesen and de Hooge, 2019). This has been confirmed in a study by de Hooge et al. (2017), who found that people with a higher commitment to environmental sustainability and higher food waste awareness both have a stronger tendency to favour suboptimal food. Prior studies have also shown that moral norms play a significant role in the context of food waste, since consumers tend to feel disturbed or guilty about wasting edible food (Stefan et al., 2013; McCarthy and Liu, 2017). Accordingly,

1 It is not the aim of this paper to compare the results of the mouse-tracking experiment with self-reported subjective ambivalence. Although the two methods differ in the nature of the measurement (motor behaviour vs. self-reported), combining the data from these measures enables us to validate the results of the novel ambivalence measure (mouse-tracking) and to harness the strengths of both methods.

it can be presumed that individuals who feel "guilty" when wasting food will also hold more positive attitudes towards suboptimal food. Based on these findings, we propose the following three hypotheses:

Hypothesis (H2a): an increase in environmental concerns will increase consumers' positive attitudes towards suboptimal foods.

Hypothesis (H2b): an increase in food waste awareness will increase consumers' positive attitudes towards suboptimal foods.

Hypothesis (H2c): stronger moral norms regarding food waste reduction will increase consumers' positive attitudes towards suboptimal foods.

In addition, a study on ethical consumption by de Pelsmacker et al. (2005) has shown the importance of analysing WTP when examining (intended) purchase behaviour. Indeed, it has been shown that consumers are unwilling to pay the same amount for food they perceive as inferior (Hartmann et al., 2021). Gaining knowledge about consumers' WTP is thus important to determine the practicality of selling suboptimal fruits and vegetables.

It is widely accepted that people's attitudes are an important determinant of purchase intentions and behaviour (Ajzen, 1991), and previous studies have confirmed that intentions to purchase suboptimal food can be hindered by negative attitudes to such products (Hingston and Noseworthy, 2020; Giménez et al., 2021). From this it follows that positive attitudes towards suboptimal fruits and vegetables might also lead to a higher WTP for these products. We thus propose the following hypothesis:

Hypothesis (H2d): an increase in positive attitudes towards suboptimal foods will increase consumers' WTP for suboptimal foods.

Although consumers' attitudes affect purchase intentions and WTP, however, attitudes do not necessarily translate into corresponding behaviour. This attitude-behaviour gap has been observed in numerous studies (e.g., Barbe et al., 2017; Schäufele and Janssen, 2021) and is often triggered by product prices (de Pelsmacker et al., 2005). For example, in a study of German consumers, Barbe et al. (2017) found that while 85% of the participants expressed willingness to support supermarkets that agree to relax their aesthetic standards on fruits and vegetables, only 27% would purchase misshapen carrots for the same price as flawless carrots.

In our present study we propose that this gap between attitude and WTP can be explained by consumers' experience of ambivalence. This proposal is partly supported by previous research on healthy eating which has demonstrated that ambivalence has a moderating effect on the attitude-behaviour relationship by showing that people with a low degree of ambivalence are associated with higher levels of attitude-behaviour consistency (Sparks et al., 2001; Conner et al., 2003). Hence our following hypothesis:

Hypothesis (H3): higher levels of subjective ambivalence will moderate (weaken) the relationship between attitude and WTP for suboptimal foods.

We present a model conceptualising all our hypotheses in Figure 1. We tested these hypotheses through a pre-registered experiment[2] using an online survey.

Materials and methods

Participants

The data were collected in Germany during May 2021 using a web-based survey. The participants were recruited from an online access consumer panel of a market research agency, taking into account gender, age and residence at state level to resemble the German population. The following two inclusion criteria were established to ensure the eligibility of the participants: (i) being a consumer of organic food (at least occasionally) and (ii) being (partly) responsible for buying groceries in their household. A total of 1,136 individuals were invited to participate, of whom 580 completed the online survey, amounting to a response rate of 51%.

Following the data collection, the responses of 28 participants were deleted because these participants refused permission for using their mouse-tracking data. During the pre-registered data cleaning, a further 59 cases were excluded due to errors in the recording of mouse coordinates, overly rapid completion of the total survey (i.e., faster than half the median survey duration of 549 seconds), and "straightlining" (i.e., no answer variance in the questionnaire). The final sample thus amounted to 493 participants, 57% of whom were female. The age of the participants ranged from 18 to 75 years, with an average age of 47 (S.D. = 15 years). The rate of high school completion among the participants was 56%.[3] A summary of the socio-demographic characteristics of the final sample is presented in Table 1.

2 The pre-registration record of our study is available at: https://osf.io/2qpsu/?view_only=7d376685f53a4c2e982c784138ddfe61. The material, data, R scripts and syntax for the study are available at https://osf.io/mazr4/?view_only=df0a78570f404c32903ee1e4309686af. The Supplementary material include one-way ANOVA analyses for the evaluation of suboptimal food, ambivalence and WTP for suboptimal food among organic consumers with different organic purchase frequencies, together with a summary of the items used in the questionnaire.

3 This is higher than the 33.5% average for high school completion in the entire German population, which is based on the results of the 2019 microcensus (2020): https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bildung-Forschung-Kultur/Bildungsstand/Publikationen/Downloads-Bildungsstand/bildungsstand-bevoelkerung-5210002197004.pdf?__blob=publicationFile.

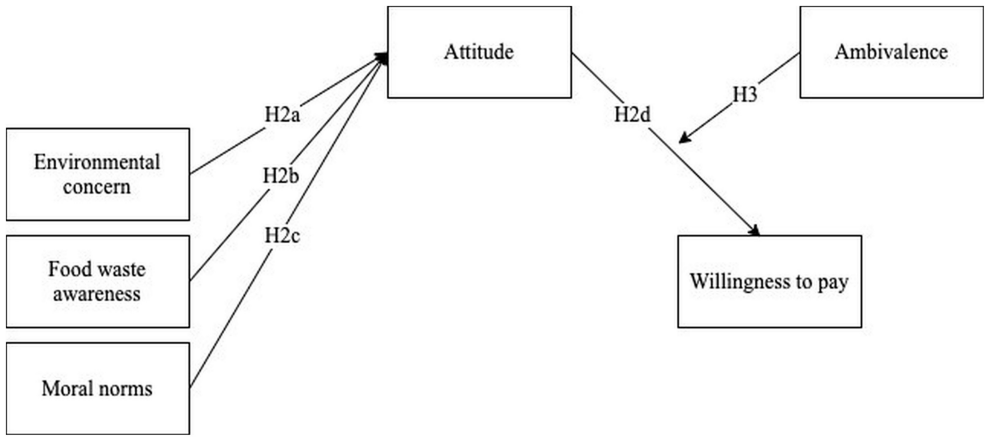

FIGURE 1
Conceptual model of consumers' WTP for suboptimal foods.

Procedure and measures

At the beginning of the survey the participants were informed of the strict protection of their anonymity and privacy, and a declaration of consent was obtained. The subsequent survey consisted of two parts: (i) a mouse-tracking experiment, which adopted a one-factor (suboptimal food vs. optimal food) within-subjects design; and (ii) a self-administered questionnaire. Prior to the survey, a pilot test was conducted with 57 participants, resulting in the addition of two filter questions to screen out participants not using a computer (PC/laptop) and a mouse in order to optimise the mouse-tracking measurement.

At the end of the questionnaire, the participants were informed that their mouse movements had been recorded at the beginning of the survey in order to be used for scientific purposes. This clarification was only given afterwards in order to avoid influencing the response behaviour in the mouse-tracking experiment. The participants were then given the option of actively agreeing or refusing to allow the use of their data. Any data whose usage was refused were removed from the dataset before the analysis began.

Mouse-tracking as a measure of ambivalence

A mouse-tracking experiment was used to determine the subjective ambivalence of the participants towards suboptimal and optimal fruits and vegetables. In order to conduct this experiment within the framework of an online survey, the open-source software developed by Mathur and Reichling (2019) for analysing a mouse-tracking experiment was adapted for use in the Unipark online survey platform.

For this experiment the participants were presented with 30 different pictures of fruits and vegetables in randomised order in the centre of their browser window. These stimuli were divided into 16 target stimuli (2 optimal and 2 suboptimal apples, potatoes, pears, carrots) and 14 distractor stimuli (optimal fruits and vegetables) to disguise the primary purpose of the study. In each trial the participants were asked to use their mouse to click on a "Positive" or "Negative" button in the upper-right or left corners of their browser window to indicate which response best represented their attitude to the food depicted. The participants' evaluations of the food stimuli were recorded and the movements of their mouse cursors were tracked during each evaluation. The mouse recordings each started with a click on the "Next" button (German translation: "Weiter") in the bottom middle of the browser window and ended with the selection of a positive or negative response button[4] (see Figure 2).

During each trial, the cognitive conflict between opposing evaluations was operationalized as the extent to which the curvature of the participants' mouse trajectories diverged most from the ideal trajectory, with this "ideal" being a straight line from the "Next" button to the selected response button. As the start and the end mouse position of every individual is different, this "ideal" trajectory is recalculated for each individual in every trial (Mathur and Reichling, 2019). The maximum distance between the ideal and the actual trajectory followed by the participants is defined as the maximum deviation (MD), and this was computed using the recorded mouse coordinates. As depicted in Figure 2, we predicted that the ambivalent stimuli, i.e., the suboptimal food, would generate a greater MD than univalent stimuli, i.e., the optimal food

4 To counterbalance any bias arising from the location of the response button, two versions of the mouse-tracking experiments were created by switching the positions of the Positive and Negative response buttons. The two versions were randomly distributed among the participants, each of whom saw only one version.

TABLE 1 Socio-demographic characteristics of the participants from the final sample ($N = 493$).

		Overall (%)
Gender	Female	57.4
	Male	42.4
	Other	0.2
Age	18–39	38.5
	40–59	34.1
	60–75	27.4
Education (years of school visit)	No degree	0.4
	9 or 10 years of school visit	42.2
	12 or 13 years of school visit	26.6
	College or university degree	29.6
	Other	1.2
Household size	Single	26.4
	2	39.4
	3	18.3
	4	11.4
	5 or more	4.6
Household components	No children under 18	75.3
	1	14.8
	2	7.1
	3 or more	2.8
Monthly household income (€)	Under 1,300	13.2
	From 1,300 until under 1,700	11.4
	From 1,700 until under 2,600	21.7
	From 2,600 until under 3,600	23.3
	From 3,600 until under 5,000	23.1
	Above 5,000	7.3
Organic food purchase frequency	Occasional	22.7
	Regular	29.8
	Frequent	47.4

(Schneider et al., 2015), reflecting a higher experience of conflict during evaluation.

In order to ensure optimal tracking of the mouse trajectory, we implemented measures suggested by Mathur and Reichling (2019). These included an alert whenever the browser window of the participants was not large enough to fully display the mouse-tracking experiment. In addition, alerts were triggered if participants took longer than 10,000 ms on a trial or if the time limit of 1,500 ms was exceeded for the first mouse movement within a trial. The "started too late" alert was aimed at ensuring that the dynamic aspect of ambivalence during evaluation was captured in the participants' mouse trajectories by preventing participants from waiting to start moving their mouse cursors until they had already made their evaluation decisions in their minds. This was supplemented by a "started too early" alert warning the participants that the mouse had moved outside of the "Next" button before the page had fully loaded. These alerts were displayed in the form of pop-up windows at the end of each trial in order not to interrupt the experiment. To practise the procedure of the experiment, five training stimuli in the form of various household items were presented to the participants for evaluation before the start of the actual experiment.

Self-reported measure of ambivalence

The subjective ambivalence elicited by suboptimal food were also measured using the three items questionnaire developed by Priester and Petty (1996) to capture cognitive, affective and conative dimensions of ambivalence. The items began with the following statement: "Towards purchasing fruits and vegetables with cosmetic flaws I feel (have)…". The participants rated the conflicting nature of their thoughts, the degree of indecision and the extent of their mixed feelings on a 7-point scale ranging from 1 (no conflict/no indecision at all/completely one-sided reactions) to 7 (maximum conflict/maximum indecision/completely mixed reactions). The internal reliability of the three items was excellent ($\alpha = 0.94$) and the responses were averaged to obtain the mean result.

WTP for suboptimal food

Four foods (apples, carrots, potatoes and pears) were used as stimuli to measure the participants' WTP for suboptimal food using the contingent valuation method. For each stimulus, optimal and suboptimal versions of the food were presented to the participants on the left and right sides of the page respectively. The participants were asked to indicate their WTP *via* the following question:

Imagine you are looking to buy apples [carrots/potatoes/pears] and have the two products to choose from. The organic apples [carrots/potatoes/pears] on the left cost €2.49 [€1.39/€1.29/€2.69] per kilogramme. How much would you pay for one kilogramme of organic apples [carrots/potatoes/pears] on the right?

The reference prices for the optimal organic foods were determined based on the average market price of these products in Germany's organic retailing sector (AMI, 2020a,b). The participants were able to enter a price between €0 and the reference price of the optimal product. The percentage of WTP for the suboptimal foods was calculated *via* the formula (WTP/optimal product price) * 100%, and the average of the four stimuli was computed for the analysis. The internal reliability of the four stimuli with Cronbach's alpha was good ($\alpha = 0.85$). The average WTP of the participants for the suboptimal food is presented in Table 2.

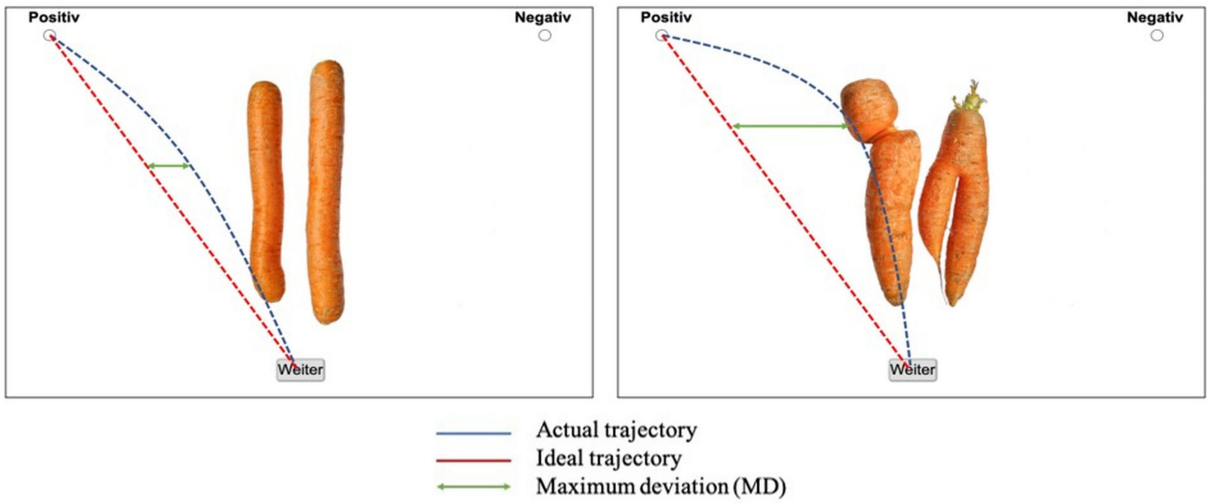

FIGURE 2
Example of the presentation of the mouse-tracking experiment, showing the mouse trajectories and maximum deviation between the ideal and the actual trajectory. Neither the ideal nor the actual mouse trajectories of the participants were visible during the experiment.

TABLE 2 Descriptive statistics on the percentage of consumers' WTP for each suboptimal food product.

Product	Mean (%)	SD	Min	Max
Apples	75.12	21.53	0	100
Carrots	75.10	20.94	0	100
Potatoes	83.16	18.20	0	100
Pears	80.17	20.71	0	100
Overall	78.39	16.84	0	100

Attitudes towards suboptimal food, environmental concerns, and food waste-related items

To measure attitudes towards suboptimal food, environmental concerns, food waste awareness and moral norms regarding food waste, a total of 22 items were taken from previous research and adapted to the context of suboptimal food purchase (see Supplementary material). The items were presented in randomised order and were rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree), with higher scores indicating a more positive attitude, higher environmental concerns, greater awareness of food waste and stronger moral norms regarding such waste. The final variables for further analysis were determined after data collection using exploratory factor analysis (EFA). Depending on the number of factors extracted from EFA (see Section Exploratory factor analysis), the average score of the items for each construct was computed for analysis.

Socio-demographic characteristics

Data on the gender, age, formal level of education, household income and household size of the participants were collected. In addition, the participants indicated the frequency of their organic food purchases on a scale from 1 (almost never) to 7 (exclusively). Based on this self-assessment, the participants were divided into occasional (answer options 1–3), regular (answer option 4) or intensive consumers (answer options 5–7) of organic food. The socio-demographics of the respondents are shown in Table 1.

Results

Exploratory factor analysis

To test the reliability and validity of the measurements and identify the underlying factor structure, we conducted an EFA (principal axis factoring, promax rotation) for the items related to attitudes towards suboptimal food, environmental concerns, food waste awareness and moral norms regarding food waste. Descriptive statistics of the items are shown in Table 3. The univariate skewness and kurtosis of each measure were less than 2 and 7 respectively, which is not considered extreme (Watkins, 2018). Bartlett's test of sphericity was significant (χ^2 (231) = 5095.90, $p < 0.001$), indicating that the correlation matrix did not suffer from multicollinearity. The Kaiser-Meyer-Olkin criterion value was higher than 0.9 (KMO = 0.92), indicating excellent sampling adequacy for factor analysis (Kaiser, 1974; Watkins, 2018).

To determine the number of factors retained, a Visual Scree test, parallel analysis and Eigenvalues were used, resulting in three extracted factors.[5] Only items with rotated factor loadings of at least 0.40 were considered meaningful for interpretation (Watkins, 2018). Four items were dropped due to low factor loadings (see the italicised items in Table 3). All six reversed items loaded on the third factor, presumably due to method effects, and these items were accordingly excluded.[6] The twelve remaining items remained were reflected in two substantive factors, representing environmental concerns and attitudes towards suboptimal food. The Cronbach's alpha was $\alpha = 0.88$ for the environmental concern factor and $\alpha = 0.85$ for the attitude factor, indicating a high degree of internal consistency. Based on the results of the EFA, the pre-registered conceptual model was modified (see Figure 3). This led to food waste awareness and moral norms being dropped, meaning that hypotheses H2b and H2c could not be tested, leaving environmental concern as the sole predictor in the moderated mediation analysis.

Hypothesis testing

The confirmatory data analysis was conducted using the pre-registered analyses.

Correlation analysis

To avoid the influence of outliers in further analyses, and in accordance with the guidelines developed by Schneider et al. (2015), all trials in the mouse-tracking experiment with a reaction time under 300 ms or over 3,000 ms were removed, amounting to 17.48% of all trials. Since conducting a mouse-tracking experiment online is still a new method for measuring ambivalence, we validated the approach by comparing the mouse tracker variable (MD) with the self-reported subjective ambivalence of participants towards suboptimal food (Schneider et al., 2015). As a threshold value, a positive correlation coefficient of greater than $r = 0.3$ between self-reported ambivalence and MD for suboptimal food was pre-registered for the mouse tracker variable to be accepted as a valid measure of ambivalence in the analyses (Schneider et al., 2015). In the case of $r < 0.3$, the self-reported ambivalence would be used for further analyses. For this purpose, a one-tailed correlation analysis between the average MD for all suboptimal foods and the self-reported subjective ambivalence was conducted. This analysis revealed that the MD in trials pertaining to suboptimal food was not significantly associated with the self-reported subjective ambivalence towards suboptimal food ($r = 0.033$, $p = 0.24$).

During the analysis of the mouse-tracking data, however, we realised that the trials in which participants moved their mouse too early were highly influential for the overall MD score because the calculation of the ideal trajectory and the relative deviation from this trajectory on the x-axis (MD) depends on the first position of the mouse in each trial, i.e., the "Next" button (Mathur and Reichling, 2019). An additional one-tailed correlation analysis was therefore carried out after the removal of all trials with the "started too early" alert, revealing that the MD in the trials pertaining to suboptimal food had a weak association with self-reported subjective ambivalence towards suboptimal food ($r = 0.25$, $p < 0.001$). As the correlation did not exceed the pre-registered threshold, the self-reported measure of subjective ambivalence was applied in the moderated mediation analysis and parallel mediation analysis.

Paired sample t-test

To test the H1 hypothesis, data on subjective ambivalence for both suboptimal and optimal food are required. However, self-reported ambivalence was only measured for the suboptimal fruits and vegetables. Data on self-reported subjective ambivalence towards optimal food was therefore unavailable. For this reason, the hypothesis (H1) could only be tested using the mouse-tracking data.[7] A one-tail paired sample *t*-test was thus performed using MD for suboptimal and optimal food (after removing trials with the "started too early" alerts),

5 Based on the recommendation from Watkins (2018), a two-factor solution was also evaluated. However, the extracted factors were not theoretically meaningful because the second factor was formed from a combination of the attitude items and the reversed items (Factors 2 and 3 from the three-factor solution), with the latter having factor loadings higher than 0.5, while the attitude items have loadings of less than 0.5. Therefore, the three-factor solution was adjudged most appropriate, as identified by the Visual Scree test, Eigenvalues and parallel analysis.

6 The use of reversed items has the purpose of reducing acquiescence bias (Paulhus, 1991). However, it could also lead to method effects that can influence the factor structure, since understanding the items becomes more difficult for the participants (Zhang et al., 2016). Method effect is defined as the tendencies of individuals to answer questions based on criteria other than the intended contents, resulting in a construct that measures something irrelevant to what the researcher expects to measure (Lindwall et al., 2012). In line with the finding from Zhang et al. (2016), the EFA in the present study extracted a total of three factors, one of which is a method factor consisting of all the reversed items (Factor 3) and was thus excluded from further analysis.

7 The results of the hypothesis (H1) testing should be interpreted with caution, as the correlation between the mouse-tracker variables and the self-reported subjective ambivalence was weaker ($r = 0.25$) than the expected threshold ($r = 0.3$; Schneider et al., 2015).

10.3389/fsufs.2022.934954

TABLE 3 Descriptive statistics and factor loadings of the items of the questionnaire for 493 participants.

Items	Descriptive statistics		Factors		
	Mean	SD	1	2	3
			EC	Attitude	(excluded)
It is important to me that the products I consume do not harm the environment.	5.45	1.35	**0.64**	0.18	−0.042
I consider the potential environmental impact of my actions when making many of my decisions.	4.72	1.45	**0.88**	−0.11	−0.056
My purchase habits are affected by my concern for our environment.	4.73	1.46	**0.83**	−0.16	0.082
I am concerned about wasting the natural resources of our planet.	5.82	1.33	**0.45**	0.39	0.042
I am willing to be inconvenienced in order to take actions that are more environmentally friendly.	4.98	1.44	**0.74**	0.047	−0.038
I would describe myself as environmentally responsible.	5.04	1.31	**0.74**	0.061	−0.12
I am strongly for that supermarket also offer fruit and vegetable in unusual shapes and sizes.	6.08	1.29	0.044	**0.76**	0.044
I like that supermarket also offer consumers to purchase food items that have minor flaws, such as apples with brown spots, crooked cucumbers, etc.	6.08	1.23	0.040	**0.69**	0.074
I believe there are no quality differences between impeccable and misshapen fruits and vegetables.	5.74	1.44	−0.071	**0.78**	−0.063
Fruits and vegetables with unusual shapes and sizes look more natural.	5.27	1.46	0.043	**0.65**	−0.20
We can avoid food waste by buying fruits and vegetables with "abnormal" shapes.	5.95	1.30	0.067	**0.71**	0.000
Most "abnormal" fruits and vegetables are wasted.	5.53	1.41	0.022	**0.64**	−0.051
Flawless fruits and vegetables taste better than those with "abnormal" shapes. (reversed)	5.72	1.59	−0.25	0.38	**0.54**
Fruits and vegetables with cosmetic flaws could turn bad more quickly. (reversed)	5.56	1.65	−0.21	0.31	**0.46**
Food waste generated in Germany does not impact the resources of developing countries. (reversed)	4.80	1.86	0.075	−0.25	**0.83**
Food waste generated in Germany does not have an impact on undernourished people in the world. (reversed)	4.98	1.77	0.14	−0.18	**0.71**
Food waste is not a problem for the environment as it is natural and biodegradable. (reversed)	4.43	1.88	0.039	−0.058	**0.51**
Throwing away food does not bother me. (reversed)	5.76	1.77	−0.013	0.065	**0.49**
I compare product appearance to decide which fruit and vegetables to buy. (reversed)	*3.59*	*1.68*	*−0.036*	*−0.003*	*0.33*
Food waste increases the burden on the environment.	*5.94*	*1.37*	*0.37*	*0.26*	*0.19*
I feel disturbed by the amount of food being wasted since it takes a lot of resources to grow, process, package and transport food.	*5.80*	*1.38*	*0.38*	*0.37*	*0.088*
I feel guilty/bad when I throw away food because some people don't have enough to eat.	*5.79*	*1.43*	*0.39*	*0.16*	*0.18*

EC, environmental concern.
Factor loadings ≥ 0.40 on pattern matrix in boldface. Items that have a low loading < 0.40 on all factors are italicised and excluded from the analysis.
Factor 3 is excluded from further analyses as it is a methods artefact containing a mix of reversed scored items.
The italic parts show all items that have a loading of lower than 0.40 on all factors and thus were excluded from further analysis .

representing ambivalence levels for suboptimal and optimal food respectively.

Hypothesis H1 predicted that suboptimal food would elicit a higher degree of subjective ambivalence in comparison to optimal food. As predicted, the analysis revealed a significant difference between the MD for suboptimal food and the MD for optimal food. Participants were observed to experience a higher degree of subjective ambivalence when presented with suboptimal food (0.34 ± 0.27) as opposed to optimal food (0.27 ± 0.21), which is a statistically significant difference of 0.063 (95% CI [−0.086, −0.40], $t(457) = -5.36$, $p < 0.001$, $d = 0.25$).[8]

Moderated mediation analysis

To test hypotheses H2a, H2d and H3, moderated mediation analysis was conducted using PROCESS v3.5 macro Model 14 in SPSS (10,000 bootstrapped samples; Hayes, 2018), with WTP as the dependent variable, environmental concerns as the independent variable, attitudes towards suboptimal food as the mediator, and self-reported subjective ambivalence as the moderator. The analyses were conducted with the z-standardised values of the variables. See Figure 3 for a schematic visualisation of the moderated mediation analysis.

Hypotheses H2a and H2d predicted that higher level of environmental concerns would increase consumers' positive attitudes towards suboptimal food and thus their WTP for suboptimal food. As predicted, the analysis reveals that environmental concern has a significant effect on attitudes towards suboptimal food, $a = 0.56$, $SE = 0.049$, $p < 0.001$, 95%

8 The same results were observed in the analyses using the mouse-tracking data without the removal of any trials with alerts and after the removal of trials with all alerts.

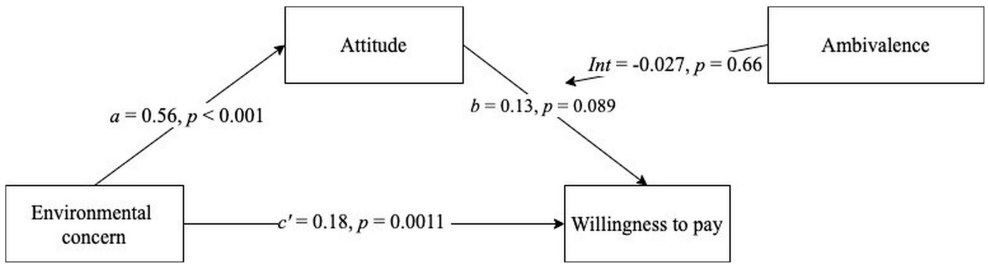

FIGURE 3
Moderated mediation analysis visualising the effect of environmental concerns on WTP for suboptimal food mediated by attitudes towards suboptimal food and moderated by ambivalence.

CI [0.46, 0.65], and a significant positive direct effect on WTP towards suboptimal food, c' = 0.18, SE = 0.056, p = 0.0011, 95% CI [0.073, 0.29]. However, attitude is shown to have no significant effect on WTP towards suboptimal food, b = 0.13, SE = 0.075, p = 0.088, 95 % CI [−0.019, 0.28], even though a higher WTP does correspond with positive attitudes towards suboptimal food.

Hypothesis (H3) suggested that the relationship between attitudes towards suboptimal food and WTP is moderated by ambivalence towards suboptimal food. However, the link between attitude and WTP was not significantly moderated by ambivalence towards suboptimal food, Int = −0.027, SE = 0.061, p = 0.66, 95% CI [−0.15, 0.093]. Furthermore, the index of moderated mediation was not significant, B = −0.015, 95% CI [−0.078, 0.040]. This analysis thus provides no support for hypotheses H2d and H3.

Exploratory data analysis: Parallel mediation analysis

Following Buttlar et al. (2021) research on the mediating role of ambivalence in premeditated food waste, the mediating effect of ambivalence on WTP for suboptimal food was assessed by a parallel mediation analysis using PROCESS v3.5 macro Model 4 in SPSS as recommended by Hayes (2018). The analysis was performed using WTP as the dependent variable, environmental concerns as the predictor, attitudes towards suboptimal food as the first mediator, and self-reported subjective ambivalence as the second mediator. These variables were analysed in z-standardised format. The mediation analysis, based on 10,000 bootstrap samples, is presented in Figure 4.

Conditional on the model assumption shown in Figure 4, our statistical test shows an indirect effect of subjective ambivalence that accounts for a significant portion of variance of the relationship between environmental concerns and WTP for suboptimal food, $a'b'$ = 0.09, 95% CI [0.05, 0.15], but not in the case of attitudes towards suboptimal food, ab = 0.07, 95% CI [−0.01, 0.14]. The analysis further reveals significant associations between environmental concerns and subjective ambivalence, a' = −0.33, SE = 0.05, p < 0.001, 95% CI [−0.42, −0.23], and between subjective ambivalence and WTP for suboptimal food, b' = −0.29, SE = 0.06, p < 0.001, 95 % CI [−0.40, −0.17], accounting for 26.7 % of the total model. Regardless of this indirect effect, environmental concerns had a significant direct effect on WTP for suboptimal food, c' = 0.19, SE = 0.05, p = 0.0005, 95% CI [0.083, 0.30], accounting for 53.98% of the total model.

Discussion

Consumers' in-store choices for suboptimal food play an important role in reducing food waste (Aschemann-Witzel et al., 2015). Our research aimed to contribute to a better understanding of the factors influencing these choices by applying a psychological perspective to investigate the barriers to and opportunities for the acceptance of suboptimal fruits and vegetables among organic consumers.

Using the study participants' mouse trajectories as indicators of evaluation conflicts, our analysis reveals that suboptimal fruits and vegetables elicit greater ambivalence than optimal products (in line with Hypothesis H1). This suggests that organic consumers perceive both positive and negative aspects of suboptimal food, although the reasons for this can only be assumed in the present study. These findings corroborate the results of a study by Bolos et al. (2019) indicating that suboptimal food is an ambivalent attitude object, which is consistent with our assumption regarding the experience of ambivalence among organic consumers towards suboptimal fruits and vegetables. For instance, the participants' lack of familiarity with externally suboptimal fruits and vegetables may have led them to move their mouse initially towards the

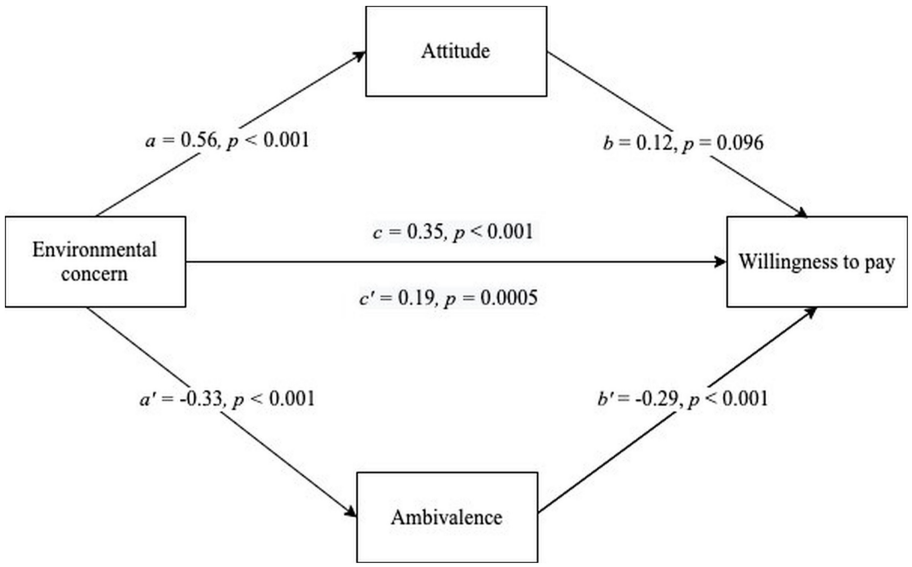

FIGURE 4
Parallel mediation analysis visualising the effect of environmental concerns on WTP for suboptimal food mediated by attitudes towards suboptimal food and ambivalence.

"Negative" response button before considering the products' environmental benefits and ultimately clicking the "Positive" response button. Indeed, despite the experience of ambivalence, the organic consumers rated most of the suboptimal foods positively (see Supplementary material), which further supports the findings of earlier studies with environmentally concerned consumers (van Giesen and de Hooge, 2019; Stöckli and Dorn, 2021). Despite these encouraging findings from the mouse-tracking data, the results should be interpreted with caution. This is because the correlation between the mouse-tracker variables and the self-reported subjective ambivalence was weaker than we expected based on previous studies in the lab (Schneider et al., 2015). Accordingly, our main analyses focused on the participants' self-reported experiences of ambivalence towards suboptimal food.

In this way, we further identified several barriers (or drivers) contributing to lower WTP among organic consumers for suboptimal fruits and vegetables. As predicted in hypothesis H2a, our findings reveal that environmental concern is a good predictor of attitudes towards suboptimal food and also plays a significant role in increasing consumers' WTP for suboptimal fruits and vegetables. These results are mostly consistent with previous studies that have found consumers with stronger environmental concerns to have higher preferences and purchase intentions for abnormal-looking foods (de Hooge et al., 2017; van Giesen and de Hooge, 2019; Stöckli and Dorn, 2021; for a conflicting finding, see Loebnitz et al., 2015). However, we did not find evidence that attitudes towards suboptimal food are related to people's WTP, which indicates an attitude-behaviour gap in consumer decision-making regarding suboptimal food. While this gap could not be explained by the moderation of ambivalence as predicted in H3, our exploratory analysis revealed that subjective ambivalence was directly related to WTP for suboptimal food. This means that the participants with higher levels of environmental concerns not only had more positive attitudes towards suboptimal food but were also less ambivalent. However, only ambivalence was associated with WTP.

We believe that these findings are sensible even though we did not find the expected moderating effect of ambivalence. Previous studies have mainly assessed objective ambivalence to show its moderating effect on the attitude-behaviour link (Sparks et al., 2001; Conner et al., 2003). This is understandable given that the coexistence of positive and negative evaluations (objective ambivalence) can be construed as reflecting a weaker attitude (Hohman et al., 2014),[9] which in turn is less predictive of behaviour than strong univalent attitudes (Armitage and Conner, 2000). Based on this explanation, people with a strong objective ambivalence should demonstrate a weaker attitude-behaviour relationship similar to our hypothesis H3 (Hohman et al., 2014). For our study, however, we measured subjective

9 Objective ambivalence is measured through questions such as the following (Conner et al., 2003, p. 82): "Consider for a few moments only the positive [negative] things about X and ignore any negative [positive] things about it. Please rate how positive [negative] those positive [negative] things are".

rather than objective ambivalence, finding a direct link between this meta-cognitive conflict and people's WTP. This finding accords with theorising on ambivalence which claims that simply holding both positive and negative associations towards an attitude object does not always have an impact on what people think and do because this ambivalence may remain dormant (van Harreveld et al., 2015). In contrast, subjective ambivalence refers to the meta-cognitive awareness of ambivalence that often arises in choice situations (van Harreveld et al., 2015). This subjective experience of conflict often generates negative emotions and thus leads to coping behaviour (e.g., van Harreveld et al., 2009). As such, subjective ambivalence has a more direct impact on people's behaviour than objective ambivalence (van Harreveld et al., 2015). This has been confirmed in a study by Buttlar et al. (2021) which showed—with similarities to our own findings—a direct negative association between people's ambivalence towards food past its best-before date and their premeditated waste of and WTP for these products. This might suggest that the experience of ambivalence evoked by meta-cognitive awareness of conflicting attitudes may play a crucial role in people's intentions and behaviours regarding the purchase and consumption of suboptimal food.

The present study has contributed to theory as it extends previous knowledge on the inconsistencies between consumers' attitude and behaviour by showing the importance of cognitive conflict for the acceptance of suboptimal food. Indeed, people's subjective ambivalence outweighed the impact of people's mere attitude on their willingness to pay for suboptimal food. This suggests that it is rather the meta-cognitive awareness about the conflicting evaluations of suboptimal food that affects people's purchases than their attitudes. While this is in line with the idea that ambivalence-induced discomfort might affect people's actions beyond their attitudes, it extends previous theorising on the acceptance of suboptimal food (Adel et al., 2021). Taken together, we see this study as one piece of the puzzle to better understand the determinants of purchase decisions for or against suboptimal food.

Practical contributions

Our findings can help inform retailers, policymakers and other relevant stakeholders in their efforts to reduce food waste by supporting the market for suboptimal fruits and vegetables. Indeed, the present study suggests that subjective ambivalence affects the WTP of organic consumers for suboptimal food beyond mere attitudes. Outside the scope of our study, it is likely that this subjective ambivalence is even more important in real life situations, such as a supermarket, where people constantly have to make decisions between different food products. For instance, previous research has already shown that avoiding decisions involving ambivalent attitudes is a common way for people to resolve such internal conflict and circumvent its negative affect (van Harreveld et al., 2015). When people decide which food to buy, ambivalence may thus be reflected in lower WTP for suboptimal products (Russel et al., 2011). Why would someone pay the same for a product that makes them feel uncomfortable? Notwithstanding this effect, applying price discounts for suboptimal food may not be the best long-term solution, since discounts may be perceived as a cue that such products are indeed inferior not only in appearance but in their internal qualities (Aschemann-Witzel et al., 2017).

Our study contributes to alternative solutions to discounting by highlighting the positive association between environmental concerns and WTP for suboptimal fruits and vegetables among organic consumers. Such consumers generally attach great importance to environmental friendliness in the process of their food purchases (Hamm et al., 2012; Lord et al., 2021). Furthermore, (intensive) organic consumers also tend to have a greater tolerance for visual imperfections on fruits and vegetables and a higher purchase intention for these products (see Supplementary material; Hermsdorf et al., 2017; van Giesen and de Hooge, 2019). Our findings further confirm that organic consumers are an important target group for suboptimal fruits and vegetables on account of their pro-environmental concerns.

By showing that environmental concern is strongly associated both with higher WTP and lower ambivalence towards suboptimal food, our findings further underline the importance of addressing consumers' ambivalence towards suboptimal food by highlighting the benefits of purchasing these products for reducing food waste. From this it can be argued that people with environmental concerns value the positive environmental aspects of suboptimal food and that this leads to more positive and univalent attitudes rather than ambivalence, since for them the positive aspects of suboptimal food outweigh the negative aspects. One pathway to reduce ambivalence towards suboptimal food would thus be to promote the environmental benefits of such products while seeking to increase the environmental concerns of organic consumers. This is because organic consumers are not all driven by environmental concerns, with many choosing to purchase organic foods due to other factors such as health, taste or animal welfare (Hughner et al., 2007; Schleenbecker and Hamm, 2013). This implies that there is still potential to increase the environmental concerns of organic consumers, which in turn underlines the importance of education about sustainable food in schools and families and the need for activities to reconnect children with nature (e.g., picking and growing produce) in order to increase their familiarity with imperfect foods and encourage their development into environmentally conscious adults (Hingston and Noseworthy, 2020; Makhal et al., 2020).

At present, however, even pro-environmental consumers such as organic consumers may not recognise the purchase of suboptimal food as a type of "green" behaviour because they are accustomed to seeing foods with an impeccable appearance

(Yue et al., 2009; Loebnitz et al., 2015). To overcome this barrier, our findings suggest to convey the environmental benefits of buying suboptimal products more effectively, including through targeted TV cooking shows (Elhoushy, 2022) and social media campaigns (Young et al., 2017). Current efforts in Germany to increase awareness of the benefits of suboptimal food include the use of the private label *Die Naturgut Bio-Helden* ("Naturally good organic heroes") by Penny supermarket (Penny, n.d.) and the "Too Good for the Bin" campaign of Germany's Federal Ministry of Food and Agriculture (BMEL, n.d.).

Given that most people base their purchase decisions on a mixture of several product attributes, including a product's environmental footprint, price, and perceived qualities (de Pelsmacker et al., 2005; de Hooge et al., 2017; Aschemann-Witzel et al., 2018), multi-component interventions are necessary to increase acceptance of suboptimal food. Such interventions should aim at increasing consumers' exposure to different-looking fruits and vegetables alongside effective communications (de Hooge et al., 2017; Hingston and Noseworthy, 2020; Bolos et al., 2022). More hands-on experience with suboptimal food could both help persuade organic consumers of their benefits and counteract negative associations such as lower expectations regarding taste (Loebnitz and Grunert, 2018; Hingston and Noseworthy, 2020). In this way multi-component interventions could decrease the intensity of ambivalence experienced by consumers towards suboptimal food and might shift prevailing cosmetic expectations and demands among consumers and retailers.

Limitations and future research

This study initially aimed to measure attitudes towards suboptimal food, environmental concerns, food waste awareness and moral norms towards food waste reduction, as pre-registered. Therefore, relevant items from previous studies were collected and structured into assumed constructs. To ensure these assumed constructs were actually distinct, we used EFA to obtain the best factor solution for this data (Watkins, 2018). However, we failed to show that these multiple latent constructs could explain the covariation between the variables except for attitudes towards suboptimal food and environmental concerns. This highlights the need for a more systematic construction of scales able to measure relevant constructs regarding the underlying factors of food waste.

Our research is based on the hypothetical WTP of consumers participating in an online survey using on-screen food pictures. Although this method has often been used (e.g., Grewal et al., 2019), it can lead to an overestimation of WTP since consumers may behave differently when in a real purchase decision involving a real trade-off between cost (i.e., money) and benefits (i.e., products and their qualities) (Yue et al., 2009). Future studies based on incentive-compatible techniques could be conducted to compare and calibrate the results of the present study.

The present paper also offers a methodological contribution. Conducting mouse-tracking experiments within the context of an online survey is particularly useful given the increasing importance of online studies in consumer research. Moreover, this implicit measure of ambivalence provides a mean to capture the spontaneous motor reactions that unfolds during evaluation process, which is not possible to be captured through self-report. Although the correlation with the self-report data was lower than expected, we nonetheless believe that having different measures of the same construct is useful for research in the area of suboptimal food (cf. Bolos et al., 2019) and that the results of this study are a promising first step towards validating online mouse-tracking. Indeed, after removal of outliers, the correlation coefficient approached our pre-determined threshold. Moreover, the results on our H1 demonstrate the expected differences in ambivalence towards optimal and suboptimal food. We believe that this suggests that the mouse-tracking paradigm may help to better understand cognitive conflicts in consumer psychology. Nonetheless, researchers who wish to adopt this method are encouraged to take some precautions, for instance, increasing the number of trials per stimuli category to increase reliability and pre-register outlier exclusion (including "started too early" alerts) to increase validity. Future studies should also try to account for further factors (e.g., mouse sensitivity and pointing device) that may introduce unsystematic variance in the mouse-tracking experiment (Kieslich et al., 2020). This is especially relevant for conducting mouse-tracking in online settings, despite the fact that Mathur and Reichling (2019) have already tried to account for such issues in their software.

In this study we did not apply a one-size-fits-all approach but specifically aimed to study organic consumers. Interestingly, evaluations for suboptimal food, ambivalence and WTP for suboptimal foods differed even among organic consumers in relation to their organic purchasing frequencies (see Supplementary material), with more frequent purchasers of organic foods evincing more positive evaluations of suboptimal food, lower experience of ambivalence and higher WTP. Given that the experience of ambivalence might thus be linked to increased purchases of suboptimal food, a completely different pattern of results might be obtained from conventional consumers who might be more prone to univalent negative attitudes towards visually imperfect foods. Considering the interindividual differences of consumers, our findings cannot easily be generalised and, therefore, need to be verified using different samples (e.g., socio-demographic, frugality norms and attitude towards the food in general).

Conclusions

Fruits and vegetables from organic agriculture are often more susceptible to suboptimal appearance, making organic consumers an important target consumer for these food products. With this study we aimed to gain deeper insights into the barriers and drivers for purchasing suboptimal fruits and vegetables among organic consumers by incorporating psychological perspectives into a consumer research study. Our research suggests that attitudes are not a good predictor of people's WTP, rather indicating that consumers' WTP for suboptimal food is associated with experiences of ambivalence and environmental concerns. Higher environmental concerns were shown to be an important driver for the acceptance of suboptimal food precisely because it reduces such ambivalence. If food waste is understood and communicated as a consequence of ambivalence towards suboptimal food, we argue, policymakers, retailers and other stakeholders could try to reduce ambivalence among organic consumers to increase sales. Information campaigns and communication efforts should highlight the environmental benefits of suboptimal fruits and vegetables to promote a more positive and univalent attitude towards these food products. In addition, increasing the exposure of organic consumers to fruits and vegetables of various sizes, shapes and colours could help normalise such products to reduce the experience of ambivalence, thereby increasing the willingness of organic consumers to purchase these purportedly ugly but beautiful foods.

Data availability statement

The datasets presented in this study can be found in online repositories at https://osf.io/mazr4/?view_only=df0a78570f404c32903ee1e4309686af.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. This study was carried out in accordance with the University's guidelines for good scientific practice. The participants provided their written informed consent to participate in this study.

Author contributions

BP: conceptualisation, methodology, software, formal analysis, validation, investigation, writing—original draft, and visualisation. BB: conceptualisation, methodology, software, formal analysis, validation, writing—review and editing, and supervision. BJ: conceptualisation, methodology, investigation, writing—review and editing, supervision, project administration, and funding acquisition. All authors contributed to the article and approved the submitted version.

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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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.934954/full#supplementary-material

TABLE S1
One-way ANOVA analyses, comparing the evaluation, subjective ambivalence and WTP for suboptimal food of different organic purchase frequency groups.

TABLE S2
Summary of the items in the questionnaire with German translation and source information.

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Improving adherence to the Mediterranean Diet through a bio-psycho social and sociotype approach

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Introduction

In spite of the very many papers indicating that the Mediterranean Diet (MD) is one of the most healthy and sustainable eating patterns, adherence to it diet is diminishing in most Mediterranean countries.

In the study published by Vilarneau et al. the adherence to the MD over a 50-year period (1961–1965 to 2004–2011) in 169 countries declined in most countries (overall from 2.86 to 2.03 according to the Mediterranean Adequacy Index) in particular the Mediterranean Europe, Southern Mediterranean, and Central Europe countries. These regions have undergone significant cultural, social and political changes, which may have influenced the dietary transition and changes in food habits. Moreover, different studies reported an association between adherence to the MD and socioeconomic factors, with greater wealth being associated with increased adherence to the MD (1–3).

There is therefore a necessity to "revitalize" the MD and to return to a model that is considered a reference for all nutritional guidelines throughout the world (4).

The term *sociotype* describes the reciprocal relationship of an individual with the social environment during life. The sociotype is a theoretical ecological framework to emphasize the bio-psycho-social and environmental factors involved in coping with life stresses (e.g., food insecurity) (5) and patient self-management for chronic illness such as diabesity (6). The sociotype is a framework for helping in coping with different life challenges (7): it has been used for food security (5) and also during the recent COVID shutdown (8). All three domains are involved to different extent in these situations depending on the person and the issues involved. The three domains of the sociotype refer in this paper to: Individual, Relationships/Social environment, and Institutional Context.

The sustainability of the MD has been defined through four dimensions: socio-cultural, economic, environmental, health-nutritional (9). Enhancement of adherence to the MD and its eating pattern should consider (Figure 1):

1) its longitudinal vector—involving the individual called to make healthy and sustainable choices, the family/social relationships and living environment in which these choices must be favored, and the institutional context necessary to promote a such a model for people and the planet and
2) its transversal vector—involving the four domains of sustainability: socio-cultural, economic, environmental, health-nutritional dimensions. Together, these can represent important driving forces to improve adherence to the Mediterranean eating pattern.

The aim of this article is to discuss promoting adherence to the MD by considering the four dimensions of sustainability in an integrating bio-psycho social and sociotypic approach (10).

Sustainable development—The economic dimension

The economic dimension of sustainability deals with the economic conditions of stakeholders, and on economic systems at local, national, regional and global levels (11). It includes:

1. Economic functioning (generated and distributed economic values).
2. Market presence (wages and social benefits by gender, employment opportunities, number of senior management hired from the local community).
3. Indirect economic impacts (development of infrastructure investments and supported services).
4. Procurement policies (proportion of expenditure on providers at key locales).

It has been shown that MD has signficant economic benefits due to its beneficial influence on the prevention of non-comunicable chronic diseases (12), including obesity, some cancers and degenerative neurological diseases, and thereby reducing health expenditure for individuals and health care systems.

A MD based on local foods promotes the economic valorisation of territories and will keep their traditional products linked to history and culture, thereby boosting business both for local producers and distributors.

In particular, recently, the idea of eating food grown and produced locally has gained much attention since it reduces the environmental and economic impacts of transportation, with a reduction of household spending, and increasing the nutritional value of foods (in particular fruits and vegetables) (13).

The sociotypic approach to enhance the adherence to MD, considering in particular the economic dimension of MD, includes individual commitment, interventions engaging the social environment, and the institutional context as described in Table 1.

Sustainable development—The socio-cultural dimension

The social dimension of sustainability is based on equal opportunities for all to healthcare and an adequate level of education. Equality and the refusal of any form of discrimination together with the warranty of peace, all contribute to a socially sustainable development. Food security is an essential part of this feature of sustainability.

Social aspects of sustainability are tightly linked to cultural dimensions. A sustained level of culture and (5, 14) traditional knowledge is in fact absolutely necessary to ensure sustainable development, to find the right solutions that align economic considerations with environmental protection and influence politics at a national and international levels (15).

The report "Culture in the implementation of the 2030 Agenda" (https://agenda21culture.net/sites/default/files/culture2030goal_high.pdf) provides key recommendations for all parties involved in the Implementation Decade (2020–2030) of the Sustainable Development Goals (SDGs) considering:

1. including cultural aspects initially in national frameworks for implementing the SDGs;
2. the importance of local culture in the implementation of the SDGs and the critical roles played by the civil society, institutions, and organizations;
3. commitment to developing multi-level partnerships to strengthen the integration of the cultural dimensions of the SDGs.

Territorial diets, such as the MD, are by nature related to specific geographic regions which have over time, assimilated other influences through the transfer of people material and cultural merchandise, including victuals. In keeping with the local cultural, socio-economic, and environmental contexts, territorial diets are linked not only to the biophysical reserves (soils, microclimates, landscape) that define agriculture and economic practices, but also to particular historical contexts, ecologies, and socio-cultural resources including institutions, and traditional knowledge. Examples of such territorial diets include: The Japanese Diet, the Mediterranean Diet, the Traditional Nordic Diet, and the New Nordic Diet (16).

The MD promotes:

- awareness of the local terroir, seasonality, and biodiversity
- traditional and local foods and culinary activities;
- social interactions through conviviality;
- awareness of the entire historical and cultural heritage of the MD—which is s a dietary tradition passed on from generation to generation.

The sociotypic approach to enhance the adherence to MD, considering its the socio-cultural dimension, includes its three domains described in Table 2.

Sustainable development—The health and nutrition dimension

Much research has considered the environmental impacts of various diets, concluding that a plant-based diet, with less animal-sourced foods confers both improved health and environmental benefits—as encouraged by the motto "more forks than knives."

A healthy diet should optimize health, as defined by a state of complete physical, mental, and social wellbeing and not merely the absence of disease. Healthy diets, such as the MD, have an optimal caloric intake and consist of a wide range of plant-based nutrients, low amounts of animal foods, containing more unsaturated than saturated fats, and with limited amounts of refined grains, highly processed foods, and added sugars (17).

Very many scientific papers (18–21) have demonstrated the health benefits of MD through the prevention of cardiovascular and metabolic diseases, cancer, and depression while slowing the degenerative processes related to aging. In particular Sofi et al.

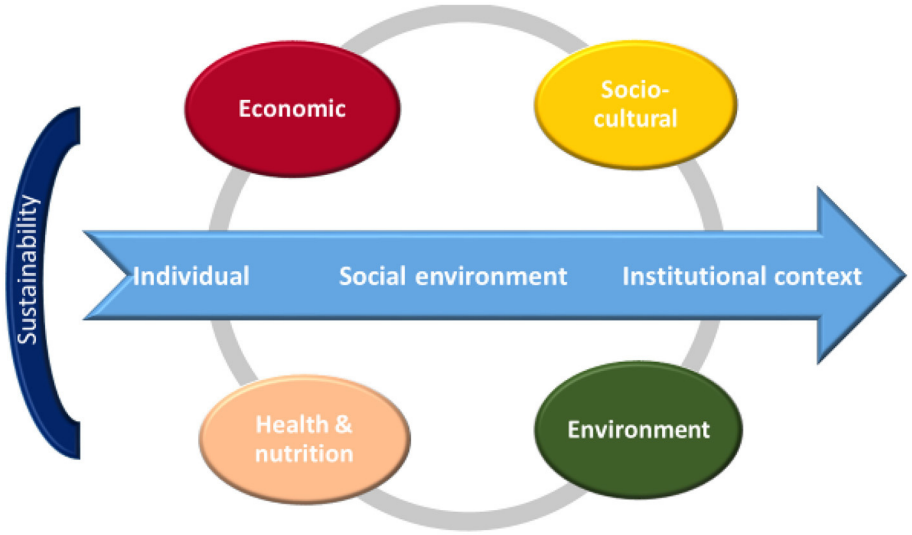

FIGURE 1
Sociotypic approach to the sustainability of food chain.

TABLE 1 Sociotypic approach to the economic dimension of food chain sustainability.

Individual	Social environment	Institutional context
Sensible food choices considering resources employed for their production (energy, water, land use)	Less expensive foods	Policies to support the consumption of high-priced foods (e.g., olive oil, fish)
Reduce food waste without looking at the aesthetic aspects of food	Ensure sustainable and production patterns	Poverty alleviation, equity, and social justice
Consider correctly the expiration dates of foods and "consume preferably by" indication	Adopt recycling procedures for reducing food waste	Demographic transition: less young, more elderly; Urbanization
Choose cheaper but equally nutritious foods (chicken, milk, eggs, legumes,...)		

TABLE 2 Sociotypic approach to the socio-cultural dimension of food chain sustainability.

Individual	Social environment	Institutional context
Revive conviviality and culinary activities	Promotion through social media; role models	Public health and nutrition education (in schools, for health care professionals, and policy makers, . . .)
Awareness of the characteristics of healthy and sustainable diets; improved lifestyle choices	Changing role of working women in the family: time constraints preventing preparation and cooking meals	Fine-tuning and updating dietary guidelines for a healthy and sustainable diet
Adopt more vegetarian eating patterns (more forks than knives)	Role of the family in transmitting food culture and traditional knowledge	Promotion of healthy and sustainable dietary models throughout the catering systems
Choose fresh, home-made foods rather than ultra-processed and fast foods	Promotion of farmers markets	Effective food labeling

have shown analyzing a global population of nine cohort studies including 514,118 subjects, an increase of two points in the adherence score determined an 8%-protection against a premature death (RR: 0.92, 95% CI 0.90–0.94, $P < 0.0001$) (21, 22).

The sociotypic approach to enhance the adherence to MD, considering in particular the health and nutritional dimension of MD are listed in Table 3.

Sustainable development—The environmental dimension

The food chain has important impacts on the environment through the release of huge amount of carbon dioxide (CO_2) into the atmosphere, together with water, soil, land use, and energy consumption (23). Moreover, the production of foods has led to deforestation of large parts of the planet while, *pari passu*, biodiversity of plants and animals used for human nutrition has decreased. This has been caused by a progressive homogenisation of eating habits all over the world, and to the lobbying to increase live-stock and the productivity of the agricultural system.

Moreover, in this Anthropocene epoch, the global food system must operate to optimize human wellbeing and food production to ensure, from sustainable food systems,

TABLE 3 Sociotypic approach to the health and nutritional dimension of food chain sustainability.

Individual	Social environment	Institutional context
Empower people to take responsibility for a healthy lifestyle	Decrease screen time [the Am Acad of Pediatrics recommends: (1) no screen time for children under 2 years; (2) 1 h per day for children 2–12 years old; (3) 2 h per day for teens and adults; www.healthychildren.org] and encourage physical activity (https://www.who.int/publications/i/item/9789241599979)	Positive instead of negative nutritional messages
Adopt food choices in line with dietary guidelines	Parental responsibility and education on healthy lifestyle	Creation of playgrounds and spaces suitable for physical activity
Awareness of the early warning signs for eating disorders	Discourage rewarding with food	Encourage breast feeding (up to 90% of exclusive breastfeeding on discharge and 80% at 4 months—https://extranet.who.int/nutrition/gina/en/node/23607)
Limit portion size		High quality health care services

TABLE 4 Sociotypic approach to the environmental dimension of food chain sustainability.

Individual	Social environment	Institutional context
Consume only seasonal products	Promotion through social media	Promoting resource efficiency
Prefer local food products	Discourage "all-you-can-eat" promotions	Food-banks/food aid
Maintain biodiversity in food choices	Minimizing food loss and waste	Consider sustainability costs for food price policies
Consume only what is needed		

healthy diets for nearly 10 billion people by 2050, while guaranteeing food security, without negatively impacting on the environment. Finally, it is estimated that around a third of the global food production is lost throughout the entire food chain, equally distributed during the production process, along the transportation/conservation/transformation procedures and the consumption sites (including households; https://www.fao.org/in-action/seeking-end-to-loss-and-waste-of-food-along-production-chain/en/).

The MD, as a plant-based dietary model, has demonstrated its environmental benefits that are linked to the reduced use of natural resources (water, soil) and the reduced GHG emissions (13). The use of seasonal products, which is one of the cornerstones of the MD, may contribute to reduce environmental impact of food chain (reduction of greenhouse crops and transport costs from distant countries) and to the preservation/increase of biodiversity (safeguarding small producers, different sowing, and rotation of crops). Frugality (consumption of moderate portions, and of fresh, minimally processed foods) and culinary activities and recipes (in many cases based on the recycling of foods) typical of the MD may contribute to the reduction of food waste.

The sociotypic approach to enhance the adherence to MD, considering the environmental dimension of MD, is described in Table 4.

Conclusions

The bio-psycho-social and sociotypic approach to the multi-faceted nature of the MD can enable nutritionists and policy makers to focus on the different domains—Individual, Living/Social environment, and Institutional contexts—to make practical actions to improve the adherence to the Mediterranean diet and lifestyle.

The concepts discussed in this article may be translated into *policy decisions* at the Institutional—Context level as follows (24):

1) Ensure that Food Systems are Sustainable along the entire food chain—from production to consumption; reduce food losses and waste. Involve multi-stakeholder partners. systemic policies designed to recognize food systems as complex adaptive systems (25).
2) Promote agriculture toward the best Sustainable Ecosystem services and practices. Reduce the use of pesticides and fertilizers (26).
3) Ensure the right of all members of the population to healthy, adequate, and affordable food.
4) Monitor regularly the safety of the food supply chain to be environmentally friendly and free of pathogens.
5) Legislate (and incentivize) the Food Industry to produce healthy (minimally processed foods), with less added sugars, trans fats, salt, and additives. *Informative Labeling* (27, 28). Ensure honest and transparent marketing with. No *junk food adverts to children*
6) Improve Public Health Education on healthy life styles, nutrition, cooking (Mediterranean Diet Patterns), and physical activity.

Once these policies are set in place, then implementation will follow by improving the living/social environment (relationships) and ensuring a healthy, safe external environment (institutional context) to affect the individual and, thereby, enhance adherence to the Mediterranean diet (29).

Finally, we note that diets should not be a list of do's and don'ts, but rather a pleasurable and tasty experience (Individual) in which we respect traditional and cultural preferences (Social Environment). We have to eat to live and not *vice versa*.

Author contributions

LD and EB together conceived and developed the concept and contributed to the final manuscript. All authors contributed to the article and approved the submitted version.

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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.

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Is food produced by farmers healthier, more natural, and gaining more popularity? Research on the influencing mechanism of food producer labels on consumers' food choices

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Introduction: Extant studies have demonstrated the relationship between naturalness and healthiness, and the effectiveness of various food labels in influencing consumers' perception of food and subsequent food choices. However, little attention has been given to food producer labels.

Methods: Drawing on Stimulation-Organism-Response theory, the current study explored the causal relationship between food producer labels and consumers' food choices. Three studies (562 participants) were employed to test the main effect, the mediating effect, and the moderating effect.

Results: The results showed that: (1) food producer label could influence consumers' food choice, that is, produced-by-farmer label (vs. produced-by-enterprise label vs. control group) could significantly increase consumers' food choices, while there is no significant difference between produced-by-enterprise label and control group. (2) Perceived naturalness and standardization perception mediate the effects on consumers' food choices of food producer labels. (3) Food processing level moderates the effect of food producer label on consumers' food choices.

Discussion: The current study enriches the research of food label and food choice, expands the application of Stimulation-Organism-Response theory in consumer behavior, and provides some practical suggestions for consumers, enterprise and policy-maker. Various kinds of experiments (online and offline) enhanced the conclusions' ecological validity. Finally, the limitations and future research are discussed.

KEYWORDS

food choice, food producer label, perceived naturalness, standardization perception, food processing level

1. Introduction

Food is a fundamental part of our daily lives. A food label provides some significant information to consumers, and it is widely used in marketing, e.g., clean food label (1, 2), genetically modified food label (3–5), organic label [(6); B (7)], hygiene warning label (8), all natural label (9), Eco-label (10, 11), fair trade label [(12); Gunne (13)], traffic-light label (14, 15), guideline daily amount label (16), menu label (17), expiration date label (18), etc. and such food labels, have been proven to be effective in influencing consumers' food purchasing intention and consuming behaviors. However, very few studies have examined the food

producer label. It is possible that consumers may have different perceptions of different food producers (19), which means that they might judge the quality of food based on that perception. In the context of food production by individuals and enterprises, the unexplored food producer label (produced-by-farmer vs. produced-by-enterprise vs. control group) seems to be significant and worthy of further investigation.

2. Literature review and hypotheses development

2.1. Food labels and food consumption

A small food label can have a significant impact on food choices (20). ***Food label*** is an important communication tool that provides consumers with information about a product's composition, nutritional profile, and quantity of contents so that they can make product comparisons and selections (21). ***Food choice*** is the process by which individuals and households decide what and how to produce, acquire, prepare, distribute, and consume food (22). Obviously, ordinary citizens do not need to produce and distribute the food all by themselves. However, most of ordinary citizens need to buy, eat, or even recommend food in their daily life. Hence, *the current study defines food choice as the process by which individuals and households decide what to buy and eat food, and whether to recommend the food*. Previous researches have studied some specific food labels' effects on food choices and consumption, i.e., clean food label, GMO label, organic label, hygiene warning label, all natural label, Eco-label, fair trade label, traffic-light label, GDA label, menu label, shelf label, etc. Specifically, some researchers empirically find that organic label significantly increases the health perceptions of a product, i.e., consumers generally perceive organic labeled foods to be healthier than conventional foods (G (23).). Meanwhile, the presence of an organic label can lead to a bias in consumer perception of the product, often referred to as the halo effect which has given some food companies the opportunity to use the organic label to attract health-oriented customers by adding organic labels to non-organic foods (24). In addition to influencing consumers' perceptions of health, organic labels further improve their perceptions of safety. Food processing safety and hygiene warning labels can significantly reduce consumers' perceptions of risk (8). Furthermore, food label also raises moral perceptions among consumers, with GM food label more often triggering negative moral perceptions and reducing consumers' willingness to pay, as consumers generally perceive GM technology as an unethical manipulation of the laws of nature (25), while the presence of an Eco-label increases consumers' moral perceptions of the retailer. On the one hand, this is because eco-friendly products themselves demonstrate a sense of corporate social responsibility. On the other hand, it also significantly increases the social identity of individuals who purchase such products (26). Thus, food labels significantly affect consumers' food perceptions, including the impact on consumers' perceptions of health, the perceptions of safety and risk, and the perceptions of morality. On the basis of the above results, existing literatures demonstrate that food labels further influence consumers' trust in products (27), willingness to pay and purchase intentions (28, 29), and food choices.

Food labels serve as a primary source of information for consumers about food, and they have a significant impact on consumers' food choices (30). In this case, consumers are looking for food information to judge the characteristics and attributes of the food, and food labels can enable them to discern pertinent information. Farmers earn income from planting and selling produce (31, 32), which are the original ingredients of most food. People, therefore, always make an implicit connection between farmers and food, especially the produce. We could thus conclude that consumers might prefer to buy and consume food if they find some information about farmers (vs. enterprise vs. control group) on the surface or package of the food. Meanwhile, the company employs large-scale and standardization operations, and when customers discover the corporate message on food products' surface or packaging, they may feel assured of food quality. The enforcement of laws and the effectiveness of regulatory institutions also make customers subconsciously believe that the quality of food is guaranteed, even if there is no information on the food products' surface or packaging. Hence, we infer that there lies no difference of the effect between produced-by-enterprise label and the control group. The **Simulation-Organism-Response theory** (SOR theory) assumes that the environment contains stimuli (S) that cause changes to people's internal or organismic states (O), which in turn cause approach or avoidance responses (R) (33). Based on SOR theory, produced-by-farmer label (vs. produced-by-enterprise vs. control group) is a stimulation (S) that could increase individuals' perceived naturalness (O), which further enhances consumers' food choices (R). Thus, we propose the following hypothesis. Formally stated:

> *H1:* Food producer label (produced-by-farmer label vs. produced-by-enterprise label vs. control group) could influence consumers' food choice. Specifically, consumers show a higher willingness to purchase food when they are faced with produced-by-farmer label (vs. produced-by-enterprise label vs. control group), and there is no significant difference between produced-by-enterprise label and control group.

2.2. Perceived naturalness and standardization perception

Humans have been in natural environments for most of their evolutionary life, and nature has a positive effect on physical and mental health, cognitive functioning, curriculum learning, increasing levels of well-being and positive thinking, and reducing aggression and violence (34). Farmers have a higher implicit association with nature compared with enterprises, thus farmer-related information gives consumers a deeper sense of perceived naturalness than enterprise-related information. ***Perceived naturalness*** is the degree to which consumers perceive a product to be natural in terms of appearance, workmanship and other dimensions (35), and the natural property of an object is one of the key indicators of its quality for consumers (L. (36)), because people have the "naturalness equals healthiness" bias (37), and consequently prefer naturalness, especially for food, even the natural and artificial objects are specified as equivalent (38). The biophilia hypothesis proposes that humans have evolved over time to genetically prefer certain natural environments that help them have an increased chance of survival, escaping from danger and access to food (39). The stress recovery theory suggests that three elements, i.e.,

non-threatening landscape elements, greenery elements, and specific natural landscapes, are effective in reducing stress and stimulating positive emotions in humans (40). All these studies suggest that perceived naturalness increases positive human emotions. The presence of a farmer-owned label improves consumers' food choices, as has been empirically demonstrated using Dutch consumer milk consumption data, which shows that not only does the farmer-owned label increase consumers' willingness to buy, but also that consumers are willing to pay a premium for milk containing the farmer-owned label (41). Based on SOR theory (33), produced-by-farmer label is a stimulation (S) that could increase individuals' perceived naturalness (O), which further enhances consumers' food choices (R).

The commodity flow path shows that agricultural products are processed into food and traded on markets, and that food standardization increases the perceived quality reliability of the commodity. ***Food standardization*** means that the production, processing and distribution of food are done according to specific standards. A standard is a set of details and criteria that must be adhered to throughout the whole process in order to be successful. From food production and processing to sales, each process requires scientific and technological attention and management (42). There is evidence that marketing standardization (43) and channel management standardization (44) are significantly associated with firm performance. Standardization significantly contributes to firm performance in the production industry and not so significantly in the service industry (45). However, the effect of standardization on service quality exceeds the effect of customization on service quality (46). As can be seen from the above, the majority of studies on standardization in the literature have focused on enterprises, and little literature has begun to explore the feasibility of standardizing production for individual farmers, suggesting that the link between standardization and enterprise is in line with people's common sense. According to SOR theory (33), when consumers are confronted with a produced-by-enterprise label (vs. produced-by-farmer label), it activates the consumer's ***standardization perception***. On the contrary, produced-by-farmer label (vs. produced-by-enterprise label) could decrease consumers' standardization perception, consequently weakening consumers' food choice. Additionally, most of foods' ingredients are from produce, and people always make an implicit connection between farmers and the produce. Therefore, produced-by-farmer label (vs. produced-by-enterprise label) could increase consumers' perceived naturalness and decrease standardization perception, and the effect on perceived naturalness is bigger than that of standardization perception. Thus, we develop the following hypothesis. Formally stated:

> *H2:* Perceived naturalness and standardization perception parallel mediate the effect of food producer label on consumers' food choice. Specifically, perceived naturalness positively mediates the main effect, while standardization perception negatively mediates the main effect, and the effect of perceived naturalness is bigger than that of standardization perception.

2.3. Food processing level

Food processing has increased the diversity of nutritious foods in the modern diet (47) and has met the needs of consumers for food diversity. Depending on the degree of processing and the purpose of processing, food products can be classified into different types. Among these classifications, the **NOVA *classification*** of processed foods is popular and widely accepted (48, 49), and scholars' studies on food classification have mostly adopted the NOVA classification or expanded their exploration based on the original NOVA classification (50, 51). NOVA divides food into four categories. Firstly, raw or minimally processed foods, such as fruit, rice, etc. Secondly, culinary ingredients, raw foods that have been refined for cooking, such as edible oil made from nuts, rape flowers, etc. Thirdly, processed foods, foods that have been processed with salt, oil, sugar, etc. Their properties have been altered as a result of these processing, e.g., canned fish, fresh bread, cheese, etc. The fourth category is ultra-processed foods, i.e., foods that are processed on the basis of processed foods, which usually contain more than or equal to five industrial ingredients and are high in sugar, fat and calories, such as sugary drinks, biscuits, ham sausages, ice cream, cakes, etc. (52, 53). It is very clear that the more processed the food is and the more food additives it has, the less healthy it is, and processed and over-processed foods are often considered to be of low nutritional quality and unhealthy (54). The unnatural and unhealthy properties of ultra-processed foods are particularly pronounced (55). In conclusion, the properties of 3rd and 4th food are altered by processing, while the properties of 1st and 2nd food are not (52, 53, 56), which could influence perceived naturalness, standardization perception, and consumers' food choice. Specifically, for 1st (raw or minimally processed foods) or 2nd (culinary ingredients) foods, the properties of foods keep unchanged, and produced-by-famer label (vs. produced-by-enterprise label) is a stimulation (S) that could increase individuals' perceived naturalness and decreases standardization perception (O), which further significantly enhances consumers' food choices (R). For 3rd (processed foods) or 4th (ultra-processed foods) foods, the properties of foods (especially some properties about naturalness) have been alerted, there is no statistically significant difference in the effects of food producer labels (produced-by-farmer vs. produced-by-enterprise) on consumers' food choices. Therefore, we develop the following hypothesis. Formally stated:

> *H3:* Food processing level plays a moderating role in the effect of food producer label on food choices. Specifically, for 1st or 2nd foods, produced-by-farmer label (vs. produced-by-enterprise label) could increase their food choices. For 3rd or 4th food, there is no statistically significant difference in the effects of food producer labels (produced-by-farmer vs. produced-by-enterprise) on consumers' food choices.

3. Study design, experiments, and study results

We tested our hypotheses with 3 studies. Study 1 verified the causal relationship between food producer label and food choices with 2 kinds of foods, that is, consumers showed a higher willingness of food choices when they faced produced-by-farmer label (vs. produced-by-enterprise label vs. control group), and there was no significant difference between produced-by-enterprise label and control group. Study 2 tested the parallel mediating effects of perceived naturalness

and standardization perception of food producer labels on consumers' food choices. Specifically, perceived naturalness mediated the effects of produced-by-farmer labels on food choices, and standardization mediated produced-by-enterprise labels' impact on food choices. Study 3 explored the boundary condition of food processing level on the effect of food producer labels on consumers' food choice.

3.1. Study 1: test of the main effect

3.1.1. Design, participants, and procedure

Study 1 used a between-subjects design experiment with three manipulated condition (food producer label: produced-by-farmer label vs. produced-by-enterprise label vs. control group). After an estimation of the sample size with G-Power, 160 Chinese residents (65.00% females; Mage = 29.54, SD = 7.90) were recruited from an online experiment platform named CREDAMO for monetary reward, and 5 participants were excluded from the study for their answers being beyond 3 times of standard deviation, remaining a final sample of 155 ($n_{produced\text{-}by\text{-}farmer} = 54$, $n_{produced\text{-}by\text{-}enterprise} = 48$, $n_{control} = 53$). After the participants agreed to participate in a questionnaire study about The Willingness of Orange Choices with 3 items, they were told that:

> Imagine one day you were wandering in the food market and you came across a fruit stall and saw oranges as shown in the picture (see Supplementary Figure 1). How would you make the following decision? (1) How likely are you to buy the oranges? (2) How likely are you to eat the oranges? (3) How likely are you to recommend the orange to your relatives or friends? (1 = not at all likely, 7 = very likely; α = 0.837).

3.1.2. Results and discussion

The three food choices measuring items were averaged to create an index. In support of hypothesis 1, a one-way ANOVA revealed a significant main effect of food producer label on consumers' food choices [$F(2,152) = 9.803$, $p = 0.000$, $\eta^2 = 0.114$]. Specifically, the participants of produced-by-farmer label (M = 5.963, SD = 0.723) reported higher likely of food choice than control group [M = 5.208, SD = 0.752, $t(105) = 5.299$, $p = 0.000$, Cohen's d = 1.024] and those of produced-by-enterprise label [M = 5.396, SD = 1.227, $t(100) = 2.880$, $p = 0.005$, Cohen's d = 0.563]. Additionally, there was no significant difference between the produced-by-enterprise and the control group [$t(99) = 0.99$, $p = 0.350$]. All the results supported hypothesis 1.

3.1.3. Supplementary study

To verify the robustness of the results of hypothesis 1, the participants ($N = 160$, 65% female, $M_{age} = 29.54$, SD = 7.90) who had participated in the above study, were instructed to fill out another survey named The Willingness of Meat Choices with 3 items. All 160 participants were kept for the study ($n_{produced\text{-}by\text{-}farmer} = 54$, $n_{produced\text{-}by\text{-}enterprise} = 53$, $n_{control} = 53$). They were told that, someday, you went to a supermarket for shopping and wandered into the meat section and saw pork as shown in the picture (see Supplementary Figure 2), what your choices were for the following questions: (1) How likely you are to buy the pork? (2) How likely you are to eat the pork after cooking as you wish? (3) How likely you are to recommend the pork to your relatives or friends? (1 = not at all likely, 7 = very likely; α = 0.894). Being identical with the above study, the supplementary study supported hypothesis 1. A one-way ANOVA showed the significant effect of food producer labels on consumers' food choice [$F(2,157) = 6.534$, $p = 0.002$, $\eta^2 = 0.077$]. The participants of produced-by-farmer label (M = 5.691, SD = 0.878) reported higher likely of food choice than control group [M = 5.239, SD = 1.301, $t(105) = 2.111$, $p = 0.037$, Cohen's d = 0.407] and those of produced-by-enterprise label [M = 4.748, SD = 1.737, $t(105) = 26.62$, $p = 0.001$, Cohen's d = 0.685]. Additionally, there was no significant difference between the produced-by-enterprise group and the control group [$t(104) = 1.645$, $p = 0.103$]. Hypothesis 1 was tested again by the study 1B.

Study 1 proved the main effect, as we expected, that food producer labels could influence consumers' food choices, that is, the participants from produced-by-farmer label group reported higher levels of food choices than control group and those of produced-by-enterprise label group, and there was no significant difference between the produced-by-enterprise group and control group (Hypothesis 1). With supplementary study, we validated hypothesis 1 in another context and with a different type of food in order to ensure the robustness of the main effect. Our following work aimed to test the mediating role of perceived naturalness and standardization perception, which could provide insights into how the main effect occurs.

3.2. Study 2: test of the mediation of perceived naturalness and standardization perception

3.2.1. Design, participants, and procedure

As tested in study 1, there was no significant difference between produced-by-enterprise label and control group, thus study 2 used a one-factor (food producer label: produced-by-farmer label vs. produced-by-enterprise label) between-subjects design. 150 CREDAMO workers (63% female, Mage = 43.19, SD = 161.72) took part in the study for monetary payment, and one participant was removed from the study because he/she guessed the purpose of the study, leaving 149 participants for the study ($n_{produced\text{-}by\text{-}farmer} = 74$, $n_{produced\text{-}by\text{-}enterprise} = 75$). First of all, the participants reported their personal information about gender, age, income, purchasing experience and preference of baby Chinese cabbage. After that, they were told to participate in the investigation named ***The Willingness of Baby Chinese Cabbage Choices***, they read the following instruction: *Imagine you are wandering at a wholesale vegetable market and find baby Chinese vegetables as shown in the picture* (see Supplementary Figure 3), *what your choices of the baby Chinese cabbage are, consisting of 3 items, (1) How likely are you to buy the baby Chinese cabbage? (2) How likely are you to eat the baby Chinese cabbage after cooking as you wish? (3) How likely are you to recommend the baby Chinese cabbage to your relatives or friends?* (1 = not at all likely, 7 = very likely; α = 0.806). Then all the participants answered the questions of perceived naturalness, whose scale was derived from Hagen's research (37), rating the extent to which they thought the baby Chinese cabbage was "natural" "pure" and "unprocessed" (1 = not at all, 7 = very much; α = 0.883). Along with perceived naturalness, the participants rated the degree to which the baby Chinese cabbage was "production standardization" "logistics standardization" and "sale standardization" (α = 0.817), which referred to Yuan's study (57). Besides, they were instructed with some questions about the degree of their current emotion, i.e., fear, anxiety, sadness, happiness, on a one-item, 7-point Likert scale, respectively. Finally, they answered some questions about alternative mediating variables, i.e., flavor perception (58), and degree of involvement (59).

3.2.2. Results and discussion

A one-way ANOVA was used to compare the food choice of baby Chinese cabbage between produced-by-farmer label and produced-by-enterprise label. Results showed a significant difference between conditions such that the participants of produced-by-farmer label (M = 5.856, SD = 0.702) reported higher likely of food choice than those of produced-by-enterprise label [M = 5.373, SD = 1.139, $F(1,147) = 9.657$, $p = 0.002$, $\eta^2 = 0.062$]. We tested gender, age, income, purchasing experience and preference of baby Chinese cabbage's effects and final results showed that gender ($p = 0.037$) and preference ($p < 0.001$) had a significant effect on consumers' food choice, while age ($p = 0.442$), income ($p = 0.098$) and purchasing experience (note: all the participants had purchasing baby Chinese cabbage experience) did not exert a significant effect on food choice. Thus, gender and preference were regarded controlling variables in the following analysis. After controlling gender and preference, food producer labels still significantly influenced consumers' food choices [$F(1,145) = 8.946$, $p = 0.003$, $\eta^2 = 0.058$].

An ANOVA analysis, using food producer label as independent variable (produced-by-farmer = "1", & produced-by-enterprise = "0") and perceived naturalness as dependent variable, revealed that produced-by-farmer label influenced consumers' perceived naturalness much more than produced-by-enterprise label [$M_{produced\text{-}by\text{-}farmer} = 5.698$, SD = 0.672; $M_{produced\text{-}by\text{-}enterprise} = 4.764$, SD = 1.382; $F(1,147) = 27.404$, $p = 0.000$, $\eta^2 = 0.157$]. In the same way, standardization perception as dependent variable revealed that the expected effect was observed [$M_{produced\text{-}by\text{-}farmer} = 5.378$, SD = 1.021; $M_{produced\text{-}by\text{-}enterprise} = 5.676$, SD = 0.735; $F(1,147) = 4.166$, $p = 0.043$, $\eta^2 = 0.028$]. Next, perceived naturalness and standardization perception were used as mediators using the procedures outlined in Piters' research (60). A bootstrapping technique with 95% confidence intervals and 5,000 samples was employed to test for mediation (model 4) (61). The results showed significant indirect effects of food producer label on consumers' food choice through perceived naturalness, $\beta = 0.3447$, 95% CI [0.1219, 0.6171], and standardization perception $\beta = -0.0648$, 95% CI [−0.1501, −0.0059], respectively. Zero did indeed fall outside of the interval, providing statistical evidence of successful mediation (see Figure 1). Finally, we ruled out some alternative mediating variables for the main effect, such as fear [CI: −0.0645, 0.0419], anxiety [CI: −0.0370, 0.0450], sadness [CI: −0.0228, 0.0664], happiness [CI: −0.0596, 0.1592], flavor perception [CI: −0.0603, 0.3442], and involvement [CI: −0.0895, 0.2157] because all the intervals included zero (see Figure 1).

Study 2 proved the expected main effect (hypothesis 1) again and tested the rationalization of the parallel mediating model of perceived naturalness and standardization perception (hypothesis 2). In the following research, we were trying to find a good moderating variable fit for the main effect.

3.3. Study 3: the moderating effect of food processing level

Study 3 had several goals. Our first objective was to gain insight into how food producer labels influenced consumers' food choices. Second, we used our study to validate the moderating effect of food processing level on consumers' food choices from food producer labels.

3.3.1. Design, participants, and procedure

After an estimation of the sample size with G-Power, 272 participants were recruited from a university of Yunnan province, China, and randomly assigned to a 2 (food producer label: produced-by-farmer vs. produced-by-enterprise) × 2 (food processing level: sliced raw fish vs. fish sauce) between-design. Twenty participants were excluded for their failure at the attention test, leaving a final sample size of 252 participants (87% female, Mage =19.89, SD = 1.219; $n_{produced\text{-}by\text{-}enterprise\text{-}sliced\ raw\ fish} = 58$, $n_{produced\text{-}by\text{-}enterprise\text{-}sliced\ raw\ fish} = 68$, $n_{produced\text{-}by\text{-}farmer\text{-}fish\ sauce} = 64$, $n_{produced\text{-}by\text{-}enterprise\text{-}fish\ sauce} = 62$). Following their agreement of participating in the survey of ***Products' Market Acceptance from Self-Owned Shop***, all participants were asked to read the following sentence:

> Imagine that a self-employed shop is proposing to launch an innovative product as shown in the picture (see Supplementary Figure 4) and is conducting market research to determine whether it will eventually sell the product. Observe the picture carefully for a period of time and answer the following questions: (1) How likely are you to buy the product? (2) How likely are you to eat the product (after cooking as you wish if it needs)? (3) How likely are you to recommend the product to your relatives or friends? (1 = not at all likely, 7 = very likely).

Participants might see either sliced raw fish (2nd food: culinary ingredients) or fish sauce (3rd food: processed food), each of which had a produced-by-farmer label (the produced-by-farmer group) or a produced-by-enterprise label (the produced-by-enterprise group). [Note: Sliced raw fish are kinds of a product obtained by cutting fresh fish into slices, and they are not cooked by traditional methods such as stir-frying, deep-frying or steaming. Fish sauce is a product made by stir-frying fish, ginger, garlic, peppers and other ingredients in oil (see Supplementary Figure 4). According to the classification of NOVA; (52, 53), sliced raw fish is the 2nd food (culinary ingredients), and fish sauce is the 3rd food (processed food). Hence, sliced raw fish and fish sauce were used as experimental materials]. After they answered the questions of food choices, they reported their gender, age, monthly income, preference of fish.

3.3.2. Results and discussion

Our experiment used an item (Please recall that the green label in the top right corner of the picture is: A. produced-by-farmer, B. the produced-by-enterprise, C. other content) at the end of the experiment to conduct a manipulation check. All 252 participants answered the question correctly, indicating there is no difference among them in identifying food producer labels, suggesting a successful manipulation.

An ANOVA result showed that food producer labels significantly influence consumers' food choice [$M_{produced\text{-}by\text{-}farmer} = 3.934$, SD = 1.169; $M_{produced\text{-}by\text{-}enterprise} = 3.559$, SD = 1.362; $F(1, 298) = 5.478$, $p = 0.020$, $\eta^2 = 0.021$]. More importantly, the regressing result, using the interactive term of food producer label and processing level as independent variable, food choice as dependent variable, was statistically significant ($p = 0.001$). After controlling gender, age, monthly income, and preference for fish, the result kept significant too ($p = 0.003$). Specifically, for sliced raw fish, the effect of food producer labels on consumers' food choice is statistically significant [$M_{produced\text{-}by\text{-}farmer} = 3.621$, SD = 1.157; $M_{produced\text{-}by\text{-}enterprise} = 3.152$, SD = 1.425; $F(1,250) = 6.065$, $p = 0.015$, d = 0.361]. For fish sauce, the effects of food

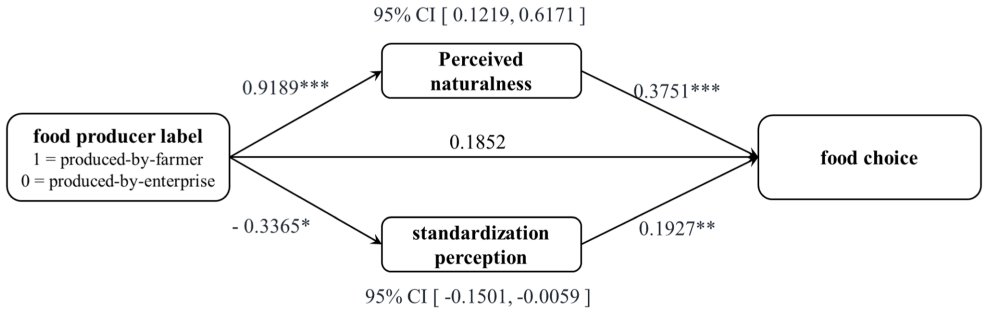

FIGURE 1
The parallel mediation model. * = $p < 0.05$; * = $p < 0.01$; * = $p < 0.001$.

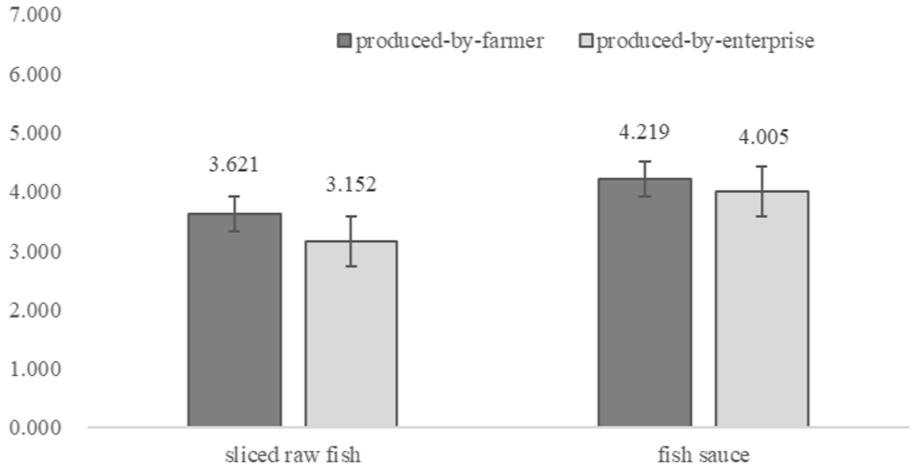

FIGURE 2
The results of moderating effect.

producer labels on consumers' food choice aren't significant ($M_{produced\text{-}by\text{-}farmer} = 4.219$, $SD = 1.146$; $M_{produced\text{-}by\text{-}enterprise} = 4.005$, $SD = 1.143$; $p = 0.291$; see Figure 2), supporting hypothesis 3.

With different types of food and different purchasing conditions, study 3 examined the effect of food producer labels on consumers' food choices. Most importantly, food processing level (1st or 2nd food vs. 3rd or 4th food) was found to moderate the effect of food producer label on consumers' food choice. To this end, all hypotheses (hypotheses 1, 2, and 3) had been tested successfully.

4. General discussion

It is very common that many foods have labels posted on the surface of foods or on the package of foods in our daily life. These labels are to attract consumers' attention and influence their subsequent purchasing behaviors, by conveying some attributional information about the foods. Previous researches have proved that naturalness could lead individuals perceive health, and a lot of food labels, e.g., clean food label, (non) genetically modified food label, organic label, hygiene warning label, all natural label, Eco-label, fair trade label, traffic-light label, guideline daily amount label, menu label, etc., could enhance consumers' purchasing intention and behaviors. According to the present study, food producer labels can have a considerable impact on consumers' food choices. Our study, to some degree, enriches the existing literature on food labels and food choices. It also provides some practical implications for business practice, consumers' food choices and policy makers' decision making.

4.1. Theoretical contributions and practical implication

The current work studies the mechanism of food producer label on consumers' food choice, proves that food producer label (produced-by-farmer vs. produced-by-enterprise vs. control group) could affect consumers' food choice, including purchasing, eating and recommendation, and makes several theoretical contributions to the mainstream literature on food labels and food choices. Firstly, by two different circumstances and foods, our research tests the influencing mechanism of food producer labels on consumers' food choices, that is, produced-by-farmer label (vs. produced-by-enterprise vs. control group) could strengthen consumers' food purchasing, food eating and food

recommendation, while there is no significant difference between produced-by-enterprise and control group (study 1). Secondly, we develop a parallel mediating model to provide an explanation for the main effect (study 2). Within the parallel mediating model, perceived naturalness and standardization perception statistically significantly parallel mediate the effect of produced-by-farmer, and produced-by-enterprise, on consumers' food choices, respectively. Finally, food processing level is tested as a boundary condition of the main effect (study 3). Specifically, for 1st (raw or minimally processed foods) or 2nd (culinary ingredients) foods, *produced-by-farmer label (*vs. *produced-by-enterprise label) could increase their food choices*. For 3rd (processed foods) or 4th (ultra-processed foods) foods, there is no statistically significant difference in the effects of food producer labels (produced-by-farmer vs. produced-by-enterprise) on consumers' food choices. All these conclusions contribute to the current mainstream literature on food labels and food choices, and expand the application of Stimulation-Organism-Response theory in consumer behavior.

By highlighting the role of food producer labels for decision making of enterprise, consumer, and even government, our research has potentially vital practical implications. ***From a marketing perspective***, for unprocessed food, e.g., fruit, rice, flour, vegetable, (roasted) potato, tomato, cooking oil, pork, fish, etc., adding a produced-by-farmer label could enhance consumers' perceived naturalness and consequently, increase their willingness to purchase, eat and recommend. Obviously, the effect of perceived naturalness is driven by individuals' perceived health, which could improve consumers' emotional value and increase their welfare. In order to increase sales, enterprises should display the produced-by-farmer label on food surfaces or food packages if the product or its original ingredients are produced by farmers. There is also the possibility that posting a produced-by-farmer label can reduce consumer food price sensitivity because people have the feeling that healthy means expensive (62). In the meantime, it is not advisable for companies to show the produced-by-enterprise label on food surfaces or packaging, since there is no statistically significant difference between the produced-by-enterprise group and the control group. Besides, posting an additional food label would increase the cost of food. However, for processed food, e.g., canned fish, fresh bread, cheese, sugary drinks, biscuits, ham sausages, ice cream, cakes etc., it is not effective to include a produced-by-farmer label because there is no significant difference between the produced-by-enterprise group and the produced-by-farmer group. Additionally, ***ordinary consumers*** should be aware that, under the principle of ensuring food quality, there is no significant difference in quality and nutrition between the food labeled produced-by-farmer label and other labels. Therefore, you should focus on food price, food quality, and your own food flavor preference. Lastly, ***policy makers*** must monitor whether businesses are legal in how they implement food labelling practices in order to avoid businesses deceiving consumers through labels. Meanwhile, if policy makers plan to push guiding consumers to a healthy diet to refrain from the illness caused by fatness, they could mandate companies to post the produced-by-farmer label on healthy foods appropriately, if the product or its original ingredients are produced by farmers, to increase consumers' healthy food choice and consequently enhance consumers' and the whole society's welfare.

4.2. Limitation and future work

Although we have designed and implemented two different purchasing circumstances to support the main effect (study 1), one experiments to test the mediating effect (study 2), and one experiment to validate the boundary conditions of the main effect (study 3), ensuring that our conclusions are theoretically-based, tested and robust, there still might be some limitations in our study. Firstly, the current study examined the parallel mediating effect of perceived naturalness and standardization perception on the main effect. Besides, food producer labels might elicit consumers' health perception and hygiene perception, and both of them are not discussed. Future research could try to test the two alternative mediators. Secondly, we discussed two levels of food producer labels, i.e., produced-by-farmer and produced-by-enterprise. However, there might be some other food producer types. Even for produced-by-enterprise food, the enterprises might adopt different technologies, e.g., traditional technology or eco-environmental technology. The potential future research could explore other food producer types to enrich the study. Finally, our study focuses on the consumers' food choice, and we think such labels might be applied in other fields, such as tourist accommodation, leisure restaurant, ethnic clothing etc. Future study could examine their applications in new fields.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Association for Science and Technology of Chuxiong Normal University, China. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

XJ: Conceptualization, Writing – review & editing, Project administration. YZ: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing.

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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.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1255023/full#supplementary-material

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From future diets to dishes: communicating dietary shift associated with a 1.5°C scenario for Brazil, China, Sweden and the United Kingdom

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Introduction: With the pressing need to mitigate greenhouse gas emissions, this study aims to simplify complex data from Integrated Assessment Models (IAMs). It focuses on identifying dietary shifts that align with the 1.5°C global warming limit as stipulated by the Paris Agreement.

Methods: The research utilises the IMAGE Integrated Assessment Model and applies the Diets, Dishes, Dish Ingredients (DDDI) communication framework. This methodology enables the visualisation of potential dietary and dish composition changes, thereby making the data more comprehensible to a broader audience.

Results: The study effectively translates traditional IAM outputs into accessible visualisations. These visual tools provide a nuanced understanding of a low greenhouse gas diet, extending its relevance beyond academia to include professionals in diet and nutrition.

Discussion: This research stands as a significant advancement in the field, lowering the barrier to understanding sustainable diets for the future. It enriches the existing dialogue on dietary change and climate goals and serves as a catalyst for further research and practical applications in diverse contexts.

KEYWORDS

communicating dietary change, plant-based diets, DDDI framework, visualisation techniques, sustainable diets, climate-compatible diets, future food changes, hybrid diets

1 Introduction

The increasing world population and associated increase in food consumption are putting pressure on natural resources worldwide, with the increased food production resulting in expanded agricultural land use and agriculture-related greenhouse gas (GHG) emissions. The global agricultural sector contributes approximately 23% of total greenhouse gas emissions (~12 $GtCO_2$ eq per year; Chen and Önal, 2016; IPCC, 2022), with much of these emissions arising

from methane and nitrous oxides produced by human activities, primarily livestock rearing for meat production (Clark et al., 1979; Clune et al., 2017; IPCC, 2022). These emissions are projected to grow by 6% within the next decade, with livestock accounting for 90% of this increase (FAO, 2022a).

Dietary shifts towards healthier and more sustainable food systems could contribute to achieving all 17 United Nations Sustainable Development Goals (SDGs) by 2030 (FAO, 2022a). Furthermore, such dietary changes could aid countries in reducing greenhouse gas emissions, supporting the implementation of the Paris Agreement (UNFCCC, 2015). Numerous interventions have been proposed to promote these dietary changes, including reducing meat consumption and increasing plant-based protein intake (Macdiarmid et al., 2012; Tilman and Clark, 2014; Springmann et al., 2016). Their primary focus is on transitioning from meat-based to plant-based protein sources, reducing food waste, and consuming more locally. However, a holistic approach incorporating a decrease in caloric intake, a reduction in food losses and waste, and advancements in agricultural practices is essential for staying within planetary boundaries, alongside the shift from meat-based to plant-based diets (EAT, 2019). Achieving a reduction in meat consumption requires individual action (Laestadius et al., 2016; Jebb, 2018), information provision (Bailey and Harper, 2015), as well as institutional and national level involvement (UNFCCC, 2015; Jebb, 2018; FAO, 2022a). However, interpreting research findings on low-carbon diets can be challenging due to data being presented in various ways and units, such as percentage reductions in meat (De Boer and Aiking, 2022), grams/day (Scarborough et al., 2014; Micha et al., 2015; Godfray et al., 2018), kcal/capita/day (Tuninetti et al., 2022), and servings per day or per week (Hogbin and Hess, 1999; Micha et al., 2015). The relatively complex information provided often fails to capture the diverse range of individuals' diets within a country and can be too abstract for direct interpretation (Stehfest et al., 2009).

This study aims to interpret the implications of modelled changes in food demand for protein food items and individual diets in four countries (van Dooren et al., 2015; Bijl et al., 2017; Torstensson et al., 2021): Brazil, China (both rapidly developing), and Sweden and the United Kingdom (UK; developed countries) consistent with a 1.5°C emissions pathway to 2050. The selection of the four nations for analysis aligns with the different low-carbon development pathways outlined by the Centre for Climate Change and Socal Transformations, providing a diverse yet focused lens through which to examine the impact of dietary changes on climate goals (Howarth et al., 2019). To achieve this the study interprets the outputs from a 1.5°C emissions pathway generated using the IMAGE model (PBL Netherlands Environmental Assessment Agency, 2019); this model is frequently used to inform international global policy and contains a detailed food demand component. The detailed food demand component within the IMAGE climate Integrated Assessment Model (IAM) is a part of the model used to interpret the implications of changes in food demand, specifically focusing on protein food items and individual diets in various countries, in alignment with a 1.5°C emissions pathway to 2050. An IAM, such as the IMAGE IAM, simulates interactions between climate, economy, society and the biosphere to evaluate climate change impacts and develop mitigation policies.

De Boer and Aiking (2019) propose a hierarchical framework known as 'DDDI' (Diets, Dishes, and Dish Ingredients) to articulate a protein transition from animal to plant-based proteins. This framework aligns with the structure of food items used by the FAO and food groupings by various authors (Poore and Nemecek, 1979; Tilman and Clark, 2014; Springmann et al., 2016; Mazac et al., 2022; Tuninetti et al., 2022), as well as (Stehfest et al., 2009; Bijl et al., 2017; Van Vuuren et al., 2018), to represent dietary change within an IAM. Offering a more direct visualisation of dietary patterns, the DDDI framework can seamlessly connect to the results of IAM models, thanks to the novel linkages of both DDDI and IAM output to FAO information.

The Lifestyle Change (LiStCh) scenario, derived from the IMAGE IAM, plays a significant role in this context. This scenario represents a mitigation pathway that anticipates constrained technological advancement in the energy sector, leading to a more gradual reduction in greenhouse gas emissions. Within the framework of the IMAGE IAM model, four distinct mitigation scenarios are delineated (van Vuuren et al., 2011):

- Business-as-Usual (BAU): Presuming the absence of additional climate mitigation policies.
- Sustainable Development (ScD): Envisaging robust technological progress and a rapid transition to a low-carbon economy.
- Stabilisation (ScE): Projecting moderate technological advancement to stabilise greenhouse gas emissions at safe levels.
- Lifestyle Change (LiStCh): Anticipating barriers to technological progress in the energy sector, including innovation costs, political reluctance, and vested industrial interests, with limited public support for climate mitigation measures.

The LiStCh scenario within the IMAGE IAM assumes limited technological progress in the energy sector, leading to a slower decline in greenhouse gas emissions, and employs measures like bioenergy with carbon capture and storage to reduce emissions (Clery et al., 2021; Freer et al., 2021, 2022). While IAMs are valuable for assessing policy cost-effectiveness, evaluating impacts, and communicating risks, they also face challenges such as complexity and data requirements, leading to uncertainty. Despite these limitations, IAMs remain essential tools for understanding climate change and shaping mitigation strategies.

The LiStCh scenario offers insights into the modification of protein foods to align with a healthy diet, consistent with previous studies (Stehfest et al., 2009; Bijl et al., 2017). This scenario encompasses the role of food production and consumption within a 1.5°C pathway, integrating the broader context of GHG emissions. Data derived from the LiStCh scenario were instrumental in informing the creation of future diet and dish visualisations for this study, laying the groundwork for the potential re-application of the visualisation process to other distinct mitigation scenarios in future research. Such an approach could provide a more nuanced perspective on potential dietary shifts.

In the present study, the DDDI framework is synergistically combined with the LiStCh scenario outputs. This integration facilitates the calculation of the number of portions of key food groups consumed *per capita* within each country, illustrating the evolution of these quantities within the scenario from 2020 to 2050. The subsequent analysis explores the implications of such dietary changes on the ingredients of a popular dish selected for each of the four case-study

countries. This examination vividly demonstrates the shifting patterns of meat and non-meat protein consumption, complemented by images of representative dishes from each nation.

These outputs serve a dual purpose: they translate traditional IAM outputs into a more accessible and salient set of information for audiences beyond the IAM academic sphere, and they offer insights into potential future food changes necessary to comply with the Paris Agreement. Furthermore, these findings contribute valuable comparative data for other studies focused on low-carbon food futures.

2 Methods

This section describes how the DDDI framework (De Boer and Aiking, 2019) is applied in order to communicate the outputs from the IMAGE LiStCh scenario of food demand measured in (tonnes/yr). The outputs from LiStCh provide annual *per capita* consumption for the food categories set out in Supplementary Table 2 for Brazil, China and Western Europe for 2010 (baseline year), 2020, 2030, 2040 and 2050 (scenario pathway). In order to communicate these through the DDDI framework, the numbers of portions of each food category consumed in 2020, 2030 and 2050 for Brazil, China, the UK and Sweden – the 'Diet' of DDDI are calculated. Secondly, typical dishes consumed in each country are identified (the 'Dish') and the recipes were illustrated according to the relative proportions of protein sources, staples and vegetables for the baseline year. Finally, the proportions and the type of protein (animal or plant-based) are used to illustrate how the Dish Ingredients would change over time to follow the LiStCh scenario.

As previously discussed, the LiStCh scenario is part of four scenarios demonstrating alternative pathways to 1.5°C by incorporating various lifestyle change measures. Alongside dietary change, the LiStCh scenario shows the possibility of achieving 1.5°C with significantly less reliance on Bioenergy with Carbon Capture and Storage (Van Vuuren et al., 2018). The DDDI framework is applied using the food demand data from the IMAGE IAM LiStCh (Lifestyle change) scenario (Van Vuuren et al., 2018). The LiStCh scenario includes dietary changes and delivers broader GHG emission reductions in line with 1.5°C (Van Vuuren et al., 2018; De Boer and Aiking, 2019).

The methodological structure of the analysis presented in this article, as illustrated in Figure 1, systematically examines the impact of modelled changes in food demand on regional diets and dish visualisations. The approach involves preparing and interpreting IAM scenario data, establishing food consumption baselines for Sweden, China, the UK, and Brazil, and applying the DDDI framework to analyse shifts in food consumption patterns and create visual representations of potential dishes for 2050.

The methodology first describes the LiStCh scenario outputs and how the base year was established. This is followed by a description of how the outputs were processed to develop the baseline and scenario trajectory. The methodology then describes how the portion sizes and dishes were selected and describes how the dish ingredients were adjusted to reflect the LiStCh scenario. The section concludes with the description of the dish visualisation process.

2.1 Preparation of integrated assessment model scenario datasets

2.1.1 Extracting and interpretation of IMAGE data

The analysis employs food demand outputs from the LiStCh scenario and the emissions reduction pathway from IMAGE (Scarborough et al., 2014), aligning with a pathway consistent with a 1.5°C increase. Within the IMAGE model, food demand propels food production, leading to GHG emissions from the agricultural sector and throughout the food supply chain (Van Vuuren et al., 2018).

The LiStCh scenario from 2020 to 2050 outlines a reduction in meat consumption, supplanted by pulses and oil crops (primarily soy). Concurrently, staples and luxuries are adjusted to preserve the total caloric intake, mirroring the default scenario SSP2. This SSP2 scenario is part of the Shared Socioeconomic Pathways (SSPs), a set of five future pathways describing global development in terms of population, economic growth, technological change, and environmental degradation. Specifically, SSP2 is a 'middle of the road' scenario, assuming moderate technological progress and steady global economic growth, and is widely used as a reference scenario, with 'middle-of-the-road' assumptions on various factors influencing emissions, ranging from economic growth to population growth and policy choices (Van Vuuren et al., 2018).

In the context of the LiStCh scenario, the changes in consumption are meticulously crafted to align with a healthy diet, contributing to emissions reduction through dietary transformation by 2050. The LiStCh 2050 healthy diet takes cues from the Willett diet (Willett, 2001), comprising 50% fruit and vegetables, 25% whole grains (including whole wheat bread, pasta, and brown rice), and protein foods such as meat, pulses, eggs, nuts, and seeds.

The scenario envisions a linear reduction in meat consumption between 2020 and 2050, counterbalanced by increased pulses, nuts, seeds, and soybeans. This substitution is predicated on protein content, assumed to be 20% for both meat and pulses based on fresh weight (Stehfest et al., 2009). Meanwhile, fruit, vegetables, and dairy items adhere to their reference scenario SSP2 (Bijl et al., 2017), exhibiting a modest increase in *per capita* consumption over the 30 years.

The IMAGE outputs provide food demand (FD) for 46 food categories (see Supplementary Table 2) and household waste for six food categories (*Animal*, *Fruit & Veg*, *Luxuries*, *Oils and Oil Crops*, *Pulses* and *Staples*) for three regions: Brazil, China and Western Europe (WEU). The outputs are for the baseline year of 2010 and scenario years of 2020, 2030, 2040 and 2050.

2.1.2 Applying the diets, dishes, and dish ingredients framework

De Boer and Aiking's DDDI framework defines diet as patterns of food items eaten by one or more individuals over a period of time and present it at the level of dishes and dish ingredients. Dish ingredients include protein food items such as meat, fish, eggs, dairy and pulses. The dishes themselves include a combination of food items on a plate.

To follow this framework and translate the LiStCh outputs into diet, the household waste figures were subtracted from food demand to give food consumed (g/cap/day), this was converted into the number of portions per year and month. The number of portions per week has been used by a number of other studies (van Dooren et al., 2018; BNF, 2021) that have worked with this frequency and used it in

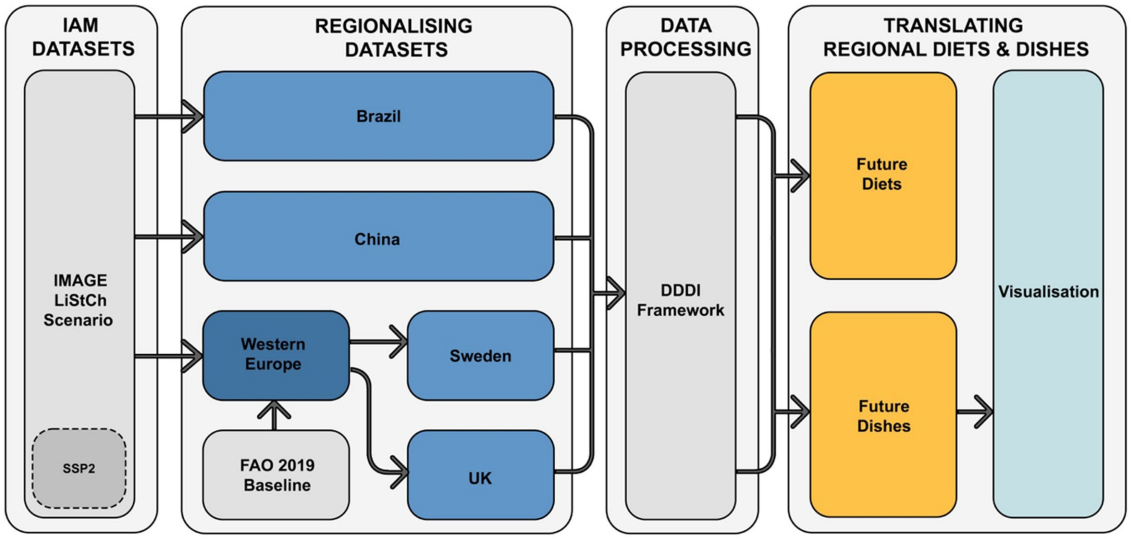

FIGURE 1
Methodology schematic representing the stages of Integrated Assessment Model (IAM) data processing and translating for the regional diets and dish visualisations.

conjunction with weekly meal planning. This analysis calculated a monthly figure as changes for some protein items were too small to appear in the weekly frequency. The data is available in the Supplementary Files 6–9. This way of communicating information can inform a varied dish pattern and enable different combinations for different consumers who may have different meat preferences or requirements (e.g. authenticity, convenience; De Boer and Aiking, 2019). A review of the case study countries was used to provide a context for meat consumption within that country and relative to other study countries is presented in the supplementary information (SI) for each of the four countries. Example mixed dishes for each country were identified to illustrate the 'Dish' and 'Dish Ingredient' elements of the Framework. Mixed dishes, defined by De Boer and Aiking (2019) as a mixture of both animal and plant protein, were chosen as they have the strategic potential to reduce meat. Section 'Regionalising diet and dish datasets' and 2.2 provides further detail on the application of the framework.

2.2 Regionalising diet and dish datasets

2.2.1 Food consumption year baselines for Sweden, China, United Kingdom and Brazil

Establishing consumption baselines in this study involved two interconnected steps: justifying the use of IMAGE 2020 scenario data as the baseline and downscaling WEU to the UK and Sweden. While the baseline year from IMAGE is 2010, the year 2020 was chosen for its greater relevance to the present day. To justify this choice, the 2020 LiStCh data, based on model outputs, were compared to the 2019 Food and Agricultural Organisation (FAO) data, selected for its initial use in calibrating the food demand model within IMAGE (see Supplementary File 1). The year 2019 was specifically chosen to avoid the impacts of the COVID-19 pandemic on the food supply.

The first step focused on determining the differences in the definitions of food supply between the FAO and IMAGE data related to household waste and supply chain losses. The total food supplied for each country closely matched the IMAGE food demand value in 2020, with variations of 2% for Brazil, 11% for China, and −5% for Western Europe (see Supplementary Table 1). This level of agreement was deemed acceptable given the unknowns in the actual data regarding wastage, with the main interest of this analysis being the distribution of main food groups and specific protein food items.

The second step focused on establishing the baseline involved with downscaling the 2020 LiStCh data for the UK and Sweden. Since the available data from IMAGE provides food demand for Western Europe, the baseline for the UK and Sweden was achieved using the ratios of UK and Swedish food supply to the total for Western Europe from the FAO 2019 Food Supply (see supplementary section on downscaling WEU to UK and Sweden). This calibration of 2020 model projections to 2019 observations and the minor differences observed validate the use of 2020 model projections in the analysis.

Once the baseline was established, the changes associated with the LiStCh scenario were applied to give g/cap/year for each food category. For Brazil and China, the LiStCh outputs were used directly. For the UK and Sweden, the scenario narrative states that by 2050, the composition of diets globally will homogenise, resulting in a linear trajectory of food demand changes from 2020 to converge on the 2050 Western Europe LiStCh food demand applied.

2.2.2 Selection of portion size

This analysis assumes consistent food portion sizes across the four study countries (Sweden, China, the UK, and Brazil) from 2020 to 2050 to enable a fair comparison of dietary changes. Portion sizes were determined using The British Nutrition Foundation's (BNF) guide (BNF, 2021), which aligns with the UK Government guidelines (PHE, 2016). Different countries present their recommended daily food consumption for specific food groups in slightly varying ways. For example, Sweden's guidelines (FAO, 2022b), produced by the Swedish National Food Agency (Livsmedelsverket, 2022), do not provide exact amounts but suggest a daily intake of at least 500 g of fruit and

vegetables and no more than 500 g of cooked red and processed meat (Fischer and Garnett, 2016). Brazil's guidelines are less specific, recommending that citizens limit red meat consumption, eat seasonal and locally grown produce, and consume foods primarily of plant origin (FAO, 2001; Fischer and Garnett, 2016). China's guidelines (FAO, 2022c) specify amounts using a pagoda, with the base consisting of cereal, tubers, and legumes, followed by fruit and vegetables, meat protein, milk and dairy products with soybeans and nuts, and topped by a roof of salt and cooking oil. The modelled food consumption data are interpreted as servings based on standard portion sizes from the BNF amounts (UNFCCC, 2015) and are presented in the Supplementary Table 5. For all countries, Supplementary Figures 1A–H display the monthly frequency of consumption (number of servings a month) for a portion of protein food items (beef, pork, poultry, pulses, soybeans, nuts and seeds, fish and eggs) for 2020, 2030, and 2040.

2.2.3 Selection of dishes and dish ingredients for each country

This analysis used the main protein sources identified by IMAGE (meat categories, dairy, eggs, fish, pulses, nuts, and seeds) to examine national dishes with each ingredient as the primary protein source. It is important to note that the IMAGE model excludes protein in fruit and vegetables, staples, or luxuries (including tea and coffee) when calculating future food demand protein totals (De Boer and Aiking, 2019). Although protein levels in fruit and vegetables are generally low, staples exhibit higher levels [e.g. wheat: 12.2 g/100 g retail weight; see Supplementary Tables 1, 2 in FAO (2001)]. As these food items remain unchanged in the LiStCh scenario used here (Bijl et al., 2017), the focus is on meat, dairy, eggs, pulses, nuts and seeds, and soybeans. Following (Bijl et al., 2017), popular dishes from the study countries were identified through academic studies (Zhai et al., 2014; Lundberg-Hallén and Öhrvik, 2015; Zhou et al., 2015; Cobiac and Scarborough, 2019; Waltner, 2022; Yang and Ford, 2022), grey literature, newspapers (Bailey, 2018), travel websites (Condé Nast Traveler, 2022; Visit Sweden, 2022; Wind Horse Tour, 2022; China Travel, 2022a,b), and market research and consultancy surveys (Statista, 2020, 2021; Commisceo Global Consulting Ltd., 2022). Selected dishes represent a range of food groups consumed in each country, reflecting the current distribution of staples, fruit and vegetables, meat, eggs, and non-meat protein food items.

Similar to the method used in (Scarborough et al., 2014), a Google search was performed to find suitable recipes for the selected dishes. Criteria for selection included:

a) A mixed dish containing a meat protein that could potentially be substituted with a non-meat protein.
b) A meat dish containing chicken, pork, eggs, or beef to highlight the changing frequency of consumption between the present day, 2030, and 2050. Fish was excluded as the focus is on terrestrial meat (Bijl et al., 2017). Although consumed in the case study countries, Lamb was not included due to its small and declining consumption in the LiStCh scenario.
c) For visualisation, several recipes of the same dish were examined to determine a realistic portion size and suitable visual image to showcase the modelled changes.
d) The dish components had to be identifiable.
e) The dish needed to be visually appealing and colourful, as desirable diet changes must be translated into appetising dishes for consumers (De Boer and Aiking, 2019).

For mixed dishes, the analysis selected dishes for each country containing protein, staples, and fruit and vegetables to demonstrate food item changes for 2030 and 2050. For single dishes, specific protein food items from a popular dish were chosen, so that the frequency of monthly consumption for 2020, 2030, and 2050 was calculated using the modelled changes for each item (see 'Translating IMAGE data into changes in dish ingredients').

In the process of selecting protein-focused dishes, primarily for lunch or dinner, recipes were extracted to identify diet ingredients within the four categories defined by Willett's Diet (and UK Dietary Guidelines): protein, staples (whole grains), and fruit and vegetables (combined). This categorisation included staples as used by FAO (2020) and Bijl et al. (2017), encompassing rice, pasta, bread, and potatoes. Since modelled trends for fruits and vegetables are similar, they were combined into one group. The Willett's Diet was chosen for this analysis because the LiStCh scenario employed its framework during creation. However, it is worth noting that relying on the Willett Diet may be a limitation for the analysis, as it could be considered outdated. Future research could explore the use of more contemporary diet frameworks such as the Mediterranean, DASH, MIND, or Planetary Health diets to determine if the LiStCh scenario data needs updating (Karanja et al., 2004; Guasch-Ferré and Willett, 2021; de Crom et al., 2022; Ojo et al., 2023).

Five main course dishes were selected for each country, including chicken, pork, and beef dishes, along with vegetarian and vegan dishes to provide information about alternative plant-based proteins as meat substitutes. Furthermore, the analysis for the UK and Sweden incorporated breakfasts that are traditionally high in meat-based foods, such as a full English breakfast, Fläskpannkaka, and Pyttipanna med korv. These breakfasts were evaluated with either meat or plant-based protein alongside a staple.

Each popular dish represents average consumption, so a small amount of meat will be retained, as reflected in the proportions displayed in the pie charts in the Supplementary Figures 2A–5C.

2.2.4 Translating IMAGE data into changes in dish ingredients

De Boer and Aiking (2019) propose promoting a varied dish pattern where some non-meat dishes can be selected as desired or a mixed dish whereby non-meat protein items can be included together with meat protein.

The analysis presented in this paper focuses on how the dish ingredients could change over the period 2020 to 2050. To keep the essential components of the dish, there are two options:

a) Substitute meat with non-meat protein (Mixed dishes)
b) Reduce the frequency of consumption of meat (Meat dishes)

The data from the previous steps was used to ascertain the amount (g) of protein based food for each selected dish for the present day (2020). The dish ingredients (food items) for each dish reflected the items consumed within that country and were allocated to one of three food groups: staples (rice, pasta, potatoes), protein [meat, eggs and non-meat (nuts and seeds, soybeans and pulses; beans, peas, lentils and chickpeas)],

and fruit and vegetables on a plate. The amount or proportion of each dish ingredient was then altered according to the LiStCh scenario's changes in daily food consumption (g/cap/day) for 2020, 2030 and 2050. The frequency of servings per protein food item for each country is shown in Supplementary Tables 6A–D. Supplementary Figures 1A–H display the changes for meat food items (beef, fish poultry, and pork) and non-meat food items (pulses, soybeans, eggs, nuts, and seeds). Fish and seafood, dairy foods (milk, butter and cream) are included in this analysis (although they follow the SSP2 reference scenario in the IMAGE model) to ensure all food items in the diet are included. The luxuries category is also included. Using the LiStCh scenario, the meat is replaced by plant-based alternatives. This analysis is synthesised and presented in section 'Translating IMAGE outputs into regional dishes and their ingredients'.

2.2.5 Creation of future dish visualisations

Visualisations can take many forms, such as infographics, graphs, or interactive tools that allow users to explore different scenarios. For example, an infographic could compare the carbon footprint of different food groups, or an interactive tool could allow users to see the impact of their dietary choices on their carbon footprint and the environment. This analysis takes the potential future regional dishes and their ingredients extracted from the IMAGE model and creates proportional visual representations to better communicate the balance of plant and meat-based foods in potential future diets.

Pie charts of the relative proportions of the main protein groups, staples and fruit and vegetables were generated for the selected dish (see Supplementary Figures 5A–C for Brazilian Feijoada; Supplementary Figures 6A–C for Chinese Sweet and Sour Pork; Supplementary Figures 7A–C for Swedish meatballs; and Supplementary Figures 8A–C for UK chicken korma). These pie charts, together with existing images of the prepared dishes (e.g. Feijoada; Unknown, 2023a,b), were then used to discuss the changes with an illustrator to produce the final dishes, as shown in Supplementary Figures 3–6. It should be noted that the protein items (meat types, nuts and seeds, soybeans, pulses) are shown separately on the pie charts to show the changes for each dish but are mixed on the illustrated dish as they would be in reality.

For present-day mixed dishes with no pulses, nuts or seeds, these ingredients were increased in line with the modelled changes to replace the reduction in meat. The plant protein items used to substitute for meat were items selected from vegetarian versions of the dish. Within the model itself, the overall calorific consumption is retained as meat protein is replaced by non-meat protein, so it is assumed that the amounts of staples for each timeframe adjust to ensure this occurs. The total amount of the dish consumed by weight is the same for 2050 and 2020.

3 Results and discussion

3.1 Daily food consumption in future diet

Figure 2 shows the IMAGE scenario output of daily food consumption (converted to g/cap/day from t/yr. using IMAGE population data) for Sweden and the UK (for comparison with Brazil and China) for 2020 and 2050. The figure highlights the changes in the LiStCh scenario whereby the amount of meat decreases and the non-meat items increase over the 2020 to 2050 period for all four countries. The IMAGE LiStCh scenario ensures

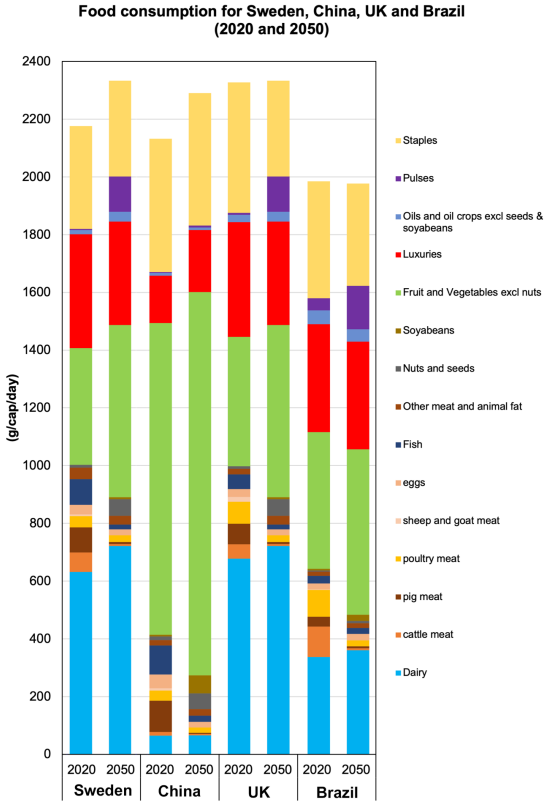

FIGURE 2
Changes in food consumption (g/cap/day) for Brazil, China, Sweden and the United Kingdom 2020 to 2050 for protein items and other food categories from the Lifestyle change (LiStCh) IMAGE Scenario.

a calorific balance within the model, as pulses, nuts and seeds or soybeans substitute meat. Figure 2 indicates that the total food consumption varies slightly between 2020 and 2050 as staples are adjusted within the model to keep total calorific consumption constant (Bijl et al., 2017). The individual countries vary between around 2000 g/cap/day for Brazil to 2,300 to 2040 for the other countries, but between 2020 and 2050, the total values are within 200 g/cap/day of each other.

The data reveals distinct trends in food consumption across Sweden, China, the UK, and Brazil from 2020 to 2050, including a universal decline in meat and fish, varied dairy trends, and a general increase in pulses and fruits/vegetables.

In Sweden, dairy consumption is projected to increase by 1.16 times, while meat and fish are expected to decrease, showing a 4.00 and 5.26 times decrease, respectively. Pulses and fruits/vegetables are on the rise, with pulses showing a dramatic 30.81 times increase and fruits/vegetables increasing by 1.48 times.

China's trends are similar, with a modest increase in dairy at 1.01 times and in meat and fish showing a 4.55 and 4.76 times decrease, respectively. Pulses are expected to increase by 2.25 times, and fruits/vegetables by 1.18 times.

In the UK, dairy and meat are both expected to decrease significantly, showing only a 4.00 and 4.35 times decrease, respectively. Fish is also projected to show a 5.00 times decrease. However, pulses are set to increase by 4.08 times, and despite a decrease in fruits/vegetables at 0.43 times, nuts and seeds are expected to surge by 5.19 times.

TABLE 1 Frequency of consumption of different protein food items for Sweden, China, United Kingdom and Brazil (number of servings a month of a portion of food item) following the LiStCh Scenario.

Food Category	Sweden			China			United Kingdom			Brazil		
	Frequency of servings per month			Frequency of servings per month			Frequency of servings per month			Frequency of servings per month		
	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050
Dairy including milk and cheese	151	161	175	16	16	16	167	172	175	82	85	88
Beef (cattle meat) – 100 g; 2 slices roast beef; serving of beef mince	20	15	2	4	3	1	15	11	2	32	23	2
Eggs	17	15	10	24	19	10	14	13	10	10	11	12
Fish and seafood	23	17	4	26	21	5	13	10	4	7	6	5
Other meat – 100 g; 2 sausages	12	11	9	5	6	7	6	7	9	5	5	5
Pork – 100 g; 2 slices; 1 chop	26	19	2	33	22	1	21	15	2	10	8	2
Chicken – 100 g; 2 slices	12	11	7	11	9	6	23	18	7	28	22	6
Lamb – 100 g; 2 slices; 1 chop	2	1	0	2	2	0	5	3	0	1	0	0
Nuts and seeds	12	37	88	20	39	85	11	36	88	6	8	11
Soybeans	0	1	2	2	8	24	0	1	2	2	4	8
Fruit and vegetables (excl nuts)	154	180	227	443	484	525	170	191	227	180	195	218
Luxuries	599	585	545	252	286	328	604	588	545	569	571	567
Oils and oil crops (excl seeds and soybeans)	32	44	68	22	21	19	52	58	68	97	94	87
Pulses	2	26	74	2	4	4	4	27	74	25	46	92
Staples	144	145	134	203	195	190	183	173	133	165	159	143
Meat based	95	74	24	81	63	20	83	64	24	83	64	20
Plant based	200	288	459	489	556	657	237	313	459	310	347	416
All foods	*1,207*	*1,268*	*1,350*	*1,065*	*1,134*	*1,221*	*1,289*	*1,324*	*1,349*	*1,218*	*1,236*	*1,246*

Brazil shows a 1.07 times increase in dairy and meat is expected to decrease by 4.55 times. Fish consumption is expected to decrease by 1.28 times. Pulses and fruits/vegetables are also increasing, with pulses at 3.65 times and fruits/vegetables at 1.21 times.

The substantial reductions in beef consumption across the UK, Sweden, and Brazil to 7 g/cap/day by 2050, down from initial levels of 50 g, 67 g, and 106 g/cap/day in 2020, respectively, underscore the shifts in consumption patterns. China follows suit with a reduction to 5 g/cap/day by 2050 from 13 g/cap/day in 2020. These changes are not merely statistical observations but pivotal in shaping dietary choices and dish ingredients and aligning with a broader transition towards sustainability and health consciousness.

The core objective of this research is to make the complex IAMs from the already published IMAGE model more accessible rather than to validate its results. In this process, the study highlights certain model and scenario artefacts, such as unexpected quantities of luxuries and pulses in dietary projections (Van Vuuren et al., 2018; SBT, 2021; Aboumahboub et al., 2022). These artefacts are noteworthy for future applications, serving as focal points for subsequent research to align the IMAGE model more closely with existing dietary guidelines.

3.2 Frequency of consumption of different food groups in future diet

The frequency of consumption of a serving of meat or non-meat per person per month of different food items or dish ingredients (the number of times a portion of food can be consumed per month) will change drastically from 2020 to 2050 under the LiStCh scenario (Table 1). This analysis focused on the years 2030 (the near future) and 2050 (the longer term). The frequency of consumption of the analysed food groups for 2020, 2030 and 2050 is presented in Table 1.

Across all 4 nations, the number of servings of meat-based food groups will decrease and plant-based food groups will increase towards 2050. The number of meat-based foods will decrease from 81–95 servings per month in 2020 to 20–24 servings per month in 2050, while the number of plant-based foods will increase from 200–489 servings per month in 2020 to 416–657 servings per month in 2050.

There is a greater change in LiStCh scenario diets for the four nations from the present-day to the long-term than the present-day to the short-term. Currently, meat-based foods constitute 8, 8, 6 and 7% of diet in Sweden, China, the UK and Brazil, respectively, and plant-based foods constitute 17, 46, 18 and 25%. In 2030, the proportion of meat-based foods decrease in diets to 6, 6, 5 and 5% for Sweden, China, the UK and Brazil, respectively, and the proportion of plant-based foods increase in diets to 23, 49, 24 and 28%. In the 2050 lifestyle change scenario, the proportion of meat-based foods on a weight basis decreases in diets to 2% for all four nations, and the proportion of plant-based foods increases in diets to 34, 54, 34 and 33%. In other words, meat consumption converges between the four nations by 2050 by the percentage share of consumption. However, plant-based consumption does not converge by 2050 and will vary in percentage depending on the proportion of food staples in diets.

The proportion of meat-based foods within individuals' diets decreases over time in the LiStCh scenario for all nations, resulting in smaller proportions of diets containing meat-based food by 2050. However, a complete elimination of meat is not included in the scenario. Both national interpretations and individual preferences will influence the remaining proportion of meat-based foods in diets,

allowing for variations among individuals and households while maintaining consistency with national averages or aggregates. This concept is akin to a 'meat-budget'. The introduction of national meat-budgets could reduce greenhouse gas emissions and align consumption patterns with lifestyle changes consistent with a 1.5°C scenario, as suggested by the IMAGE modelling (Van Vuuren et al., 2018). It is important to note that while the IMAGE model provides national averages or aggregates, the dish-level analysis allows for individual variations. Further research is necessary to examine the socio-environmental and lifestyle implications of implementing national meat-budgets and evaluate the social acceptability of top-down government dietary interventions.

The primary objective of this research is to render the complex IAMs of the previously published IMAGE model into more tangible forms. As previously discussed, several model and scenario artefacts have been identified, such as the high servings per month of luxuries and the large number of fruit and vegetable servings projected for China by 2050. These artefacts serve as indicators for future research to align the IMAGE model more closely with current dietary guidelines, such as the Mediterranean or Planetary Health diets (Van Vuuren et al., 2018; Guasch-Ferré and Willett, 2021; Ojo et al., 2023).

3.3 Current and future diet protein content in regional diets

The future protein content in diets is subject to many influences, such as shifts in global dietary patterns, technological advancements in food production, and changes in agricultural practices (Bijl et al., 2017; Torstensson et al., 2021). These factors create a complex landscape that makes it challenging to predict specific changes in protein content. In the LiStCh scenario, the protein sources for the diets of Sweden, China, the UK, and Brazil are categorised into dairy, meat, eggs, fish and plant-based origins, as illustrated in Figure 3. While the LiStCh scenario standardises the calorific content in its projections, it does not extend this standardisation to other nutrients like protein, which is a major criticism of the scenario (SBT, 2019; Toth, 2022; Cordova-Pozo and Rouwette, 2023).

The data on projected changes in protein content from 2020 to 2050 for the UK, Sweden, China, and Brazil reveals significant shifts in dietary patterns. In the UK, dairy-derived protein is expected to increase by 5%, while protein from meat and fish is projected to decline by 75 and 69%, respectively. Protein from eggs will also decrease at a more moderate rate of 29%. Notably, plant-based protein is anticipated to increase dramatically by 481%.

Sweden shows a similar pattern, with a 16% increase in dairy-derived protein and steep declines in protein from meat and fish, at 75 and 83%, respectively. Egg-derived protein is also expected to decrease by 41%, while plant-based protein is projected to increase by 489%.

In China, dairy-derived protein levels are expected to remain stable, with no change projected. However, meat and fish-derived protein are expected to decline by 75 and 81%, respectively. Protein from eggs will decrease by 58%, and plant-based protein will increase by 189%.

Brazil's projections indicate a 7% increase in dairy-derived protein and an 83% decline in meat-derived protein, the most significant decline among the four countries. Fish-derived protein is expected to decrease by 29%, while egg-derived protein is projected to increase by 20%. Plant-based protein is expected to rise by 121%.

These projections highlight a universal decline in meat-derived protein and a substantial increase in plant-based protein across all four countries. However, the extent of these changes varies by country. Dairy and egg-derived proteins show mixed trends. These findings emphasise the complex factors that will influence future diets, especially in the context of protein sources.

The LiStCh scenario, while insightful, has a notable limitation in that it standardises future diet projections to maintain calorific content but does not do the same for protein content. This could result in inadequate nutritional intake by 2050, particularly concerning protein (Neufingerl and Eilander, 2022). The scenario assumes that people will continue their current dietary habits, an assumption that may not hold due to several factors that could influence future protein content.

One key factor is the potential change in the availability of protein sources. For instance, declining fish stocks could limit access to marine-based protein. Another consideration is the shift in dietary habits, such as increasing adoption of vegetarian or vegan diets, which would necessitate alternative protein sources. Technological advancements, like the development of lab-grown meat, could also introduce new protein options, thereby altering future dietary compositions.

The transition to plant-based or mixed diets, as projected by the LiStCh scenario, poses significant health risks due to potential nutrient inadequacies. For instance, the less efficient absorption of iron from plant foods could lead to anaemia, a condition that is already prevalent in certain populations. Similarly, the lower bioavailability of zinc in plant foods could compromise immune health, making populations more susceptible to infections. The absence of Vitamin B12 in plant foods is particularly concerning, as its deficiency can result in neurological issues.

Moreover, the risks are not uniformly distributed among nations. For example, countries with existing lower intake levels of certain nutrients may find these deficiencies exacerbated in a plant-based transition. The decline in meat-derived protein by 83% in Brazil, as per the LiStCh data, could make the population more vulnerable to protein-energy malnutrition. On the other hand, the 489% increase in plant-based protein in Sweden might not offset the risks associated with other nutrient deficiencies.

These health risks highlight the need for caution in implementing broad dietary transitions, as they could inadvertently exacerbate existing public health issues (Neufingerl and Eilander, 2022). The LiStCh scenario serves as a valuable tool for understanding these complexities, but it also underscores the need for more nuanced strategies to ensure nutritional adequacy during such transitions.

While the LiStCh scenario provides a useful framework for understanding the potential impacts of climate change on future diets, it is but one of many possible scenarios. The actual future will be influenced by a range of factors not currently accounted for in the model.

Future studies could benefit from exploring alternative IMAGE modelling scenarios that aim to stabilise protein content across diet projections. This could be extended to other essential nutrients like carbohydrates, vitamins, fibre, amino-acids and water, offering a more comprehensive view of future diets (Tessari et al., 2016). Such an approach would address the current limitations of the LiStCh scenario and contribute to a more robust understanding of the complex interplay between climate change and global diets.

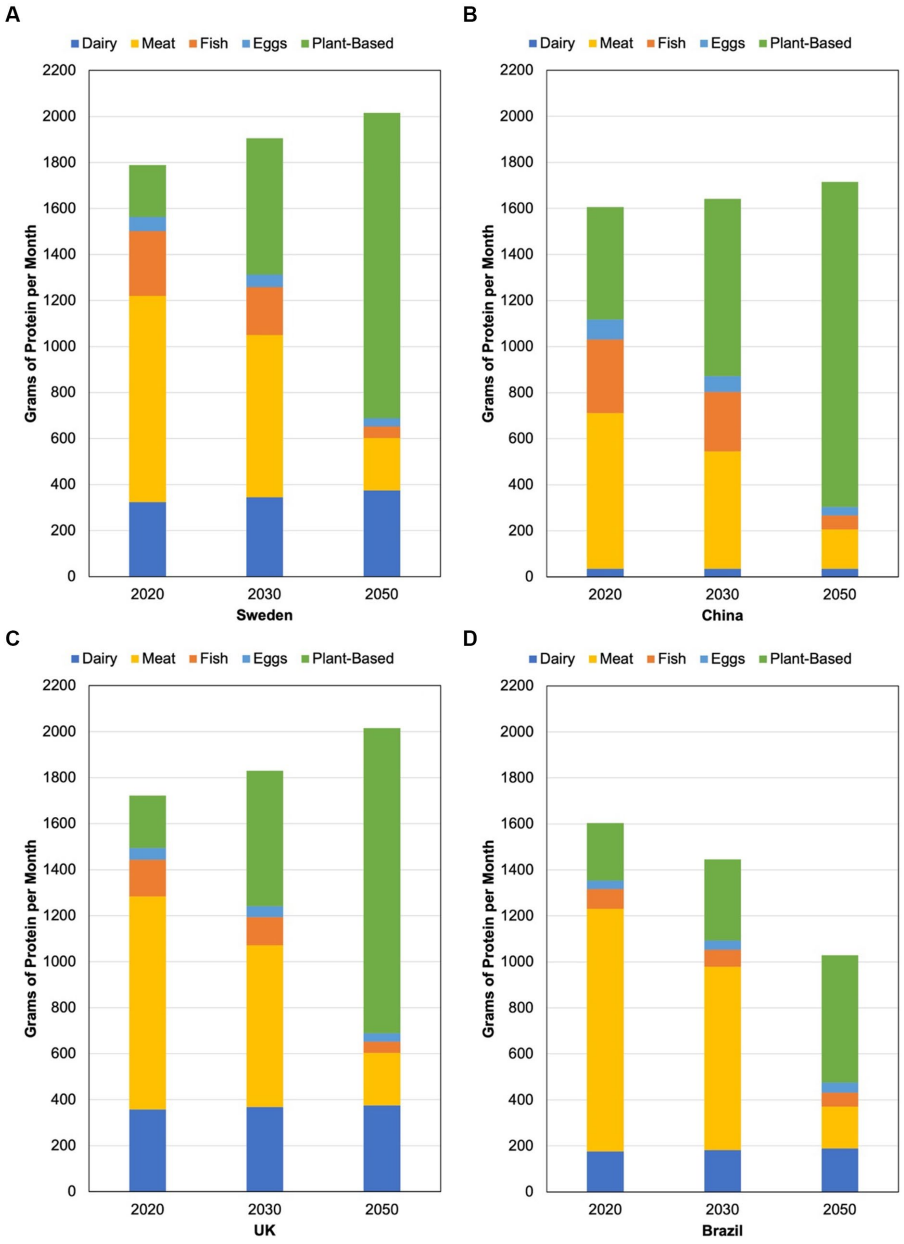

FIGURE 3
Sources of dairy, meat (beef, pork, chicken and lamb), eggs, fish and plant-based (nuts, seeds, soybeans, fruits, vegetables and pulses) protein in grams per month projected to 2020, 2030 and 2050 diets for **(A)** Sweden, **(B)** China, **(C)** United Kingdom and **(D)** Brazil.

3.4 Translating IMAGE outputs into regional dishes and their ingredients

The ingredients of the four regional dishes projected for 2020, 2030 and 2050 were extracted from the IMAGE modelling and are presented in Table 2. Ingredients from other regional dishes from Sweden, China, UK and Brazil extracted from the IMAGE modelling are presented in Supplementary Files 4–7.

Across all of the dishes and similar to the overall projected diets of the four nations, the percentage of meat-based food in the traditional dishes will converge at 1–2% by 2050, and the percentage of plant-based food in the dishes will vary against the proportion of staples in the dish from nation to nation. Presenting the proportional percentages of plant-based and meat-based ingredients in future dishes will aid the communication of how the dishes that people eat will change in the future. These meat-based vs. plant-based can be replicated for a range of future dishes across any nation to improve the communication of how people's dishes may change in achieving 1.5°C.

In the research presented, the shift to alternative diets is modelled to occur between 2010 and 2030, without accounting for implementation or other associated costs. Proteins from meat, eggs, and dairy products, including milk, butter, and cheese, are replaced by proteins from pulses and soybeans across all scenarios. This substitution is based solely on protein content, estimated at 20% for

TABLE 2 Composition of projected traditional dishes for Sweden, China, the United Kingdom and Brazil for 2020, 2030, 2050 in percentage of the dish for each food groups.

	Percentage of Dish Composition (%)											
	Sweden: meatballs			China: sweet and sour pork			United Kingdom: chicken korma			Brazil: feijoada		
	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050
Dairy	–	–	–	–	–	–	–	–	–	–	–	–
Cattle meat	7	5	1	–	–	–	–	–	–	10	7	1
Eggs	–	–	–	–	–	–	–	–	–	–	–	–
Fish and seafood	–	–	–	–	–	–	–	–	–	–	–	–
Other meat and animal fat	–	–	–	–	–	–	–	–	–	–	–	–
Pig meat	9	6	1	6	4	1	–	–	–	3	2	1
Poultry meat	–	–	–	–	–	–	8	6	2	–	–	–
Sheep and goat meat	–	–	–	–	–	–	–	–	–	–	–	–
Nuts and seeds	1	2	5	1	1	3	1	2	5	0	0	1
Soybeans	0	0	1	0	1	3	0	0	1	1	1	2
Fruit and vegetables (excl nuts)	44	47	54	65	68	69	45	48	53	44	47	51
Luxuries	–	–	–	–	–	–	–	–	–	–	–	–
Oils and oil crops (excl seeds and soybeans)	–	–	–	–	–	–	–	–	–	–	–	–
Pulses	0	4	11	0	0	0	1	4	11	4	7	13
Staples	38	35	29	28	25	24	46	40	29	38	36	31
Meat based	*17*	*11*	*1*	*6*	*4*	*1*	*8*	*6*	*2*	*13*	*9*	*1*
Plant based	*45*	*54*	*70*	*66*	*71*	*75*	*47*	*55*	*69*	*49*	*55*	*67*

both meat and pulses, and 4% for milk, calculated based on fresh weight. Soybeans are projected to constitute 60% of the additional food-pulse production, aligning with the current fraction as of the year 2000. All other aspects of food crop consumption and livestock production systems, such as feed composition and conversion efficiencies, are assumed to align with the reference case, detailed in Table 2. For further information on the reference case, the authors can be contacted (Lee et al., 2022).

While the current analysis has the potential to utilise visualisation as a useful tool for communicating dietary change in alignment with national guidelines, it does not encompass the nutritional adequacy of the proposed dietary shifts. This omission could be an area for future research, bridging the connection between visual representation and 'nutritional reality'. Such an approach would ensure that the visualised future dishes align with environmental goals and nutritional soundness, providing a more comprehensive heuristic for future diet and dish guideline planning. For instance, the quality of proteins is known to vary, and certain nutrients such as calcium, iron, and vitamin D may be less readily accessible from plant-based sourced foods. This could lead to inadequate intake of these key nutrients, an aspect that would further enrich the understanding of the proposed dietary shifts.

3.5 Visualisation of projected future regional dishes for Sweden, China, United Kingdom and Brazil

Visualisations of future diets and highlighting the potential proportions of plant and meat-based ingredients in future dishes will play an important role in improving communication about the impact of diets on climate change and empowering people to make informed decisions about their food choices. Presenting information in a visual format can make it easier for people to understand and remember the key points and see the potential benefits and trade-offs of different dietary patterns. The visualisations of the four future regional dishes from Sweden, China, UK and Brazil are presented in Figure 4. For visualisation purposes, the dietary changes are illustrated in the form of a plate for a popular dish from each country and presented in Supplementary Table 7.

This study's methodology builds upon and enhances existing dietary research by illustrating how visualising dishes has the potential to aid the communication of future dietary shifts. The representation of diets as dietary plates align with national guidelines, which many countries adopt to communicate such changes. Visual charts, including plates of food exemplifying a healthy diet, often supplement these guidelines.

The dish visualisations more intuitively illustrate how the ingredients in each meat-based dish from Sweden, China, the UK, and Brazil evolve from present-day to future dishes in line with the LiStCh scenario. These future dishes incorporate alternative protein sources such as lentils, chickpeas, nuts and seeds, tofu, and fruit and vegetables. However, these visualisations should be used in conjunction with the data in Table 2 to act as a more rounded heuristic for future diet and dish guideline planning.

Between 2020 and 2050, the dish components change according to the LiStCh scenario, including meat decreases, pulses increase, fruits and vegetables remaining relatively and staples experiencing a slight decline. See Supplementary Figures 2A-5C for the changing proportions for 2020, 2030, and 2050. This study's methodology effectively complements existing dietary research by demonstrating how visualising dishes can be a useful tool for communicating dietary change in alignment with national guidelines.

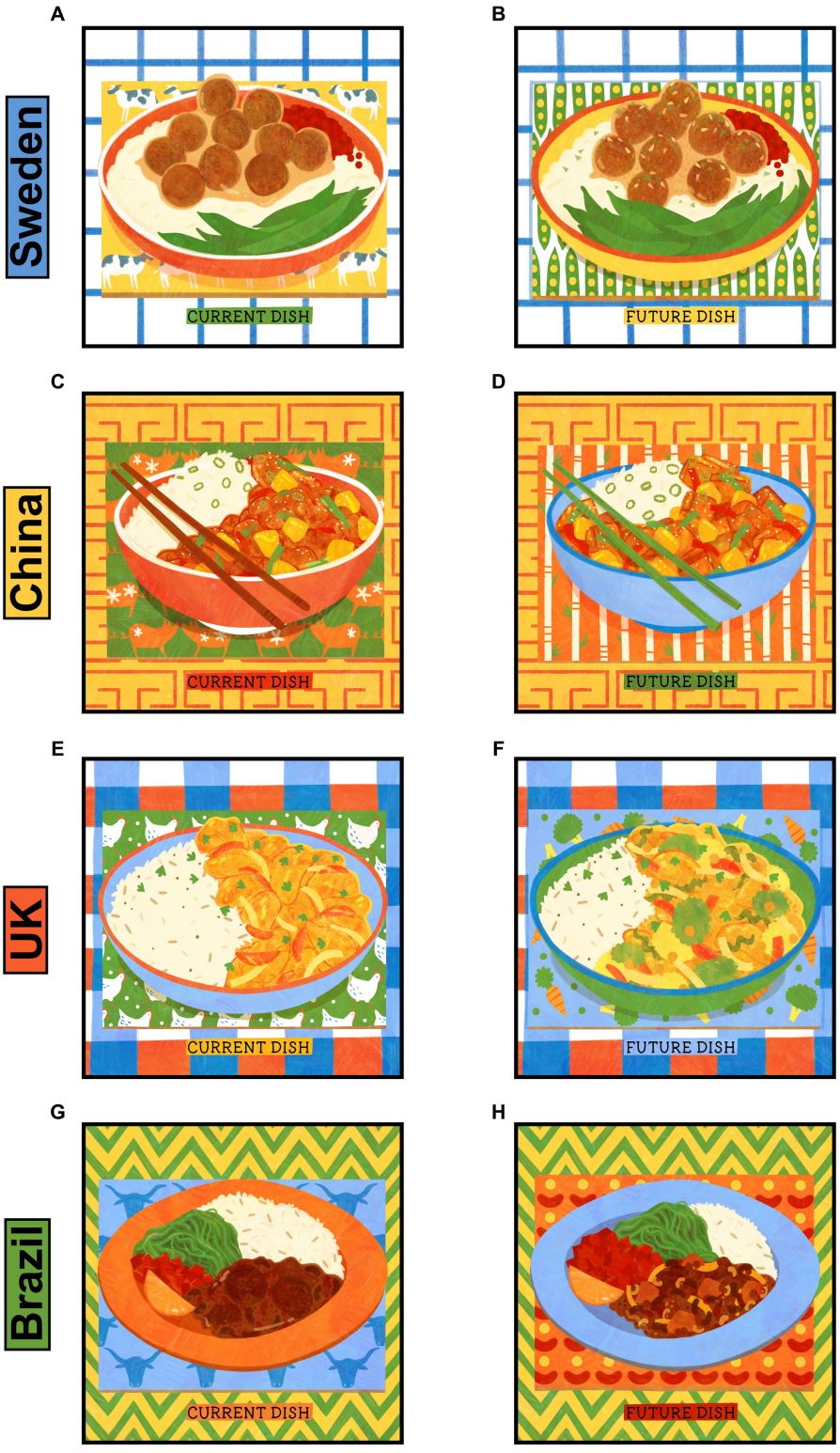

FIGURE 4
Visualisations of potential current and 2050 dish compositions. **(A)** Current Swedish meatballs, **(B)** future Swedish meatballs, **(C)** current sweet and sour pork, **(D)** future sweet and sour pork, **(E)** current chicken korma, **(F)** future chicken korma, **(G)** current feijoada, **(H)** future feijoada.

3.5.1 Potential future Swedish dish – meatballs

The meatballs comprise beef and pork and are served with gravy, mashed potatoes, lingonberries, and green beans (Figure 4A). Gradually, meat (beef and pork) is replaced by lentils, nuts, and seeds, while the proportion of vegetables expands to occupy half the dish. By 2050, the quantity of meat in the future dish (Figure 4B) will

correspond to the UK's levels and reflects a healthy diet. See Supplementary Figures 4A–C for the changing proportions for 2020, 2030, and 2050.

3.5.2 Potential future Chinese dish – sweet and sour pork

The current dish (Figure 4C) features pork with pineapple, red and green peppers, and onions. Chinese diets already comprise significant amounts of fruit and vegetables (almost two-thirds of the diet), which is apparent in the dish composition. Meat (pork) accounts for roughly 6% of the dish. By 2050 (Figure 4D), the meat will diminish to a sixth of its present amount, replaced by soy curd and tofu. Rice decreases marginally by around 4%, while vegetable proportions remain fairly constant. See Supplementary Figures 3A–C for the changing proportions for 2020, 2030, and 2050.

3.5.3 Potential future British dish – chicken korma

The current visualised dish (Figure 4E) consists of chicken, vegetables (onion, tomatoes, and a sprinkling of coriander), and rice, with proportions based on the existing UK diet and ingredients from a recipe. By 2050 (Figure 4F), chicken will constitute a reduced 2% of the dish (down from 8%) rice will decrease from just under half to around a third, and pulses (chickpeas and lentils) will make up 10% of the dish. Broccoli is introduced, shifting from 46% to 56% of the meal, shifting from around a third to 50% of the meal. See Supplementary Figures 5A–C for the changing proportions for 2020, 2030, and 2050.

3.5.4 Potential future Brazilian dish – feijoada

The present-day feijoada (Figure 4G) is protein-dense, featuring pork, beef, and beans, and is accompanied by a slice of orange, salsa, pan-fried collard beans with garlic, and rice (Amigo Foods, 2023). Collard beans are a leafy vegetable common in Brazil and belong to the cruciferous family, which includes kale and broccoli. In the future dish (Figure 4H), beans will increase to 12% of the dish, joined by sweet potato (considered a staple similar to rice) and black-eyed peas (pulses). The salsa and collard beans also increase by approximately 15%, together comprising around half the dish. The meat content is dramatically reduced to 1% of the dish composition.

3.6 Better communicating shifts in future diet and dish

People's reactions to proposed future diet change to help tackle climate change can vary greatly depending on several factors, such as cultural and personal beliefs, socioeconomic status, and the perceived impact of dietary changes on their daily lives. Some people may embrace the idea of dietary change as a way to take action on climate change and may be motivated by the potential environmental and health benefits. Others may resist change, particularly if they are attached to traditional diets or feel that dietary changes would significantly impact their way of life or food choices.

It is essential for researchers to effectively communicate their work regarding climate change and carbon targets to a wide audience, helping people make informed decisions (Sparks et al., 1996; Laestadius et al., 2016) about possible lifestyle adjustments. These changes can promote healthier living and contribute to reducing overall global emissions from agriculture by decreasing *per capita* meat consumption. The quality of information and the expertise of those providing it are significant factors influencing such decisions (Sparks et al., 1996; CCC, 2020, 2023). Often, the public may not be fully aware of academic work, especially in the area of modelling. Integrated assessment models offer a distinctive analytical approach, as they compute long-term cumulative carbon budgets for all emitting sectors of the economy, encompassing land use and food. These models are the sole tools capable of connecting comprehensive lifestyle-related changes to warming outcomes, such as a 1.5°C climate stabilisation target. This analysis aims to present data in an engaging visual format to encourage discussions on individual behavioural actions and promote broader conversations about Integrated Assessment Models and their findings.

The balance of protein in plant and meat-based diets needs to be highlighted and communicated clearly to better inform the selection of dishes people need to choose to better tackle climate change while still making the decision to shift their diets their own. The analysis within the paper provides a potential replicable visual heuristic to better communicate how people's future diets and dishes will consist of in a more understandable and friendly manner compared to the complex modelling outputs created by IAM analysis. The selection of the four regional dishes in this analysis represents potential future dishes that future populations may consume, and further examples of future dish compositions are presented in Supplementary Figures 1A–F and Supplementary Table 7.

The shifting of future diets and the composition of dishes to tackle climate change may be controversial as people are protective of what they eat. The shift in people's diets will face barriers such as increased food costs, changes in habits and preferences, accessibility of plant-based foods and potential cultural and social barriers that may hinder the shift in diets to tackle climate change. However, the use of visual communication frameworks showcased in this paper may help ease the transition to more sustainable diets within communities. The value added from this article highlights that the use of visualisations of future diets and dishes can be a useful tool for improving communication about future diets compared to complex and aggregated modelling outputs from IAMs, while enabling people to make informed decisions about their food choices to tackle climate change and help nations achieve 1.5°C more sustainably.

3.7 Limitations of dish and diet visualisations for communicating integrated assessment model future diet change

The approach taken in this study is notable for its attempt to present model output in a way that non-academics can more easily understand. While the representation of diets as plates is not new, this analysis adapts this familiar visual tool to the specific context of IAM's results. Many countries use similar

visual guidelines to depict a healthy diet, often including plates of food. By applying this visual tool to IAM data, the study aims to make model output more accessible to a wider audience, including the general population, academics, and policy-makers.

One of the promising aspects of this method is its potential for automation. The process of creating these visualisations can be automated to depict any dish for any country, allowing multiple countries to apply the engagement technique. This adaptability may offer a flexible approach to communicating dietary changes across various contexts.

The visualisations will be brought to stakeholder engagement workshops to determine their potential impact, underscoring the study's commitment to practical application and dialogue with various stakeholders. The careful consideration of colours and design in the illustrations is a key aspect of this approach. The choice of colour may significantly impact attracting or deterring people, and the study acknowledges this factor in its methodology.

The study's use of dish-based analysis and visualisations opens up the possibility of wider discussions about dietary change. It translates modelled data into an understandable format, complementing other dietary studies, and explores how this visualisation can be used to communicate dietary change.

The research provides insights into the dietary shifts necessary to align with the 1.5°C climate stabilisation goal of the Paris Agreement. The approach contributes to the ongoing dialogue about dietary change, climate goals, and the broader understanding of IAM data by exploring familiar visual representations and the potential for automation.

The study represents an effort to make complex dietary transition data more accessible. Its application of familiar visual tools, combined with its adaptability and exploration of automation, offers a path for future research and communication in the field. Mindful of its approach and existing visualisation methods, the study adds to the ongoing dialogue about dietary change and the understanding of IAM data. It serves as a thoughtful contribution, inviting further exploration and adaptation in various contexts and actively engaging with stakeholders to assess the real-world impact of its findings.

4 Conclusion

This study embarked on the task of translating complex IAM data into accessible visualisations of potential diets and dishes for 2050, utilising the IMAGE LiStCh scenario (Van Vuuren et al., 2018). The analysis, guided by the DDDI framework (De Boer and Aiking, 2019), paints a picture of the dietary transition from 2020 to 2050 in selected countries, including the UK, Sweden, Brazil, and China.

The novelty of this approach lies in adapting a familiar visual tool, the representation of diets as plates, to the specific context of IAM's results. While not a new concept, the study leverages this method to make model output more relatable to a diverse audience, ranging from the general population to academics and policy-makers.

With the translation process now published, the visualisations are set to be brought to stakeholder engagement workshops. This next step underscores the study's commitment to practical application and opens the door for dialogue with various stakeholders to determine the potential impact of the findings.

The study's application of dish-based analysis and visualisations not only opens up the possibility of broader discussions about dietary change but also complements existing dietary studies. Exploring familiar visual representations and the potential for automation, it adds a new dimension to the dialogue about dietary change, climate goals, and the broader understanding of IAM data.

In alignment with the 1.5°C climate stabilisation goal of the Paris Agreement, the research provides valuable insights into the necessary dietary shifts. It serves as a thoughtful contribution to the field, inviting further exploration and adaptation in various contexts.

In conclusion, this study offers a path towards making complex dietary transition data more accessible without claiming to revolutionise the field. Combining familiar visual tools with the exploration of automation adds to the ongoing dialogue about dietary change and the understanding of IAM data. It stands as a testament to innovative thinking, actively engaging with stakeholders, and assessing the real-world impact of its findings.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SL: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. MF: Data curation, Formal analysis, Investigation, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. RW: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. OE: Conceptualization, Data curation, Formal analysis, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MS: Conceptualization, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing. DV: Conceptualization, Investigation, Methodology, Project administration, Validation, Writing – review & editing. CW: Conceptualization, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. JD: Conceptualization, Investigation, Methodology, Project administration, Validation, Writing – review & editing.

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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.

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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.2023.1266708/full#supplementary-material

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Drivers of consumers' intention to adopt sustainable healthy dietary patterns: evidence from China

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Introduction: In line with the shift towards sustainable consumption, sustainable healthy dietary patterns (SHDP) have received considerable attention, but no study has examined Chinese consumers' intention to adopt SHDP.

Methods: Based on the theory of planned behaviour (TPB), this study integrated health consciousness, environmental concerns, and past eating behaviour to construct an expanded TPB framework for analyzing the factors influencing Chinese consumers' intention to adopt SHDP. The mediating role of attitude between perceived value and consumers' intention to adopt SHDP was also analyzed. The study empirically tested the research model using structural equation modelling estimation, based on the data collected from 402 local consumers in Wuxi, China.

Results and discussion: The results showed that attitude, perceived behavioural control, health consciousness, and past eating behaviuor positively and significantly influenced consumers' intention to adopt SHDP, whereas perceived value indirectly influenced adoption intention through attitude. Subjective norms and environmental concerns had no significant influence on adoption intention. Based on these findings, interventions through dietary education and information campaigns are recommended to enhance consumers' value awareness and attitudes towards SHDP. Interventions, such as nudging, should be designed to enhance consumers' perceived behavioural control and dietary practises. The findings of this study provide important insights for the development of dietary change intervention strategies.

KEYWORDS

food consumption, sustainable healthy diets, dietary change, eating behaviour, theory of planned behaviour, structural equation modelling

1 Introduction

The increase in prevalence of diet-related non-communicable diseases (NCDs) has become an international public health challenge, amid issues such as climate warming, resource degradation, and the world's growing population that have put the global food system at risk of pushing environmental boundaries (Harrison et al., 2022). Current unsustainable dietary patterns must be transformed on a global scale to make them healthier and more sustainable (Chen et al., 2022). To scientifically promote global dietary change, the Food and Agriculture Organisation of the United Nations (FAO) and World Health Organisation (WHO) jointly released in 2019 the Guiding Principles for Sustainable Healthy Diets (FAO and WHO, 2019). Practising sustainable healthy diets, which are 'dietary patterns that promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable', can help towards the achievement of United Nations Sustainable Development Goals (e.g., SDG3: Good

Health and Well-Being, SDG12: Responsible Consumption and Production, and SDG13: Climate Action; United Nations, 2015). Sustainable healthy diets, as a good start for developing sustainable lifestyles (De Koning et al., 2015), have increasingly attracted widespread attention globally, with a growing body of evidence highlighting actual and potential value in improving public health, mitigating climate change, and contributing to food security (Jarmul et al., 2020).

Dietary change is an important component of a sustainable future (Sobhani et al., 2019). For governments worldwide, promoting the adoption of sustainable healthy dietary patterns (SHDP) by citizens is an important task that requires urgent action, although promoting dietary change is quite difficult (Gonera et al., 2021). A successful shift in the dietary patterns of the Chinese population, currently at 1.4 billion, towards sustainable healthy diets will be crucial for the implementation of the UN 2030 Agenda for Sustainable Development. The Chinese government attaches great importance and actively responds to the UN SDGs initiative, and has established a policy action programme to 'establish a good dietary culture' and 'promote green, healthy and safe consumption' (The 14th Five-Year Plan and 2035 Vision Plan, 2021). Although the Chinese government has a clear vision of promoting a shift in citizens' dietary patterns and consumption towards health and sustainability, social problems arising from irrational dietary consumption continue to impede meaningful change. For example, diet-related chronic diseases amongst Chinese citizens are increasingly reported in younger citizens, with the overweight and obesity rate exceeding 50% (NHSC, 2020). Moreover, the environmental load of natural resources associated with dietary consumption is rising, and changes in the dietary structure of citizens pose an increasing challenge to China's environmental sustainability (Yin et al., 2021). Developing and implementing scientific and effective interventions to promote citizens' adoption of SHDP are thus challenges for the Chinese government.

Policymakers know that changes in consumer behaviour are critical to any policy process aimed at integrating nutritional health and environmental sustainability (Lang and Barling, 2013). Consumers are often seen as the key to driving changes within the food system (Camilleri et al., 2019) because changes in demand can be transmitted back along the supply chain (Righi et al., 2023). Driving changes in consumer dietary patterns is viewed as a reasonable solution for achieving upstream food sustainability goals (Blackstone et al., 2018; Schwingshackl et al., 2020). Steenson and Buttriss (2021), for example, proposed that by changing food consumption patterns, healthy and sustainable eating behaviour can be established at the consumer end of the chain, to achieve healthy and sustainable source-to-table development. The health and environmental benefits of large-scale dietary changes have also been investigated. Springmann et al. (2018) confirmed in a global study that a reduction in animal-derived foods reduces premature mortality. Specifically, if plant-based foods could replace 25 to 100% of animal-derived foods, global premature mortality would be 4 to 12% lower by 2030 compared with 2010. Sheng et al. (2021) suggested that if all Chinese consumers consistently adopted the recommended healthy dietary patterns, diet-related chronic diseases and mortality rates would be significantly lower, and this dietary change would also reduce greenhouse gas (GHG) emissions by 146 to 202 million tons (18 to 25%) compared with the projected emission levels in 2030. Achieving future shifts in the diets of populations towards healthier and more sustainable patterns will require the promotion of large-scale changes in consumer dietary pattern choices (Jarmul et al., 2020). However, any attempt to change dietary patterns must take full account of consumer intention and local contextual realities to achieve population-wide, lasting change.

In line with the trend towards sustainable consumption, the factors influencing choices of sustainable healthy diets have garnered significant attention from the academic community in recent years, leading to a continuous emergence of academic research. For example, Benedetti et al. (2018), approaching from a lifestyle perspective, highlighted the significant impact of education, regular physical exercise, and family dietary habits on improving dietary adherence, emphasising the importance of consumers' self-regulation abilities and lifestyle choices in developing healthy dietary habits. Fink et al. (2021), starting from a socio-economic perspective, pointed out that an individual's socioeconomic status, including their economic status and income level, plays an important role in driving consumers to adopt a sustainable diet. Baur et al. (2022) linked nutritional health and environmental impact with individual dietary intentions and found that healthy eating intentions were significantly higher than environmentally sustainable eating intentions in terms of behavioural transformation, highlighting the leading role of personal health goals in dietary decision-making. Barbour et al. (2023) analyzed the facilitating and inhibiting factors of healthy sustainable diets from a policy perspective, emphasising the role of local governments in promoting policies related to sustainable healthy diets. These studies showcase, from multiple perspectives, the diverse factors influencing the choices of dietary patterns, which offer valuable insights for understanding and directing consumer behaviour towards sustainable healthy dietary consumption.

However, existing relevant studies have the following research gaps. First, although existing studies emphasise the importance of changing dietary patterns on a global scale, little attention has been paid to the perceived value, attitudes, and adoption intention of Chinese consumers towards SHDP, and the applicability of previous findings based on samples of European and American consumers to the Chinese sociocultural context has not been tested. Second, many studies apply the theory of planned behaviour (TPB) to food consumption, but few studies have applied health consciousness, environmental concerns, and past eating behaviour as TPB-expanding factors to consumers' intention to adopt SHDP. Even fewer studies have examined whether perceived value contributes to consumers' intention to adopt SHDP. To address the above research gaps, we used an extended TPB, collected data through field questionnaires, and empirically analyzed the main influencing factors and internal mechanisms of consumers' intention to adopt the SHDP in the Chinese sociocultural context. We aimed to theoretically bridge the deficiencies in existing research on healthy sustainable dietary behaviour and provide a new empirical basis for the design of interventions that can promote dietary change in consumers.

2 Literature review and hypotheses development

2.1 Theory of planned behaviour

Proposed by Ajzen (1991), TPB is widely used to predict and explain the general behaviour of individuals and their behavioural

decision-making processes. This widely used psychological theory suggests that behavioural intention is the most reliable predictor of an individual's actual behaviour and is determined by three psychological factors: attitude, subjective norms, and perceived behavioural control (Ajzen, 1991). When an individual has more positive attitudes towards performing a certain behaviour, perceive more social pressure to perform the behaviour, and feel empowered to perform the behaviour, then the individual will have a higher intention to perform the behaviour, and consequently, the actual behaviour will more likely occur. The TPB is generally useful for predicting behavioural intention and has been widely recognised as a conceptual model for capturing behaviour. However, the TPB is not perfect, and the main criticism is that it focuses on rational reasoning and does not thoroughly explain behaviour (Visschers et al., 2016). Nejad et al. (2004) pointed out that other specific factors should be introduced to supplement and improve research on individual behavioural decision-making in specific situations to further improve the effectiveness and applicability of the TPB. Many studies have attempted to improve the explanatory power of TPB models by adding other components as predictors of behaviour (Tang et al., 2023).

The TPB has generally been used to predict consumers' behavioural intentions and has been widely used in related studies on health, pro-environment, and sustainable consumption behaviours (McEachan et al., 2011; Shukri et al., 2016; Tang et al., 2023). Some scholars have used the TPB as a theoretical basis to predict and explain individual intentions regarding healthy or sustainable diets (Visschers et al., 2016; Biasini et al., 2021; Jha et al., 2023). Many of these previous studies have focused on healthy eating intentions, and the few have focused on sustainable eating intentions to reduce food waste. Despite differences in perspectives between the literature and our study, the former provided inspiration and reference for our work. For example, Ploll and Stern (2020) applied TPB analysis to reveal the significant relation between subjective norms, attitudes, behavioural intentions, and vegetarian and vegan behaviours. Sogari et al. (2023) provided new insights into how TPB constructs (attitudes and subjective norms) significantly predict the intention to adopt a healthy diet. Kramer et al. (2023) supported the validity of the TPB in explaining healthy eating and cooking behaviour, suggesting that interventions targeting TPB constructs (attitude, subjective norms, perceived behavioural control, and intention) may help create behaviour change in specific populations. These studies suggested that attitude, subjective norms, and perceived behavioural control are important predictors of consumers' dietary adoption intention and that the likelihood of triggering an individual's dietary behaviour practise depends on their dietary intention (Kramer et al., 2023). However, the influence of various aspects (attitude, subjective norms, and perceived behavioural control) on consumers' intention to adopt dietary patterns may vary with cultural their background. As Hwang et al. (2003) pointed out, different cultural contexts may produce completely different consumer behaviours.

2.2 Hypothesis development

2.2.1 Attitude

Attitude can be defined as a positive or negative evaluation of behaviour and outcomes. Ajzen (1985) indicated that the relation between attitudes and behavioural intention may be the most predictable and more significant in the TPB framework. Scholars generally agree on the significant positive correlation between individual attitudes and adoption intention (Al-Swidi et al., 2014). In the area of food and beverage consumption, Dunn et al. (2011) also showed that consumers intention to consume fast food is significantly influenced by their attitudes. As such, we proposed the following hypothesis:

> *H1*: Attitude positively influences consumers' intention to adopt SHDP.

2.2.2 Subjective norms

Subjective norms refer to the extent to which individuals respect the opinions and evaluations of others who are important to them, and then use the same as standards or principles for personal behaviour. Subjective norms are positive predictors of consumer food purchase intentions (Sultan et al., 2020). They also predict sustainable food consumption (Shen et al., 2022). Stranieri et al. (2017) further argued that they have some validity in explaining consumers' dietary decisions and advocated for a more nuanced study of subjective norms. Hence, we proposed the following hypothesis.

> *H2*: Subjective norms positively influence consumers' intention to adopt SHDP.

2.2.3 Perceived behavioural control

Perceived behavioural control is an individual's perceived ease of performing a behaviour (including influences, e.g., time, knowledge, and money) and primarily measures an individual's perception of whether a behaviour can be accomplished by their own volition (Ajzen, 1991). Consumers' perceived behavioural control is an important factor influencing intention to consume organic food; a higher perceived behavioural relates to a stronger purchase intention (Carfora et al., 2019). Given that organic food is often considered a food choice that consumers would make if they adopt SHDP, and consumers' intention to adopt SHDP is similar in essential attributes to their intention to purchase organic food, we proposed the following hypothesis.

> *H3*: Perceived behavioural control positively influences consumers' intention to adopt SHDP.

2.2.4 Past eating behaviour

Past eating behaviour refers to whether an individual's daily dietary pattern meets the criteria for being healthy and sustainable. Increasing the intensity of past behaviours or habits significantly improves the interpretation of behaviour by the TPB (McEachan et al., 2011). The frequency of an individual's past behaviours reflects the strength of past behaviours and directly influences future behavioural choices (Honkanen et al., 2005). Good behaviours recur, and when consumers have more experience adopting a certain behavioural pattern in the past, then consumers are more accepting of that pattern, and the pattern is also highly attractive to consumers (Dean et al., 2012; Li et al., 2018). Past behaviour has been explored as an expansion factor of TPB and a powerful tool for predicting an individual's future behavioural intention (Vallejos et al., 2023). Koklic et al. (2019) noted that consumers' past organic food consumption has a positive effect on their organic food purchase intention and that the overall effect of

past behaviour on intention is stronger than that of other factors. In other words, the more an individual's past eating behaviour meets the criteria for SHDP, the stronger is their intention to adopt that dietary pattern. Therefore, we proposed the following hypothesis:

> *H4*: Past eating behaviour positively influences consumers' intention to adopt SHDP.

2.2.5 Health consciousness

Health consciousness is an important psychological construct defined as 'the degree to which health issues are integrated into one's daily activities', which reveals a person's willingness to engage in healthy behaviours (Jayanti and Burns, 1998; Espinosa, 2021). Health consciousness is an important motivator for consumers' decisions to purchase healthy foods (e.g., organic foods). Consumers with lower health consciousness have relatively weaker intention to purchase organic foods (Suttikun, 2023). In China, after the easing of the COVID-19 pandemic, consumers are paying more attention to health issues. Eating healthy food is becoming more popular, and people are more inclined to consider health factors when making dietary decisions. Considering that health consciousness may be an important factor influencing consumers' intention to adopt SHDP, we proposed the following hypothesis.

> *H5*: Health consciousness positively influences consumers' intention to adopt SHDP.

2.2.6 Environmental concern

Environmental concern indicates 'the degree to which people are aware of problems regarding the environment and support efforts to solve them or indicate the willingness to contribute personally to their solution' (Dunlap and Jones, 2002). Personal concern for the environment has a direct and positive impact on consumers' intention to purchase environmentally friendly products (Pagiaslis and Krontalis, 2014) and is directly related to environmentally friendly behaviours (Cheung and To, 2019). In the context of food consumption, environmental concern is believed to play an important role in determining purchase intention for organic food products (Smith and Paladino, 2010). Consumers who prefer organic products are more likely to engage in environmental activities (Kumar et al., 2021). As such, environmental concern may be an important predictor of consumers' willingness to adopt SHDP, leading to the following hypothesis.

> *H6*: Environmental concern positively influences consumers' intention to adopt SHDP.

2.2.7 Perceived value

According to Zeithaml (1988), perceived value is defined as a consumer's assessment based on the benefits of a product, particularly concerning the perceived or received value compared with the sacrifices one must make. Perceived value influences consumer attitudes and behavioural intention (Petrick and Backman, 2002). The more positive one's perceived value is, the more positive their intention, which further leads to a stronger motivation that drives actual actions (Fiandari et al., 2019). The importance of perceived value in consumers' green consumption behaviour is well understood. Consumers' perceived value increases their willingness to purchase green products (de Medeiros et al., 2016). Specific to the food consumption context, Jamal and Sharifuddin (2014) showed that perceived positive value enhances consumers' purchase intention for halal food. Li et al. (2020) reported a positive relation between consumers' perceived value and behavioural intention towards environmentally friendly agri-food products. Consumers' perceived value of SHDP may influence their attitudes and intention to adopt. Hence, we proposed the following hypotheses.

> *H7a*: Consumers' perceived value is a positive determinant related to attitude.
>
> *H7b*: Consumers' perceived value positively influences their intention to adopt SHDP.
>
> *H7c*: Attitude mediates the relation between consumer perceived value and intention to adopt SHDP.

3 Methods

3.1 Questionnaire design and data collection

Based on the existing measurement items (Supplementary Table S1 lists the reference sources), we designed structured questionnaires to collect data and analyse the proposed hypotheses (see as Figure 1). The full questionnaire is provided in the Supplementary materials. The three-part questionnaire investigated the participants' demographic characteristics; past eating behaviour (PEB), health consciousness (HC), and environmental concern (EC); and perceived value (PV), attitude (AT), perceived behavioural control (PBC), subjective norms (SN), and intention to adopt (IA) SHDP. The questionnaire also included a clear definition of Sustainable Healthy Diets, which was carefully explained to respondents by trained investigators during the survey. The items in the questionnaire, which addressed the eight core variables in the analytical framework of our study, were measured on a five-point Likert scale, with respondents answering how much they agreed with specific statements, ranging from 'strongly disagree' = 1 point to 'strongly agree' = 5 points. All measurement items were derived from well-established scales in existing studies and adapted appropriately to the context of SHDP adoption by Chinese consumers. The initial questionnaire was first test-filled by experts and investigators. Based on the feedback, we modified the semantic ambiguities and inaccuracies of expression in the questionnaire. Next, we conducted a pre-survey amongst 50 consumers in Wuxi. Questionnaire topics were adjusted, added, or subtracted after two rounds of testing, to form a final questionnaire for data collection.

The offline field survey was conducted in April 2023 across the administrative districts of Wuxi City, China. Wuxi is known as the 'land of fish and rice' in China, with abundant produce and a favourable ecological environment. The economy of Wuxi is well developed, with its GDP *per capita* ranking first in the country for three consecutive years from 2019 to 2022. Residents of the city have strong purchasing power and a relatively high level of scientific literacy in food safety and dietary health. The Jiangnan diet, an healthy dietary pattern similar to the Mediterranean diet, is popular in Wuxi. We used non-probability sampling, which is suitable for studies that aim to test hypotheses on the relation between specific variables and behaviour (Leary, 2004).

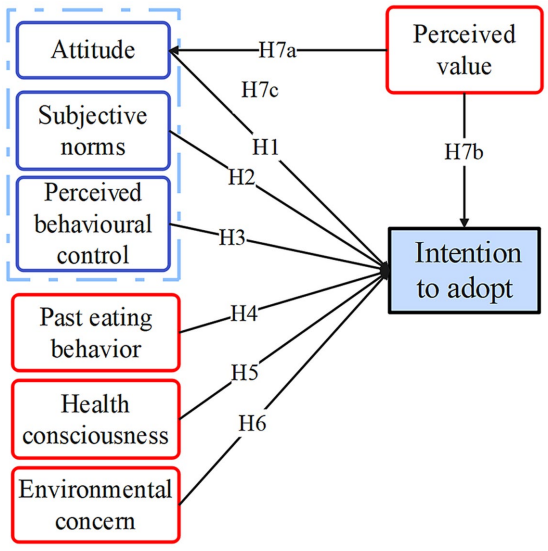

FIGURE 1
Conceptual framework.

This method also offers benefits in terms of cost, convenience, and time (de Medeiros et al., 2016; Fiandari et al., 2019). The survey was conducted mainly in large supermarkets, farmers' markets, and neighborhoods with high customer flow, targeting Wuxi residents aged 18 years and older. Trained investigators provided clear explanations and definitions of relevant terms and concepts in the process of the one-to-one questionnaire survey. A total of 422 questionnaires were distributed and 402 valid questionnaires were collected, with a valid sample ratio of 95.3%. The studies involving human participants were reviewed and approved by Jiangnan University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

3.2 Data analysis

Structural equation modelling (SEM) allows for the simultaneous analysis of many relations and is one of the most commonly used methods for interpreting behaviour and survey data (Secer et al., 2023). It can assess measurement errors, calculate latent structures, and estimate and evaluate complex (Stein et al., 2012) or multifaceted models (MacKenzie, 2001) from observed variables. We applied the SEM method of maximum likelihood estimation to test the research path hypothesis and mediation effect. SPSS (version 25.0) and AMOS (version 26.0) were used for SEM analysis. The SEM algorithm involved two stages: validating the measurement model and testing the structural model.

4 Results

4.1 Demographic characteristics

Table 1 summarises the respondent profiles. Compared with the statistics published by the Wuxi Municipal People's Government, our sample was similar to the Wuxi population in terms of sex, age, and income; however, the proportion of respondents with higher education was higher than that of Wuxi as a whole. Overall, the survey sample was acceptably representative. The mean values of each variable are shown in Supplementary Table S1, in which the mean value of consumers' IA (3.69) implied a relatively strong intention to embrace SHDP.

4.2 Reliability and validity test

First, we tested the scale using the Kaiser–Meyer–Olkin (KMO) sample fit test and Bartlett's sphericity test. The KMO value (0.930, more than 0.7) and Bartlett's sphericity test result ($\chi^2 = 6191.881$, $p < 0.001$) indicated that the data were suitable for factor analysis. We then conducted a confirmatory factor analysis to analyse the reliability, convergent validity, and discriminant validity of the scales. As shown in Table 2, the Cronbach's alpha coefficients for each latent variable were above the critical value of 0.7 (Taber, 2018), and the factor loadings were more than 0.6 (Chin et al., 1997), indicating an acceptable level of reliability. The average variance extracted (AVE) value for each latent variable was greater than the critical value of 0.5 (Bagozzi and Yi, 1988), and the composite reliability (CR) values were all greater than the critical value of 0.7 (Fornell and Wernerfelt, 1987), indicating high convergent validity amongst the variables. In addition, the square root of the AVE for each latent variable (Table 3) was greater than the correlation coefficients of the rows and columns located below the diagonal, suggesting acceptable discriminant validity between the variables (Hair et al., 2019).

Next, to avoid the impact of the non-normal distribution of data on SEM hypothesis testing (Li and Shao, 2023), we used SPSS 25.0 to test the distribution of the sample data. The results (Supplementary Table S1) showed that the absolute value of the skewness coefficient of the sample data ranged from 0.008 to 0.900, none of which was over 3, and the absolute value of the kurtosis coefficient ranged from 0.019 to 0.772, none of which was over 8, indicating that the sample data conformed to a normal distribution and could be used in the SEM for hypothesis testing (Teisl et al., 2009).

Given that the data were obtained from respondents' self-reported questionnaires, we needed to test for common method bias (CMB). Therefore, we conducted an exploratory factor analysis of all variables through Harman's single-factor test (Harman, 1976): CMB is confirmed if the first factor accounts for >50% of the variance amongst the variables (Gao et al., 2022). Our test showed that the eigenvalue variance percentage of the factor was 35.087%, much lower than the threshold of 50%, suggesting that CMB was not an issue.

To test for multicollinearity amongst the latent variables, we conducted a variance inflation factor (VIF) test. The results showed that the VIF of each variable in the model ranged from 1.622 to 3.465 (see as Supplementary Table S2), much lower than the threshold of 10 for multicollinearity amongst latent variables (Timm, 2002). Therefore, the latent variables in our model had no obvious multicollinearity problem.

4.3 Structural model testing

We constructed a structural equation model based on the theoretical model. Before testing the hypothesised relations,

TABLE 1 Demographic characteristics of respondents ($N = 402$).

Demographic	Category	Frequency	Proportion (%)
Sex	Male	206	51.2
	Female	196	48.8
Age (years)	18–22	97	24.1
	23–32	159	39.6
	33–42	94	23.4
	43–52	41	10.2
	53–65	11	2.7
Education	Junior high school or lower	25	6.2
	High school (including vocational high school)	220	54.7
	Junior college (including higher vocational college)	47	11.7
	Bachelor's degree	87	21.7
	Master's degree	23	5.7
Marital status	Married	177	44.0
	Unmarried	225	56.0
Personal annual income	<5,000 RMB	108	26.9
	5,001–8,000 RMB	132	32.8
	8,001–12,000 RMB	100	24.9
	12,001–20,000 RMB	39	9.7
	>20,000 RMB	23	5.7
Occupation	Civil servant	17	4.2
	Public sector employee	39	9.7
	Company employee	123	30.6
	Farmer	12	3.0
	Freelancer	61	15.2
	Retirees	8	2.0
	Student	100	24.9
	Unemployed	8	2.0
	Others	34	8.4

TABLE 2 Construct validity and reliability.

Construct	FL	Cronbach's α	CR	AVE
Attitude		0.788	0.793	0.562
AT1	0.685			
AT2	0.783			
AT3	0.776			
Subjective norms		0.801	0.807	0.513
SN1	0.689			
SN2	0.785			
SN3	0.737			
SN4	0.647			
Perceived behavioural control		0.754	0.753	0.505
PBC1	0.736			
PBC2	0.652			
PBC3	0.741			
Intention to adopt		0.853	0.854	0.662
IA1	0.799			
IA2	0.824			
IA3	0.817			
Health consciousness		0.782	0.784	0.548
HC1	0.768			
HC2	0.683			
HC3	0.767			
Environmental concern		0.893	0.893	0.737
EC1	0.880			
EC2	0.872			
EC3	0.822			
Past eating behaviour		0.902	0.903	0.574
PEB1	0.858			
PEB2	0.816			
PEB3	0.767			
PEB4	0.717			
PEB5	0.653			
PEB6	0.682			
PEB7	0.786			
Perceived value		0.772	0.774	0.534
PV1	0.774			
PV2	0.765			
PV3	0.647			

FL, factor loading; CR, composite reliability; AVE, average value extracted.

we compared the extended TPB model with the original TPB model. Table 4 presents the various fit indices of the model. According to previous scholars, the chi-squared degrees of freedom ratio (χ^2/df) of the model should be between 1 and 3; the root mean square error of approximation (RMSEA) and standardised root mean square residual (SRMR) should be less than 0.08 (Hu and Bentler, 1998); and the normed fit index (NFI) should be greater than 0.8 (Chakraborty et al., 2008). According to the index values of χ^2/df, RMSEA, and SRMR (Table 4), the extended TPB model had a better fit than the original TPB model. Moreover, the explanatory power of the extended theoretical model for consumer IA SHDP ($R^2_{IA} = 0.756$) was better than that of the original TPB model ($R^2_{IA} = 0.640$). Thus, our extended theoretical model had a better explanatory power than the original TPB model.

As shown in Figure 2, the assessment results of the structural model demonstrated that AT significantly and positively affected IA

TABLE 3 Discriminant validity.

Construct	1	2	3	4	5	6	7	8
1. AT	**0.749**							
2. SN	0.367	**0.716**						
3. PBC	0.625	0.608	**0.711**					
4. HC	0.689	0.458	0.521	**0.740**				
5. EC	0.425	0.475	0.539	0.487	**0.858**			
6. PEB	0.499	0.511	0.607	0.504	0.401	**0.757**		
7. PV	0.509	0.420	0.441	0.458	0.377	0.651	**0.731**	
8. IA	0.749	0.552	0.694	0.721	0.511	0.707	0.590	**0.813**

Square root of AVE in diagonal (bold). AT, Attitude; SN, Subjective norms; PBC, Perceived behavioural control; HC, Health consciousness; EC, Environmental concern; PEB, Past eating behaviour; PV, Perceived value; IA, Intention to adopt.

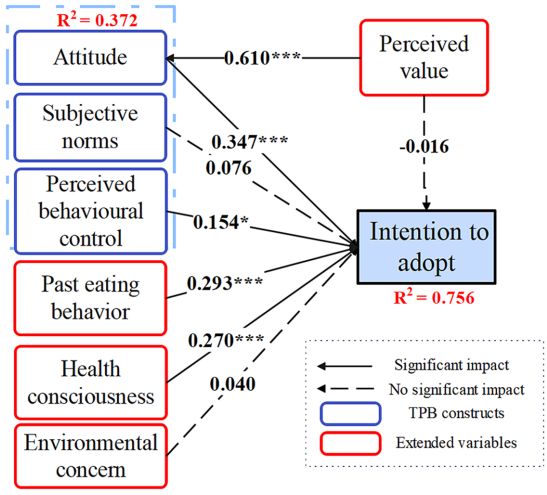

FIGURE 2
Estimated results for the extended TPB structural model.

TABLE 4 Summary of model fit.

Items	Standard value	Extended model	TPB model
χ^2/df	1–3	1.848	2.172
RMSEA	<0.08	0.046	0.054
SRMR	<0.08	0.061	0.098
CFI	>0.9	0.950	0.968
NFI	>0.8	0.897	0.942
Chi-squared		654.111	130.306
R^2		0.756	0.640

χ^2/df, the chi-squared degree of freedom ratio; RMSEA, root mean square of approximation error; SRMR, standardised root mean square residual; CFI, comparative fit index; NFI, normed fit index; chi-squared, chi-square value; and R^2, model fit.

($\beta = 0.347$, $p < 0.001$), confirming H1. SN did not significantly influence IA ($\beta = 0.076$, $p = 0.186$); thus, H2 was rejected. PBC positively influenced IA ($\beta = 0.154$, $p < 0.05$), supporting H3. PEB positively influenced IA ($\beta = 0.293$, $p < 0.001$); thus, hypothesis H4 was supported. HC positively influenced IA ($\beta = 0.270$, $p < 0.001$), supporting H5. EC did not significantly influence IA ($\beta = 0.040$, $p = 0.417$); thus, hypothesis H6 was rejected. PV significantly and positively affected AT ($\beta = 0.610$, $p < 0.001$); thus, hypothesis H7a was supported. Interestingly, PV did not have a direct effect on IA; thus, H7b was rejected. As shown in Figure 2, IA explained 75.6% of the total variance of all its antecedent variables, indicating that our hypothesised model had high explanatory validity for consumers' intention to adopt SHDP.

4.4 Mediating effect analysis

Using AMOS 26.0 software, we analysed the mediating effects included in the model. We used the bias-corrected nonparametric percentile bootstrap method, with the number of samples set to 2,000. We thus determined the direct, indirect, and total effects of the PV, AT, and IA. The results of the bootstrap test, shown in Table 5, demonstrated that consumer PV had no direct effect on IA; however, the indirect and total effects were significant. The confidence intervals for the indirect effect of the path PV → AT→AI did not contain zero, indicating that PV had an indirect, fully mediated effect on IA through AT. Therefore, H7c was supported.

5 Discussion

5.1 Interpretation of results

This study extended the TPB model to explore the drivers that promote the intention to adopt SHDP of Chinese consumers. The results showed that attitudes played an important role in driving consumers' intention to adopt SHDP—it increased significantly when the consumers had a positive attitude towards SHDP. This finding coincided with previous conclusions on the positive correlation between attitude and behavioural intention with respect to food purchasing and healthy eating intention (Al-Swidi et al., 2014; Sogari et al., 2023). Our study confirmed that consumers' perceived value affected their attitudes and had a significant indirect effect on their intention to adopt SHDP through attitude. Similarly, Albertsen et al. (2020) reported that consumer acceptance of food innovations may be related to perceived value. Indeed, SHDP is a novel dietary pattern for

TABLE 5 The results of the bootstrap mediating effect test.

Path	Effect	Point estimate	Boot SE	Bootstrapping			
				Bias-corrected (95% CI)		Percentile (95% CI)	
				Lower	Upper	Lower	Upper
PV→AT→AI	Direct effect	−0.016	0.095	−0.197	0.169	−0.212	0.156
	Indirect effect	0.212***	0.046	0.135	0.316	0.134	0.314
	Total effect	0.196*	0.084	0.044	0.364	0.032	0.354

Chinese consumers, and its adoption implies food innovation. To the best of our knowledge, in the field of research on sustainable healthy diet consumption behaviour, our study provides the first empirical evidence for the indirect incentive role of consumers' perceived value on the adoption of SHDP in the Chinese sociocultural context.

We also confirmed the importance of perceived behavioural control as a factor directly related to consumers' intention to adopt SHDP. This is consistent with the findings of previous studies on Chinese consumers' food purchase intention (Li and Jaharuddin, 2020; Qi and Ploeger, 2021). Perceived behavioural control reflected consumers' subjective feelings regarding the availability, identification, and convenience of sustainable healthy diets. When consumers subjectively perceived sustainable healthy diets as more accessible and easier to identify, then they would have fewer obstacles to adjusting their dietary patterns towards healthy and sustainable changes. As such, their intention to adopt SHDP would naturally increase.

Subjective norms did not have any effect on consumers' intention to adopt SHDP, coinciding with previous findings on the limited ability of subjective norms to predict behaviour in the TPB (Yazdanpanah and Forouzani, 2015). In a meta-analysis of the psychosocial determinants of pro-environmental behaviours, Bamberg and Möser (2007) found no direct link between subjective norms and intention. A possible explanation is that subjective norms are unstable and vary in different contexts. Moreover, different respondents may be influenced by different target groups, and the effectiveness of subjective norms is reduced when respondents do not identify with a defined target group (family, friends; Trafimow and Finlay, 1996).

The expanded TPB we constructed also contained other constructs, such as past eating behaviour, health consciousness, and environmental concern. Consumers' past eating behaviours significantly influenced adoption intention towards SHDP. That is, the more a consumer's actual past eating behaviour met the criteria for SHDP, the more acceptable and willing they would be to adopt it. Rivis and Sheeran (2003) suggested that the impact of past eating behaviours depends on whether the behaviours have become habitual, in which the individual becomes guided by external environmental cues and develops an automatic response that is not driven by cognitive factors. Thus, past eating behaviour may positively influence the intention to adopt a dietary pattern, even if the consumer lacks precise knowledge of sustainable healthy diets.

Health consciousness can predict a person's intention to engage in healthy behaviours (Rahamat et al., 2022). We found that consumers' health consciousness directly and positively influenced their intention to adopt SHDP. Indeed, amid the increased health consciousness worldwide, health consciousness is not only a driver for promoting healthy food choices amongst consumers but also a major driving factor behind consumers' adoption of sustainable dietary behaviours (Kareklas et al., 2014).

Meanwhile, we found that environmental concern did not have a direct effect on consumers' intention to adopt SHDP. Consumers' values and personal priorities are known to be important factors that influence their behavioural intentions (Arora et al., 2022); egoism-driven health consciousness is more important than altruism-driven environmental concern in the case of dietary consumption. Research on organic food has shown that consumers' environmental concerns are drivers of green consumer behaviour in China (Ahmed et al., 2021). However, Chinese consumers' awareness of SHDP is lacking because it is still an emerging concept in China, and most ignore the connection between diet and environmental sustainability. The objects of environmental concern are familiar environmental behaviours, such as reducing the use of plastic bags (Sun et al., 2017) and purchasing recycled products (Zhang and Luo, 2021). This may explain how environmental concern does not drive the intention to adopt SHDP.

5.2 Theoretical implications

We expected our study to contribute to the literature in two ways. First, it expands the scope of research on the TPB in the fields of food and diet consumption. As a social psychological model that can effectively identify and elucidate consumer behaviour and behavioural intention, the TPB has seen applications in the field of food/diet consumption behaviour, but they have focused on organic food purchasing, environmentally friendly food consumption, healthy eating behaviour, and food waste reduction behaviour (Al-Swidi et al., 2014; Visschers et al., 2016; Jha et al., 2023). Meanwhile, our study extends the TPB in terms of health consciousness, environmental concern, and past eating behaviour and applies it to explore the main influencing factors and internal mechanisms of Chinese consumers' intention to adopt SHDP. Our work fills the research gap in the TPB in the field of sustainable consumption, especially in the sociocultural context of China.

Second, it provides a new perspective for promoting consumer intention to adopt SHDP. Previous studies on individual-level sustainable healthy dietary behaviours are typically qualitative works on cognitions, attitudes, motivations, and barriers; the few quantitative empirical analyses have focused on developed countries in Europe and on the US (Van Loo et al., 2017; Verain et al., 2017; Claessens et al.,

2023). By collecting sample data from a Chinese city in Wuxi, our empirical analysis provides evidence of the importance of enhancing consumers' perceived value in motivating them to adopt SHDP, thus filling the current research gap related to the relation between consumers' perceived value and their adoption of SHDP, and providing additional evidence for elucidating the psychological mechanisms of consumers' dietary change, especially in the context of healthy and sustainable diet consumption.

5.3 Policy implications

Our findings also provide important insights for the development of dietary change interventions and offer valuable implications for policymakers. First, interventions should be designed and implemented to target attitude and awareness, as attitude and health consciousness are the most direct drivers motivating consumers to adopt SHDP. Given the close relation between attitude and perceived value, interventions should encourage consumers to develop favourable perceived values to boost positive attitudes towards SHDP. As mentioned by Verain et al. (2017) and Jalil et al. (2020), raising awareness and shaping attitude through education and information campaigns to encourage voluntary dietary behaviour change amongst consumers are the most commonly used soft policy interventions aimed at facilitating a shift towards sustainable healthy diets. Educating consumers about the impact of their dietary choices on personal health and the environment may increase their awareness, interest, and recognition of the value of sustainable healthy diets (Van Loo et al., 2017), thereby improving attitudes and facilitating dietary shifts. The accumulation of information increases the overall social awareness, gradually motivates consumers to take action (Cummings and Proctor, 2014), and encourages educational campaigns to raise social awareness (Willett et al., 2019). We recommend that governments and public welfare organizations strengthen dietary education and information popularisation. In particular, education campaigns should inform consumers on not only the 'what' (promoting the concept of sustainable healthy diet consumption and providing scientific knowledge about sustainable healthy diets) but also the 'why' (emphasising the egoistic and altruistic values of sustainable healthy diets, focusing on the health benefits and complementing it with scientific information on the environmental impacts of diets) and the 'how' (providing consumers with personalised advice and guidance, such as healthy and environmentally friendly recipes and easy-to-follow cooking tips).

Given that individuals with little knowledge or interest in sustainable healthy diets may be less likely to respond immediately to awareness-raising interventions (Jalil et al., 2020), policymakers should also focus on the impact of perceived behavioural control and past eating behaviour on consumer adoption of SHDP. We recommend 'nudging' interventions that push consumers towards sustainable healthy diets but do not rely on education to raise awareness. In nudging, 'nudges' use mild, more implicit intervention strategies that can easily and even unconsciously influence people's choices and behaviour in a desired direction (Thaler and Sunstein, 2008). Interventions designed on behavioural nudges (product accessibility, default options, priming), such as meat-free days in public canteens and positive positioning of sustainable healthy foods in retail settings, can lead consumers to voluntarily switch to SHDP in a gentle way in the immediate choice context (Junghans et al., 2015; Van Loo et al., 2017; Pelle G Hansen et al., 2021). These types of nudging interventions based on behavioural insights may help repeatedly trigger consumers' healthy sustainable eating behaviour to change their future dietary choices.

The integrated implementation of multiple policies and interventions will create more opportunities for dietary change in the population. Therefore, in addition to soft policy interventions, hard policy interventions, including laws, fiscal measures, subsidies, penalties, and other economic and structural measures (Willett et al., 2019), are critical for building a supportive environment for sustainable healthy diets. For example, incentives or subsidies should be provided to encourage the production and marketing of sustainable healthy foods, promote the sustainable development of the food industry, and support food production practises that reduce GHG emissions. In addition, promoting sustainable healthy diets at the population level requires multiple actors to work together, which in turn requires strengthened governance and partnerships to address the challenge of changing diets in an effective cross-sectoral manner (De Schutter et al., 2020). Interventions to promote mass sustainable healthy diets must benefit people of low socioeconomic status and be developed in conjunction with the social safety nets necessary to effectively address poverty and inequality (De Schutter et al., 2020).

5.4 Limitations and future directions

There are inevitably some limitations in interpreting our study, and these limitations provide opportunities for further research. First, we investigated the drivers of consumers' intention to adopt sustainable healthy dietary patterns, as exemplified by residents of Wuxi City in China. However, it must be acknowledged that other factors, including consumer self-regulation and the social environment, were not covered due to constraints in the research scope and methodology. Second, our study did not address consumers' actual food choices. Future studies could combine participation measurements and actual food choice data, such as those obtained through choice experiments or dietary intake assessments, to further investigate the relation between participants and sustainable healthy food choices, and to more objectively estimate the health and sustainability attributes of sustainable healthy diets. Finally, as with most research in the field, our study relied on self-reported measures that, whilst providing valuable insights, may introduce some biases and limitations, such as the possibility that respondents may be influenced by social expectations and thus deviate from actual behaviour (Fisher, 1993). Additional experimental and observational studies are required to overcome these limitations.

6 Conclusion

Dietary consumption is an indispensable component of daily consumption, and promoting dietary change towards healthy and sustainable patterns is essential for sustainable consumption. We proposed an extended TPB analytical framework to explore the key drivers of Chinese consumers' intention to adopt SHDP. Our findings suggested that attitudes, health consciousness, past eating behaviour, and

perceived behavioural control positively influenced consumers' intention to adopt SHDP, whereas perceived value had a significant positive effect on adoption intention through attitudes. However, we did not find a significant effect of subjective norms or environmental concern on adoption intention. Our results supported the notion that consumers' intention to adopt SHDP was generally high and confirmed the potential advantages to promoting sustainable healthy diets in China. These findings provide valuable insights for food policymakers seeking to stimulate a shift in dietary consumption towards sustainable healthy patterns and also contribute to the emerging research on consumer behaviour regarding sustainable healthy diets.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

XC: Conceptualization, Investigation, Supervision, Visualization, Writing – original draft, Writing – review & editing. XJ: Data curation, Investigation, Methodology, Software, Writing – original draft. LW: Funding acquisition, Project administration, Supervision, Validation, Writing – review & editing.

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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.

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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.2023.1269242/full#supplementary-material

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Perceived determinants of food purchasing behavior applicable for behavioral change toward sustainable consumption

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The paper deals with consumer behavior in the context of sustainable development of society. A questionnaire survey of 732 respondents was used to understand the determinants of food purchasing behavior toward sustainable consumption. The paper identifies the factors that the consumer determines in food purchasing as critical in terms of sustainable consumption and requiring behavioral change toward sustainability in terms of healthy lifestyle, reduction of food wastage, and conscious consumption. Respondents commented on 22 factors and the quantification of their impact on food waste and expressed the strength of opinion on sustainability issues. To evaluate the collected data, PCA factor analysis was used, which defines the importance of each factor by identifying artificial hypothetical variables, which are "Sustainability" and targeted education as appropriate tools for it, "Food usability," which is a recommendation to producers by food quality, offering new types of food with longer shelf life, as well as "Pricing," "Quality" and "Convenience." The authors also sought to understand what measures they take in relation to waste and how they behave toward sustainable consumption and environmental protection. They created 14 content questions on this topic and by using factor analysis, 3 hypothetical variables were created, namely "Sustainable behavior" which expresses a healthy lifestyle, "Thoughtful purchase" which expresses a relationship with environmental protection before purchasing and "Zero waste" which means that the household tries to make additional use of food. Thus, it seeks a use for the food it cannot consume at a given time and creates a supply for other consumers. This behavior is a good prerequisite for achieving a change in consumption behavior. The influence of selected sociodemographic indicators on the frequency of wastage was also investigated using the χ-squared test. The influence of generation and number of children in the household on the frequency of wastage was demonstrated. The results of the analyses on the importance of individual factors and consumer behavior, especially of the young generation, argue for education on sustainable consumption.

KEYWORDS

sustainable consumption, food waste, consumer behavior change, frequency of food waste, households food waste

Introduction

In addition to the scientific debate, sustainable consumption became a political debate in 1992 at the Earth Summit in Rio de Janeiro. In the decade that followed, several institutional programs were launched focusing primarily on sustainable production but also sustainable consumption. Sustainable consumption means consuming differently, consuming responsibly, or consuming less. The concept of sustainable consumption was defined in 1994 at the Oslo meeting and includes the essentials, i.e., that *"sustainable consumption is mainly related to meeting needs, improving quality of life, increasing the use of renewable energy sources and minimizing waste and emissions"* (Šajn, 2020). Purvis et al. (2019, p. 684) define sustainable consumption as *"the needs of the present without compromising the ability of future generations to meet their own needs."* The UN has already identified sustainable consumption as one of its pillars and primary goals for achieving environmental sustainability in 2010 (Marrakech Process Secretariat: UNDESA and UNEP, 2010; Yadav and Pathak, 2016). While government interventions or policy proclamations contained in countries' strategic goals have implications for sustainability (the so-called top-down approach), a bottom-up approach is also needed to achieve the desired SDGs (sustainable development goals), i.e., that individuals in different roles and with different capabilities are largely responsible for behaviors that affect their current and future well-being and that of future generations (Moschis et al., 2020).

Food production and consumption is one of the biggest sustainability issues, both in production and consumption and is associated with various environmental impacts (Tobler et al., 2011; Berčík and Gálová, 2013). Country strategies need to take into account not only projected changes in people's diets (eating habits, food waste) but also the entire value chain of food production and consumption options, including food waste. Stakeholder institutions, including education, have a key role to play in changing consumption behavior in favor of healthy eating behavior and healthy lifestyles, especially in stimulating and supporting the proposed changes. Although market demand has a strong influence on the structure and quality of supply, i.e., on food producers, measures outside the agricultural sector are also key for a successful transition to sustainable food production, which is precisely sustainable consumption and education (Morais et al., 2021; Veselá et al., 2023). The key is then to identify the determinants (determinants) through which we can influence consumers so that education for sustainable consumption has the greatest impact. These determinant variables are not well described in the current literature and thus represent a research gap.

Food producers and retailers in the context of sustainable food consumption, therefore, expect the following from the research: to identify the factors that are consumer-determined as critical for sustainable consumption and requiring a change toward sustainable behavior in terms of healthy lifestyles, reducing food waste and conscious consumption, etc. This identification of factors, together with the understanding of consumer behavior in the food market, including the effectiveness of measures to reduce food waste, is what the authors seek to do in the present paper.

Purvis et al. (2019) define three key dimensions of sustainability: environmental sustainability (planet), economic sustainability (profit), and social sustainability (people). These dimensions are interdependent and interact with each other. From an environmental perspective, according to Southerton et al. (2004), sustainable consumption means using goods and services that meet basic needs and deliver a better quality of life, while minimizing the use of natural resources, toxic materials, and life-cycle emissions of waste and pollutants, with the goal of not compromising the needs of future generations. In economic terms, according to Reisch and Thøgersen (2015), this means that the economy must move away from producing too many unsustainable consumer products and toward producing more sustainable products, services, and infrastructure. The responsible behavior of individual consumers is crucial for sustainable development (Lubowiecki-Vikuk et al., 2021).

Francis and Sarangi (2022) state that sustainable consumption is based on a decision-making process that takes into account the social responsibility of the consumer, which is particularly evident in the younger generation, in addition to individual needs and wants (Su et al., 2019; First Insight and The Baker Retailing Center, 2021; Kiliç et al., 2021; Orea-Giner and Fusté-Forné, 2023). Different studies conclude different determinants of sustainable consumption. Shen et al. (2022), who compared models of the theory of planned behavior using a meta-analytic structural equation modeling approach, concluded that individual consumer attitude has the strongest influence on sustainable food consumption intention, followed by subjective norms and perceived behavioral control.

When we think about sustainability in the context of food consumption, we can look at it from both a supply and a demand perspective. That is, both the sustainability of production and the quantity consumed (Hoogland et al., 2005). The main approach to sustainable consumption is to shape the demand for food (Moschis et al., 2020). Demand for food and non-food agricultural products is increasing as the global population grows. The United Nations median estimate (The United Nations, 2017) is that there will be 9.73 billion people on planet Earth in 2050. Yue et al. (2020) highlight the challenges of not only ensuring food production in quantity for a growing population but at the same time how reconciling sustainable production and sustainable consumption.

The concept of sustainable consumption in the context of food purchasing has gained considerable attention in recent years (Su et al., 2019; Holotová et al., 2021; Liu et al., 2021; Shen et al., 2022). From the consumer side, it is about sustainable product choice and furthermore sustainable dietary patterns (e.g., the amount consumed and the composition of the diet). According to Liu et al. (2021), the trend is to be concerned with the origin of food and the nutritional aspects of food. Reynolds et al. (2019) discuss the issue of food waste, which has become a topic of international concern, with the goal of halving global food waste at the retail and consumer level by 2030. According to Morávková et al. (2022) and Kubíčková et al. (2021) findings, households are the main producers of food waste. According to their findings, it follows that households waste more in urban developments than in rural areas. The cause of wastage can be food spoilage caused by buying large quantities of food (Kubíčková et al., 2021; Morávková et al., 2022). Wastage and its structure are more related to household consumption patterns (Parfitt et al., 2010). It is in households that wastage can be reduced by a number of external measures such as pack size, buying large quantities of food, buying randomly instead of planned, poor storage, monitoring expiry dates and others (Flanagan and Priyadarshini, 2021; Jungowska et al., 2021). From the above, it is appropriate to examine the factors that influence households in food waste.

Hazuchová et al. (2020) show the importance of the approach to the issue of waste by the individual, or how the issue of waste is perceived by the individual. This knowledge can be used to target appropriate tools to achieve a change in attitudes toward waste and consequently reduced food waste. However, there is no review that addresses the effectiveness of interventions aimed at preventing food waste at the consumption stages. Nevertheless, it is possible to find authors who address this very issue (Kubíčková et al., 2021; Morávková et al., 2022). This important gap, if filled, could help those trying to reduce food waste. Which measures to reduce food waste are effective and efficient is a key issue. There is a range of possible strategies for each area of the food chain, with examples including improved communication on forecasting between retailers and agricultural producers, public information campaigns, skills programs in the home or workplace, and changes in the way food is packaged and sold. Within each of these strategies, there are a number of decisions that need to be made by policymakers and practitioners that can influence the effectiveness of interventions in preventing food waste (Reynolds et al., 2019).

Verain et al. (2015) note that it is important to focus on both the level of sustainable food consumption and the quality of behavior in relation to food waste. Aschemann-Witzel et al. (2019) outline six necessary transformations to which sensory science can contribute. These are (1) promoting a dietary shift toward more sustainable foods and diets, (2) increasing food diversity, (3) reducing food waste, (4) enhancing food system circularity, (5) increasing and prioritizing food-related well-being, and (6) coping with the impacts of climate change. [(1) promotion of a dietary shift toward more sustainable foods and diets, (2) increase of food diversity, (3) food waste reduction, (4) enhancement of the circularity of the food system, (5) heightening and prioritizing food-related well-being, and (6) coping with the effects of climate change]. The popularity of adopting food from organic farming can be improved by raising the profile of these products (Aschemann-Witzel et al., 2019). Yadav and Pathak (2016) highlight the high prices and unavailability of organically grown products as major barriers for consumers to purchase organic food.

Everyday consumption practices are still largely driven by convenience, habit, personal health concerns, hedonism, and individual responses to social and institutional norms, and most importantly, are likely to be resistant to change. Puntiroli et al. (2022) agree with the temporal consistency of sustainable consumer behavior, but address the question of whether current sustainable consumer behavior will be achieved in the future or possibly encourage other types of sustainable behavior. In addition, the last decade has seen the emergence of the ethical consumer, who perceives a more direct link between what they consume and the social problem itself. This kind of consumerism primarily involves environmental issues but is also extending to animal welfare, human rights, and working conditions in the third world. In general, the ethical consumer feels a responsibility toward society and expresses these feelings through their purchasing behavior. Yet price, quality, convenience, and brand recognition are still the most important decision criteria, while ethical factors are only effectively taken into account by a minority of consumers. A recent study by Shen et al. (2022) on purchase intentions for sustainable food also showed that psychosocial variables such as attitudes, beliefs, and subjective norms, more than demographic data, independently predict purchase intention for sustainable products.

In particular, practitioners expect consumer behavior researchers to identify the factors that influence consumer behavior and to be able to predict changes in consumer behavior in advance (Shen et al., 2022). There are different approaches to identifying and classifying factors, and these approaches have undergone major changes in their identification methods over time. According to Hawkins et al. (2003), external and internal factors influence consumer behavior. They consider external factors to be those created by the social environment (culture, values, demographics, social status, reference groups, family, and household) and marketing tools. Internal factors (learning, memory, motives, personality, and emotions) are inherent in the consumer as an individual and influence the perception of a product or service. In the context of these findings, it is useful to further explore the influence of sociodemographic characteristics on food waste. For example, the influence of generation could have an impact. According to Damico et al. (2023), Generation Z shows a high interest in the sustainability of the planet and is most aware of the benefits that sustainability brings. For them, improving knowledge can play a key role in shaping their consumption behavior. But knowledge can also play a key role in the supply side of the market, which influences consumers through marketing tools.

In the opinion of the authors of the paper and in the context of the review of the cited authors, much attention has been paid in recent years to food products from different perspectives. As an example, TPB constructs have been pronounced to explain consumers' intention and purchase behavior toward organic food (Qi and Ploeger, 2019; Aungatichart et al., 2020). At the same time, there are studies where subjective norms had the weakest or no influence on intention and purchase behavior (Rong-Da Liang, 2014; Dorce et al., 2021). Therefore, further research is needed to investigate not only the external factors influencing consumer behavior but also whether and to what extent subjective norms influence consumer buying behavior for different food products. The individual's behavior in fulfilling the intention of sustainable consumption and education toward this behavior, and especially the effectiveness of different intervention modes, are a research gap that needs to be filled.

The authors are guided by the results of the survey to identify the factors that are determined by the consumer as decisive in terms of sustainable consumption and requiring a change toward sustainable behavior in terms of healthy lifestyle, reduction of wasted food and conscious consumption, etc. This identification of factors, together with the understanding of consumer behavior in the food market, including the effectiveness of measures to reduce food waste, is what the authors seek to do in the present paper. In realizing the influence of the individual and his/her perception of sustainable consumption, the influence of socioeconomic indicators should also be observed. It is proposed to test the hypotheses about the congruence or difference of the effect of these indicators on food purchase or waste. The expected results may be useful for food producers and sellers, as well as for institutions and households responsible for educating individuals toward sustainable consumption.

Materials and methods

A questionnaire survey (quota sampling, data collection: February–April 2023, Czech Republic) is used to analyze consumer behavior on food waste in the context of sustainable consumption. The

questionnaire is created in Google Forms and distributed electronically. A total of 732 responses are collected. In the distribution of the questionnaire, care is taken to maintain the representativeness of the core sample primarily in the following characteristics: gender, generation, education, and degree of urbanization, with a 90% reliability. The representativeness is verified according to data from the Czech Statistical Office (CZSO). The characteristics of the research sample can be seen in Table 1 (n = absolute frequency, p = relative frequency).

To characterize age groups, the research sample is divided by generation (Pew Research Center, 2019). Boomers I (birth year 1946–1954, or 68–76 years old); Boomers II (birth year 1955–1964, or 58–67 years old); Generation X (birth year 1965–1980, or 42–57 years old); Millennials (birth year 1981–1996, or 26–41 years old); and Generation Z (birth year 1997–2012, or 10–25 years old). Education is divided into three categories – primary, secondary, and university. To determine the degree of urbanization (village or town), a threshold of 5,000 inhabitants is set.

The questions in the questionnaire are divided into several parts. In the first part, there are questions about waste in the household, such as: how much food surplus is used in your household, how often is food thrown away in your household? Which food is most often thrown away in your household? Respondents are given a choice from a list of food items that are based on previous research (Macková et al., 2019; Hazuchová et al., 2022). Respondents are also asked about the way in which they purchase food. The different variations of the *"food shopping patterns"* are: (1) Major food purchases once a week or even at longer intervals, with the possibility of supplementing emergency purchases, (2) Major purchases several times a week, without supplementing purchases, (3) Absence of a dominant shopping pattern, (4) I buy food frequently, as needed, but do not stockpile, (5) Food is bought every day. Furthermore, question about the institutions that should be responsible for disseminating information about food waste and questions about the perceived importance of factors in the context of sustainable food consumption and environmental protection, both about the causes of waste and about measures to reduce waste. Respondents comment on a total of 22 factors related to causes of waste and 14 factors related to measures to reduce waste. The strength of their influence is assessed using a 10-point scale, (10 – high influence, 1 – almost no influence). 22 factors related to causes of waste are: *Impulse purchase, Unplanned shopping, Low prices, A purchase influenced by a promotion, No cooking ideas, Too big packaging, Lack of cooking skills, Low quality products, Too much food bought, Unsuitable storage conditions, Too large portions of food, Preparing too much food, Trad. or eco. breeding/cultivation, Type of packaging (recyclable), Regional origin and its support, Degree of processing, Food spoilage, Expires the expiration date, Discount, Price, Taste, Quality*. 14 factors related to measures to reduce waste are: *Buying seasonal products, Buying local products, Limiting meat consumption, Restriction of IPF consumption, I make a list before shopping, I check the expiry date and choose the longest ones, I use the products to prepare other meals, Packaging waste sorting, Reducing food waste, I freeze the food and eat later, I prepare preserves (pasteurization), I feed the animals, I share the excess food with others, I try to buy less*.

The next section asks questions about food prices and waste, and whether the price of food affects the amount of waste. In addition, respondents rate on a 5-point scale the extent to which the extent of food waste is affected before and after food price increases in times of high inflation. The last part of the questionnaire is devoted to identification questions such as age, gender, education, municipality, etc.

TABLE 1 Characteristics of the research sample.

Categories		Questionnaire		CZSO
		n	*p* [%]	*p* [%]
Gender	Female	431	58.88	49.29
	Male	301	41.12	50.7
Generation	Generation Z	224	30.60	15.78
	Millennials	174	23.77	20.71
	Generation X	238	32.51	24.15
	Boomers II	41	5.60	11.95
	Boomers I	76	10.38	10.26
Education	Primary	29	3.96	12.5
	Secondary	465	63.52	63.5
	Higher	238	32.51	17.6
Degree of urbanization	City/town	439	59.97	59.88
	Village	293	40.03	40.12
Number of children	0	477	65.16	
	1	156	21.31	
	2	68	9.29	
	3 and more	31	4.23	

Source: own.

To achieve the formulated research objectives and based on the current knowledge, we formulate the following assumptions:

> *Assumption 1*: There is a relationship between the change in food prices and the extent of its wastage.
>
> *Assumption 2*: There is a relationship between sociodemographic characteristics and the frequency of wastage.
>
> *Assumption 3*: There is a relationship between the way households purchase food and the frequency of wastage.

A paired t-test is used to assess the effect of price changes (before and after price increases) of food on the extent of wastage. A χ-squared test is used to assess the effect of socio-demographic characteristics (generation, education, number of children in the household, size of the municipality) on the incidence of wastage. The χ-squared test is also used to assess the effect of purchasing mode on the frequency of wastage.

Questions on the perceived importance of factors in the context of sustainable food consumption and environmental protection, both on the causes of waste and on measures to reduce waste, are developed and evaluated using exploratory factor analysis. This allows the reduction of a large number of factors to a smaller number of artificially created hypothetical variables (components, determinants) that determine consumer behavior. The application of factor analysis allows us to understand which factors are related and fit together. To achieve a specific interpretation, the new hypothetical is named. The calculation began by determining the factor loadings based on the eigenvalue of the principal components analysis (PCA). The components that have an eigenvalue >1 are selected. These components are then referred to as the determinant.

The second stage is the rotation of the factors by the Varimax method, and thus the transformation into interpreted factors. Finally, the factor loadings are calculated (Finch, 2019). The appropriateness of using factor analysis is assessed based on KMO and Bartlett's test of sphericity. The factor loading threshold determining whether a factor contributes significantly to the relevant component (determinant) is 0.6. All statistical evaluation of the data is performed using IBM SPSS Statistic 29.0.0 software (Watkins, 2021; Hague and Harrison, 2022).

Results

A questionnaire survey conducted on 732 respondents in the Czech Republic on the issue of sustainable food consumption and its perception in Czech households showed that most respondents are aware of the importance of food wastage and also waste sorting in relation to the concepts of sustainable consumption. These two factors are perceived by households as crucial factors that can contribute to environmental protection. The desire not to waste is evident from the fact that only 20% of households admit to discarding surplus food, 15% say they do not have surplus food, about 15% give surplus food to the needy, and about 50% of households use it to prepare other meals. The most commonly wasted foods are vegetables, fruit, bakery products, and ready meals. Figure 1 shows that the highest percentage of respondents (47.4%) indicated that they discard bakery products most often, followed by 43.17% of respondents who indicated that they discard ready meals most often. For vegetables and fruits, the reasons for wastage are short shelf life, while for ready meals the reasons for wastage vary (inappropriate quality and taste, large portions). The structure of wasted food helps in selecting appropriate measures to reduce waste.

The price of food can affect the amount of food wasted. When asked to what extent the amount of food waste in the household depends on the price of food products, more than 95% of the respondents answered that price does not influence waste. But when asked again whether price increases (in times of high inflation and increased food prices) have affected food waste, a different result was reached. Based on our *Assumption 1*, we formulated a hypothesis about the relationship between the price change before and after the food price increase and the amount of food waste, which we then tested using a paired *t*-test.

> *H0: Change in food prices (before and after inflation) does not depend on the extent of food waste.*

The calculated value of the paired *t*-test criterion $t = -10.536$, $p < 0.001$ tells that the change in food prices had a highly significant effect on the frequency of food wastage, in the negative direction.

Respondents also answered their perception of environmental protection in relation to consumer behavior in the context of the currently intensively communicated issue of sustainable consumption. The majority of respondents expressed the view that households can do the most good for the environment by reducing food waste and regularly sorting waste. Waste sorting is perceived by respondents as the most important factor in protecting the environment, and therefore a question is posed to producers and distributors about the need to implement measures that will lead to a reduction in the volume of material used (functionality, packaging design). This is followed by the need to reduce the volume of wasted food, and they also believe that buying seasonal and local products and reducing the consumption of industrially processed food also contribute to environmental protection.

Another assumption was that sociodemographic characteristics may influence the frequency of wastage. As the survey showed, consumer food purchasing behavior is influenced by sociodemographic characteristics that link each individual's motivation to buy with their perceived values. It is the perceived value that largely determines the direction of consumer

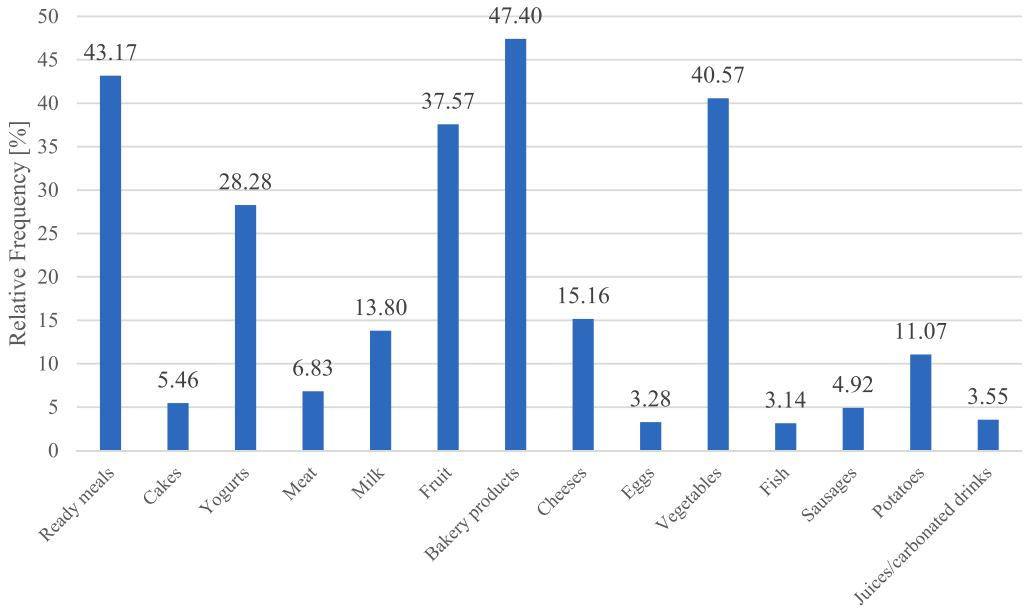

FIGURE 1
Foods that are the most often wasted by households. Source: own processing.

behavior, whether they want to satisfy their consumption first and foremost, or whether they prioritize and are aware of what they have caused by their consumption. What are the values in satisfying a need, whether a healthy lifestyle, a healthy diet, a healthy environment, and its sustainability. From our *Assumption 2*, we formulated four hypotheses regarding sociodemographic groups, which we then tested.

> *H0: Generation membership does not depend on the frequency of food waste.*
>
> *H0: The number of children in the household has no effect on the frequency of food waste.*
>
> *H0: Educational attainment has no effect on the frequency of food waste.*
>
> *H0: Size of place of residence has no effect on the frequency of food waste.*

These hypotheses were tested by the χ-squared test. The calculated values of the χ-squared test to test the hypotheses expressed about sociodemographic characteristics are shown in Table 2.

The results of the tests to test the null hypotheses showed that generation membership has a demonstrable effect on wastage, as does the number of children in the household. In contrast, there was no effect of education or size of residence on the frequency of wastage. On the basis of our next/last *Assumption 3*, we formulated a hypothesis about the relationship between the frequency of wastage and the "mode of shopping," which was also tested with a χ-squared test.

TABLE 2 Results of tested sociodemographic characteristics by Chi-square tests.

Characteristics	Pearson χ^2	Value of p
Generation	43.283	< 0.001
Number of children	37.585	< 0.001
Education	9.719	0.151
Degree of urbanization	1.398	0.845

Source: own processing.

> *H0: The mode of food shopping has no effect on the frequency of food wastage.*

The Pearson χ-squared = 50.654; $p < 0.001$ means that food shopping methods significantly influence the frequency of food wastage. The forms of grocery shopping undertaken are major grocery shopping once a week or even at a longer interval, with the possibility of supplementing emergency purchases (48.9% of respondents); major grocery shopping several times a week, without supplementing purchases (13.2% of respondents); no dominant mode of shopping (15.8% of respondents); grocery shopping frequently, as needed, but not stocking up (18.1%); and grocery shopping every day (3.9% of respondents). These food shopping patterns show that effective measures to reduce food waste can be identified in all shopping patterns, but by different measures, different for each shopping pattern. This means that it is the mode of purchase that strongly influences attitudes toward waste. These food purchasing patterns show that effective measures to reduce food wastage can be identified in all purchasing patterns but in different forms of intervention.

The issue of food waste in society is of course linked to the need to achieve a reduction in overall food consumption, especially from a global perspective. The different types of interventions to reduce food waste appear to be not very effective according to the respondents. Respondents have a strong opinion on the responsibility of education for conscious consumption and dissemination of information that will lead to a reduction of food waste. The importance respondents attach to each institution is shown in Figure 2.

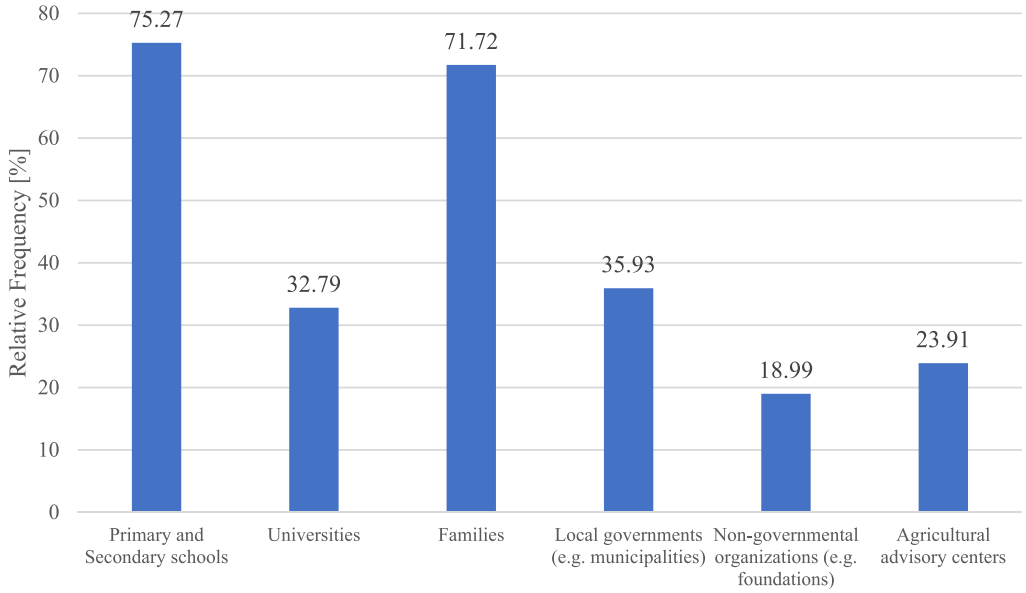

FIGURE 2
Respondents' opinion on the responsibility of institutions. Source: own processing.

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According to respondents, primary and secondary schools and parents are clearly given the main responsibility. Among other institutions, universities, local governments, agricultural and extension centers, and other NGOs (non-governmental organizations) can provide some influence and success in education, according to respondents.

The aim of the present paper and the main focus of the investigation was to gain a deeper understanding of the factors that have some influence on food wastage. Respondents commented on a total of 22 factors and rated their strength of influence using a 10-point scale. These are factors that influence food purchasing and subsequently food waste. An example is expected quality, which did not meet the customer's expectations, similar to taste. The degree and method of food processing, especially industrial processing, also have an impact on waste and can cause waste. Regional origin – its promotion, possibly organic cultivation (farming) – also appears to be important for waste, but in a positive way. Classical factors such as price, discount, and type of packaging are decisive for the purchase of food, as well as the type of purchase (planned/impulsive). On the other hand, after the purchase, factors such as perishable food, expiration date, too much food bought, too large portions of food at home for the purpose, unsuitable storage conditions, lack of cooking skills, lack of effort to process the remaining food, e.g., freezing, canning, sharing with the needy, etc. are decisive for wastage. Factor analysis was used to determine how these factors are perceived in relation to food waste and which of them has the greatest influence on food waste (Tables 3,4). The prerequisites for the appropriateness of using factor analysis were met with a KMO value of 0.892 (i.e., greater than 0.8) and Bartlett's Chi-squared test of 7924.45; $p < 0.001$. Table 3, which contains the cumulative percentage of variability from the descending order of the factors, tells us that most of the variability (64.56%) is explained by the newly created 5 hypothetical variables. Table 3 shows that the factors are newly explained by the 5 newly created components (*"Convenience," "Sustainability," "Food usability," "Pricing,"* and *"Quality"*) which contain a cumulative percentage of variability of 64.56%. These components are constructed based on Eigenvalue >1 and are in bold.

In Table 4, individual factors are in bold that contribute significantly to the formation of the respective component (factor loadings greater than 0.6). The determinant factor loadings gave rise to the following hypothetical variables that are named in columns in Table 4: *"Convenience"* (of shopping), *"Sustainability," "Food usability," "Pricing,"* and *"Quality."* The *Convenience* determinant is the only one of the five determinants that contain both factors influencing purchase and factors influencing post-purchase behavior. All of these factors are manifestations of

TABLE 3 Components of the causes of waste.

	Initial eigenvalues			Rotation sums of squared loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Convenience = 1	**7.184**	**32.656**	**32.656**	**6.586**	**29.934**	**29.934**
Sustainability = 2	**2.833**	**12.875**	**45.531**	**2.568**	**11.674**	**41.608**
Food usability = 3	**1.774**	**8.066**	**53.597**	**1.843**	**8.375**	**49.984**
Pricing = 4	**1.388**	**6.309**	**59.906**	**1.623**	**7.378**	**57.362**
Quality = 5	**1.024**	**4.656**	**64.562**	**1.584**	**7.200**	**64.562**
6	0.901	4.097	68.659			
7	0.757	3.441	72.100			
8	0.684	3.110	75.210			
9	0.630	2.866	78.076			
10	0.612	2.783	80.859			
11	0.555	2.523	83.382			
12	0.457	2.078	85.461			
13	0.440	2.001	87.462			
14	0.424	1.926	89.388			
15	0.391	1.777	91.165			
16	0.380	1.726	92.891			
17	0.324	1.471	94.362			
18	0.307	1.397	95.759			
19	0.277	1.259	97.018			
20	0.266	1.210	98.228			
21	0.236	1.072	99.300			
22	0.154	0.700	100.000			

Total Variance Explained (Extraction Method: PCA). Source: SPSS.

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TABLE 4 Rotated component matrix (Extraction method: PCA; Rotation method: Varimax with Kaiser normalization; rotation converged in 6 iterations).

	Hypothetical variables (determinants)				
	1	2	3	4	5
	Convenience	Sustainability	Food usability	Pricing	Quality
Impulse purchase	**0.832**	−0.015	0.171	−0.013	0.052
Unplanned shopping	**0.821**	−0.008	0.174	−0.016	0.054
Low prices	**0.811**	−0.039	0.115	0.145	0.057
A purchase influenced by a promotion	**0.797**	−0.038	0.085	0.116	0.016
No cooking ideas	**0.782**	0.144	0.065	−0.036	−0.191
Too big packaging	**0.771**	0.030	0.184	−0.002	0.020
Lack of cooking skills	**0.747**	0.164	0.049	−0.035	−0.251
Low quality products	**0.673**	0.157	−0.072	0.005	0.002
Too much food bought	**0.670**	−0.062	0.397	−0.109	0.193
Unsuitable storage conditions	**0.650**	0.140	0.056	0.062	−0.208
Too large portions of food	**0.612**	−0.068	0.425	−0.098	0.202
Preparing too much food	0.535	−0.093	0.486	−0.076	0.249
Trad. or eco. Breeding/cultivation	0.047	**0.837**	0.015	−0.003	0.090
Type of packaging (recyclable)	−0.010	**0.771**	0.135	0.136	−0.125
Regional origin and its support	0.088	**0.762**	−0.098	−0.123	0.199
Degree of processing	0.160	0.558	−0.026	−0.015	0.358
Food spoilage	0.074	0.000	**0.792**	0.153	−0.054
Expires the expiration date	0.320	0.119	**0.685**	−0.023	0.024
Discount	0.131	0.009	0.083	**0.862**	−0.008
Price	−0.061	−0.007	−0.006	**0.845**	0.197
Taste	−0.071	0.146	0.027	0.196	**0.808**
Quality	−0.087	0.482	0.080	0.021	**0.636**

Source: SPSS, own processing.

mindless, haphazard, and convenient purchasing without a settled view of the preferences of any of the factors. It also contains the greatest number of factors. Factors such as emotional buying, promotions such as discounts, and big packaging where the result is an unconsidered purchase are related to the form of buying. After the purchase, there is a large amount of prepared food that is not consumed, improper storage conditions, and food spoilage. The determinant of *Sustainability* is made up of factors related to environmental protection, sustainable production, sustainable consumption, healthy lifestyles, healthy diets, or organic crop or livestock farming. The determinant of *Food usability* is determined by the condition of the food, and its edibility after purchase. The determinant of *Pricing* is determined by factors relating to price, discount, and financial advantage and are decisive for the customer. For the determinant *Quality* the taste and quality of the product is decisive, and the price is suppressed. From the factor loadings achieved, it can be deduced that groups of consumers focused on quality and taste, consumers focused on price, consumers aware of their responsibility for the environment and for sustainability, and then a large group of consumers buying food impulsively, without any opinion, have been created. This large group of shoppers represents the potential for behavioral change.

It was also the authors' intention to try to find out how resourceful households are and what measures they take in relation to waste and how they behave toward sustainable consumption and environmental protection. 14 content questions developed on this topic with the respondents' opinions were evaluated using the factor analysis method. The assumptions of using factor analysis are met (KMO 0.759, Bartlett's Chi-square test 1706.17; $p < 0.001$), with only a cumulative expression of explained variability of 45% (Table 5). Table 5 shows that the factors are newly explained by the three newly created components (*"Sustainable behavior," "Thoughtful purchase," "Zero waste"*), which contain a cumulative percentage of variability of 45.74%. These components are constructed based on Eigenvalue >1 and are in bold.

These 14 factors (a list of which is included in Table 6) created 3 hypothetical variables, namely *"Sustainable behavior," "Thoughtful purchase," "Zero waste." Factors that significantly contribute to the formation of the component are marked in bold (factor loadings greater than 0.6). Sustainable behavior* means a purchase that by its nature expresses a healthy lifestyle, and *Thoughtful purchase* expresses a relationship with environmental protection before purchase. *Zero waste* means that the household makes an effort to reuse food. Thus, it seeks a use for the food it cannot consume at a given time and creates a supply for other consumers.

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TABLE 5 Components of factors of measure to reduce waste.

Component	Initial eigenvalues			Rotation sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Sustainable behavior = 1	**3.087**	**22.051**	**22.051**	**2.300**	**16.428**	**16.428**
Thoughtful purchase = 2	**2.048**	**14.628**	**36.679**	**2.118**	**15.131**	**31.559**
Zero waste = 3	**1.269**	**9.062**	**45.741**	**1.985**	**14.182**	**45.741**
4	0.962	6.874	52.615			
5	0.939	6.710	59.325			
6	0.834	5.957	65.282			
7	0.761	5.437	70.719			
8	0.727	5.195	75.914			
9	0.719	5.133	81.048			
10	0.622	4.446	85.494			
11	0.581	4.149	89.642			
12	0.553	3.953	93.595			
13	0.505	3.609	97.204			
14	0.392	2.796	100.000			

Total Variance Explained. Extraction Method: PCA. Source: SPSS.

TABLE 6 Rotated component matrix (Extraction method: PCA; Rotation method: Varimax with Kaiser normalization; Rotation converged in 6 iterations).

	Hypothetical variables (determinants)		
	1 Sustainable behavior	2 Thoughtful purchase	3 Zero waste
Buying seasonal products	**0.785**	0.058	0.031
Buying local products	**0.774**	0.033	0.079
Limiting meat consumption	**0.610**	−0.123	0.101
Restriction of IPF consumption	0.576	0.278	−0.017
I make a list before shopping	0.046	**0.641**	0.196
I check the expiry date and choose the longest ones	−0.070	**0.602**	0.082
I use the products to prepare other meals	0.076	0.575	0.320
Packaging waste sorting	0.387	0.532	−0.195
Reducing food waste	0.428	0.523	−0.133
I freeze the food and eat later	−0.051	0.500	0.413
I prepare preserves (pasteurization)	−0.053	0.047	**0.741**
I feed the animals	−0.011	−0.046	**0.691**
I share the excess food with others	0.112	0.193	**0.600**
I try to buy less	0.130	0.264	0.455

IPF, industrially processed food.

Discussion

In order to achieve the objective of the paper, i.e., to identify the factors that influence consumers when buying food, a large-scale representative survey of 732 respondents was conducted. Respondents commented on a range of factors related to sustainable consumption, food purchasing patterns, food waste, and behavior in the context of environmental sustainability. As the survey showed, most respondents have narrowed down the issue of environmental sustainability to food waste and waste segregation. Similarly to Purvis et al. (2019), we verified that respondents' behavior in relation to environmental sustainability is also linked to economic and social sustainability, and subconsciously this may influence opinion.

The influence of external factors acting on consumers, which include demographic characteristics (Hawkins et al., 2003), was investigated by asking how these characteristics influence the

frequency of food waste. A significant influence was verified for two sociodemographic characteristics, namely between generations and also the number of children in the household. The generalization of these results suggests that younger generations have a positive attitude toward environmental sustainability issues, which is in line with Orea-Giner and Fusté-Forné (2023) and Liu et al. (2021). According to Damico et al. (2023), Generation Z shows a high level of interest in the sustainability of the planet and is most aware of the benefits that sustainability brings. A study by Shen et al. (2022) showed that psychosocial variables (such as attitudes, beliefs, and subjective norms) have more influence on consumers' food purchase intention than demographic data. Therefore, it would be appropriate to focus on this Generation Z and examine psychosocial factors more closely rather than sociodemographic factors. The results also showed that neither education nor the size of the place of residence has an impact on the frequency of wastage. The results also showed that neither education nor degree of urbanization has an effect on the frequency of wastage. This is in contrast to the finding of Kubíčková et al. (2021), where higher wastage was found to occur in urban developments.

Another highly conclusive externality is the influence of shopping mode (small purchases frequently to large purchases occasionally). The influence of shopping mode on the frequency of consumer wastage speaks to the possibility of educating for sustainability – just through changing shopping behavior. Here there is room for tailoring promotional activities, the form and content of communication to consumers according to the different ways of shopping (Su et al., 2019). Alternatively, there is scope for further research in the field of marketing communication.

The survey shows that the most wasted foods are bakery products, followed by fruit and vegetables. This is in line with research (Pires et al., 2021; Morávková et al., 2022). Greater wastage with ready meals is then in line with Kubíčková et al. (2021). Almost 50% of respondents (households) make larger food purchases with occasional emergency replenishment. This trend became apparent with the onset of the COVID-19 pandemic when households just started to focus on larger purchases (Morávková et al., 2022). The cause of wastage is then just food spoilage caused by buying large quantities of food (Pires et al., 2021; Morávková et al., 2022). According to Parfitt et al. (2010), the structure of waste is related to household consumption habits, and therefore marketing communication should also aim at changing habits.

Above all, manufacturers and retailers expect to identify the factors that influence consumer behavior and be able to anticipate changes in consumer behavior in advance. They can use factor analysis to identify the factors influencing wastage in developing their production or business strategies based on the findings on the importance of each factor and reduce them to 5 determinants influencing the magnitude of wastage, which are: *"Sustainability"* and targeted education with appropriate tools, *"Food usability"* which is a recommendation to producers by the quality of food, offering new types of food with longer shelf life, *"Pricing,"* because most customers, when choosing to satisfy their needs to eat, are consciously or unconsciously influenced by price and therefore the producer must take this fact into account. The exception is the group of consumers for whom the determinant *"Quality"* is, together with taste, the decisive factor. It remains to take into account the last determinant, which is the most important and most general in terms of its representation, called *"Convenience."* It groups together factors which, in their content, concern both the way of buying and the way of behaving toward food, especially food waste. By understanding this group of factors, their influence can be regulated in a controlled way, leading to less food wastage, food sufficiency in less developed countries, and, finally, the satisfaction of needs and a sustainable environment.

The results of the investigation suggest the importance of educating individuals to achieve less wasted food (Veselá et al., 2023). This is linked to the issue of global importance, which is food scarcity (The United Nations, 2017), and to the issue of a sustainable environment (Yue et al., 2020). However, the different ways of communicating and acting to reduce waste, as shown in the survey results, are not effective according to the respondents. In their opinion, the burden of education lies mainly on primary schools and parents. And here an opportunity opens up in the sense of the authors Hazuchová et al. (2020) and Morávková et al. (2022), according to which it is necessary to focus on the individual, his perception of the issue of waste and controlled action of appropriate tools to achieve a change in attitudes toward waste and subsequently achieve a reduced amount.

As the questionnaire survey always involved respondents' opinions, these may in some cases differ from reality, for example, about the frequency of wastage (van der Werf et al., 2020; Kubíčková et al., 2021). An example is the expression of the influence of price on wastage. 95% of respondents stated that food price does not influence wastage. When asked differently whether food price increases during inflation affect the frequency of wastage, the respondents' answers showed that food price had a highly conclusive effect on the frequency of wastage. This finding was verified by paired *t*-test, including the negative direction of influence. Thus, the study suggests that food price increases have an impact on wastage, just as the COVID-19 pandemic did (Pires et al., 2021; Morávková et al., 2022).

Conclusion

The paper deals with consumer behavior in the context of sustainable development of society. The results of the survey are a generalization of the opinions of respondents in the Czech Republic. A very important finding is the fact that society and the individuals who make it up have insufficient knowledge of sustainable development and narrow the whole issue down to the areas of food waste and waste sorting. Sustainable development, characterized by improving the quality of life, reducing the negative impact on the environment, increasing the use of renewable energy sources, minimizing waste and emissions, and generally promoting a sustainable lifestyle, implies a change in consumption behavior toward sustainability. This awareness needs to be achieved in the majority of society through appropriate consumer interventions. An appropriate intervention is education and upbringing (Veselá et al., 2023). The survey also made it clear that the focus of education lies primarily with primary schools and parents. Demographic characteristics have been shown to have a clear generational influence on behavior change, including food waste. Further research should look at how to educate consumers appropriately, both in schools and in households. Therefore, it is necessary to target communication with appropriate tools to the younger generation. Generation Z shows a high level of interest in the sustainability of the planet and is most aware of the benefits of sustainability (Damico et al., 2023). Therefore, it would

be useful to focus on this generation and examine more closely psychosocial characteristics such as attitudes, beliefs, and subjective norms rather than sociodemographic characteristics. The factor analysis used to understand the effect of 22 factors revealed that the most influential factors on consumers and to be targeted are *"Quality"* of food, and *"Price,"* therefore affordable. Other determinants are *"Sustainability," "Food usability,"* and *"Convenience."* Awareness of this finding provides scope for producers to gradually change the structure of food in favor of affordable and sustainably grown and processed food. The authors also sought to understand the measures they take in relation to waste and their sustainable consumption and environmental protection. They created 14 content questions on this topic and by using factor analysis, 3 hypothetical variables were created, namely *"Sustainable behavior"* which expresses a healthy lifestyle, *"Thoughtful purchase"* which expresses a relationship with environmental protection before purchasing and *"Zero waste"* which means that the household tries to make additional use of food.

The limitations of the survey and the results expressed include 90% representativeness of the sample in the selected characteristics. The individual variables being worked with are the respondents' opinions and as such must be treated. Factor analysis to determine the determinants of the effect of the actions taken hypothetical variables leading to a reduction in wastage, only 45% of the explained variability was achieved.

From the results obtained from the factor analysis and in accordance with the authors cited, it is possible to recommend to producers and retailers, when developing strategies, to focus on (1) food quality and its sustainability, changing the structure of food due to the interest in healthy food and to follow a healthy lifestyle, while maintaining affordability; (2) respecting the size of households and thus the size of food packaging; (3) innovating ways and techniques of packaging products (avoiding large amounts of packaging waste, inappropriate materials, etc.); (4) avoiding the use of packaging materials, etc. (4) recommend to public administration and local authorities to communicate with the population about the need to change consumption behavior as a prerequisite for achieving sustainable living.

The authors see the need (as revealed by the results of the investigation so far) to continue research to contribute to the knowledge of how to change consumption behavior toward sustainable consumption. In particular, the identification of psychosocial variables (attitudes, beliefs, subjective norms) is crucial for changing consumption behavior (Shen et al., 2022). These psychosocial variables are based on the Theory of Planned Behavior (TPB) and which can be investigated through questionnaire surveys (Ajzen, 2006). To these psychosocial variables, other variables can be added depending on the specific consumption behavior problem under investigation. Furthermore, it is necessary to focus on the effectiveness of selected communication tools leading to sustainable consumption (education in schools, leisure activities, local governments, etc.). The effectiveness of selected communication channels could be investigated on Generation Z. This generation will soon start to start families and the real behavioral patterns they will start to pass on to their offspring need to be in line with the sustainability of the planet.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MP: Writing – original draft, Data curation, Formal analysis, Project administration, Funding acquisition. IB: Formal analysis, Methodology. JS: Writing – original draft, Supervision, Methodology, Conceptualization. AL: Writing – review & editing, Methodology.

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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.

Publisher's note

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Global economic crisis impact on organic food consumption in the Czech Republic

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Introduction: This study investigates the impact of the global economic crisis of 2008 on organic food consumption in the Czech Republic. The structure of this study includes general consumption attitudes and consumption of individual organic food items (organic milk). The goal of this study is to quantify the influence of selected income macroeconomic indicators on organic food consumption (in general and individually). This study is focused on analyzing how this impact changed after 2008 in both prospectives.

Methods: Methodologically, the error correction methodology (ECM) has been applied. However, it has been modified to incorporate breakpoint analysis to model the impact of the global economic crisis on organic food consumption. Thus, the total consumption of organic food and consumption of organic milk has been investigated.

Results: Econometric verification of the estimated model proved that there was a statistically significant positive dependence of both indicators of organic food consumption on all the investigated indicators of income before 2008. Nonetheless, it was also proved that this dependence disappeared after the global economic recession in 2008. This retrospective analysis provides a valuable view of the mechanisms of organic food consumption changes caused by economic crises.

Discussion: Prospective repetition of the research with the data from the current crisis could enrich the theory of organic food consumption. On the one hand, the results of hypotheses testing could be verified, and thus, the mechanisms of consumer reactions to the crisis could be identified, and the model of reaction to the next crisis cycle could be developed so as not to harm radically this sector. On the other hand, the results of hypothesis testing could be denied, and thus, the evolution in organic food perception and consumption could be stated. In this case, the need to revise the so-far formulated theoretical approaches would be proved.

KEYWORDS

organic food, organic food consumption, organic milk, organic milk consumption, consumption function, income, economic crisis, error correction model

1 Introduction

Organic farming and organic food production are becoming increasingly important in the Czech Republic. Consumer interest in organic food is deepening, and more farmers are beginning to specialize in organic food production (Rypakova et al., 2015). Between 2005 and 2008, the market for organic food in the Czech Republic grew significantly. The subsequent period, 2009–2010, showed stagnation due to the global economic crisis, but since 2011, a long-term upward trend has started again. Hlavackova and Svobodova (2020) report that since 2011, the organic food market has experienced an annual increase in the consumption of organic food for the 10th year. Between 2012 and 2013, consumption of organic food increased

by 9.5% year-on-year. In 2014, consumption grew by 3.9%, exceeding the CZK 2 billion. In 2015–2016, the organic food market grew at a rate of 11 and 14% year-on-year, and even at a rate of 30.5 and 33% in 2017–2018. In 2019, a 19% growth was recorded, and in 2020, marked by government measures to prevent the spread of COVID-19, organic food consumption grew by 14%. The importance of the organic food market is growing globally, and this growing trend is also observed in the scientific literature (Lazaroiu et al., 2019; Majerova et al., 2020; Sabau et al., 2023). The consumer demand for conventional and bio-milk in Sweden is investigated by Lindstorm (2022). The difference between consumer demand for conventional and bio-milk is analyzed in Ohio, United States, by Chang et al. (2011). They concluded that the sensitivity of demand for bio-milk to price changes depends on whether one is a suburban or inner-city resident. Maksan et al. (2022) analyzed the consumer demand for organic yogurt in Croatia, considering health concerns, nutritional value, and food safety as the main drivers of this demand. Thogersen (2010) addressed the issue of the long-term sustainability of organic food consumption and analyzed the reasons for differences between countries. His findings are in line with the expectation that the share of organic food consumption in total food consumption depends significantly on policy regulation (the legal definition of organic food standards), financial support to farmers, and a national organic food labeling system. He considers other important factors to be the land factor, an efficient distribution system, the price premium for organic food, food consumption habits in the country, and environmental care.

The regional approach to the issue, which is in contrast to the global character of this trend in consumption, is connected with the importance of national psychographic specifics of consumers (Chen et al., 2018). While on the one hand, internal motivation sources of the consumption are traditionally perceived as a reason for a regional approach, on the other hand, income is considered as a macro factor with an objective impact on the willingness to pay and its regional character is not taken into account (Garbarova et al., 2017; Gajanova et al., 2019, 2020). The importance of a regional approach in economy and management has already been verified by Nadanyiova (2014a,b). However, in light and shadow of the theory of mental accounting, created by R. Thaler, income should not be treated generally, and its psychographic character should be considered as significant. Thus, the national approach to the consumption of organic products and its research are also relevant when the income impact on consumption is analyzed. This fact has already been realized by Olivas et al. (2013), who provided research focused on the analysis of the relationship between income and consumption of organic food in specific conditions in Spain. They have found out that low-income consumers are more concerned about eating a healthy diet than those with higher incomes. Based on this finding, the original presumption that there is a positive correlation between income and attitudes toward organic consumption has been destabilized, and the space for fulfilling the scientific gap has been created. However, relevant, robust macroeconomic research on this phenomenon has not been realized until now. In light and shadow of above-mentioned, the research question can be formulated. The purpose of our research is to answer the question of whether there is an impact of macroeconomic indicators on organic food consumption in the Czech Republic. Thus, the research gap would be filled from a regional perspective, and the platform for further research in this area would be developed. The study is divided into several chapters, which are individually focused on (1) the current state of knowledge in the scope of organic food consumption; (2) the methodological background of own research; (3) the presentation of own results; and (4) the discussion of own results based on their constructive comparison with the current state of knowledge summarized in the first chapter of this study.

2 Literature review

In the Czech Republic, Zivelová and Jansky (2006) discuss the possibility of developing the organic food market. They see obstacles for further development both on the demand side (insufficient consumer awareness of the quality of organic food and their reluctance to pay a higher price for it) and on the supply side (insufficient processing capacity). The development of organic agriculture in the Czech Republic is significantly supported by government institutions. The Ministry of Agriculture of the Czech Republic (2021) issued the Action Plan of the Czech Republic for the Development of Organic Agriculture in 2021–2027, which aims to achieve a 4% share of organic food in the total consumption of food and beverages by 2027, compared to 1.52% in 2020.

The literature on organic food is dominated by studies on consumer behavior (Nadanyiova and Kramarova, 2013). Hansen et al. (2018) developed a psychological model of consumer behavior in the organic food sector based on consumers' values and motives. Thogersen and Olander (2006) describe the relationship between the attitudes and norms of consumers in Denmark and their consumer behavior in relation to the purchase of organic food. Oraman and Unakitan (2010) analyze the factors influencing the purchase of organic fruits and vegetables in Istanbul, Turkey, concluding that consumers' concern for their health and food safety is the main factor influencing consumer preference toward organic food.

The literature is very heterogeneous in the scope of the question of the income dependence of organic food consumption (Kicova and Nadanyiova, 2015; Krizanova et al., 2015; Jankalova and Vartiak, 2017). Chen et al. (2022) analyzed the demand for dairy organic food in the US in terms of socio-demographic factors. Among other things, they find that households substitute conventional milk for organic milk as their income increases. A similar conclusion regarding the income dependence of bio-milk consumption was reached by Xu et al. (2016), who discussed the issue of Chinese consumers' willingness to pay a higher price for bio-milk depending on age, gender, education, and income. One of their conclusions is that disposable income is an important factor influencing the willingness to pay a higher price. Consumer demand for organic food in China is analyzed by Yin et al. (2010). The main results of their investigation include that purchases of organic food are significantly influenced by income, trust in organic food, the degree of acceptance of its higher price, and consumers' concern for their health. Petljak et al. (2017) seek to identify the significant factors influencing the willingness of consumers in the Czech Republic and Croatia to pay a higher price for organic food. Among other things, they conclude that one of these important factors is household income. In contrast, Aschemann-Witzel and Zielke (2017), who examine the effect of income and the effect of price and its change on consumer demand for organic food, concluded that income plays only a negligible role compared to psychological factors.

The cited literature examining the relationship between organic food consumption and income has focused on microeconomic analysis

of individual households, usually based on data from questionnaire surveys. Macroeconomic analysis of the relationship between organic food consumption and income is virtually absent from the literature. A rare exception is the study by Liu et al. (2019), in which the authors analyze interest in organic food globally using data obtained from the Google search engine, and one of their conclusions is that organic food consumption is not correlated with GDP.

The above-stated is also visible in the scope of Figure 1. There is a graphical outcome of the VOSviewer analytical tool of the bibliometric analysis presented. The analysis has been provided on the Web of Science platform, where the criteria for including the analysis have been set based on the mutual appearance of selected keywords in this study. These words were "organic food" and "income". In all the archives of the database, 120 articles met these criteria. Thus, the basic dataset for further bibliometric research has been created. It has been found that there are four groups of interest of scientists when the relationship between organic food and income is analyzed in the scope of the following:

- demographic specifics in attitudes toward income spending in favor of organic food products (shown blue),
- organic food products value sources, which reflect the price and willingness to pay for them (shown green),
- national and market specifics in terms of product category and country (shown red),
- overall consumer preferences dedicated to prospective value sources of organic food products (shown yellow).

However, the macroeconomic aspect of this relationship is missing at all.

This study aims to fill the gap in the literature on the analysis of the income dependence of organic food consumption. To this end, this dependence will be examined at the macroeconomic level using a time series of aggregate indicators. Specifically, to describe the statistical dependence of the aggregate indicator of organic food consumption on aggregate income, the Error Correction Model (ECM) is applied, which allows the examination of both the long-run equilibrium relationship between organic food consumption and income and the short-run dynamics. The standard ECM model is furthermore modified in this study to include a breakpoint analysis with respect to the global economic crisis of 2008. In the context of the statistical breakpoint analysis, a second important objective of the study is to investigate how the dependence of organic food consumption on income changed after 2008 in the context of the aforementioned global economic recession. To analyze the robustness of the results obtained, this study analyzes both the total consumption of organic food and the consumption of dairy organic food. In addition, to ensure the robustness of the results obtained, both GDP and gross disposable income are used as income.

3 Research design and context

The aim of this study is to investigate the dependence of organic food consumption on income indicators using aggregate time series. Specifically, annual time series for the time period 1993–2022 are used, and an aggregate indicator of both total consumption of organic food and consumption of dairy organic food *per capita* is examined. For robustness testing, different indicators will be chosen as the income indicator in different regression equations. Specifically, a time

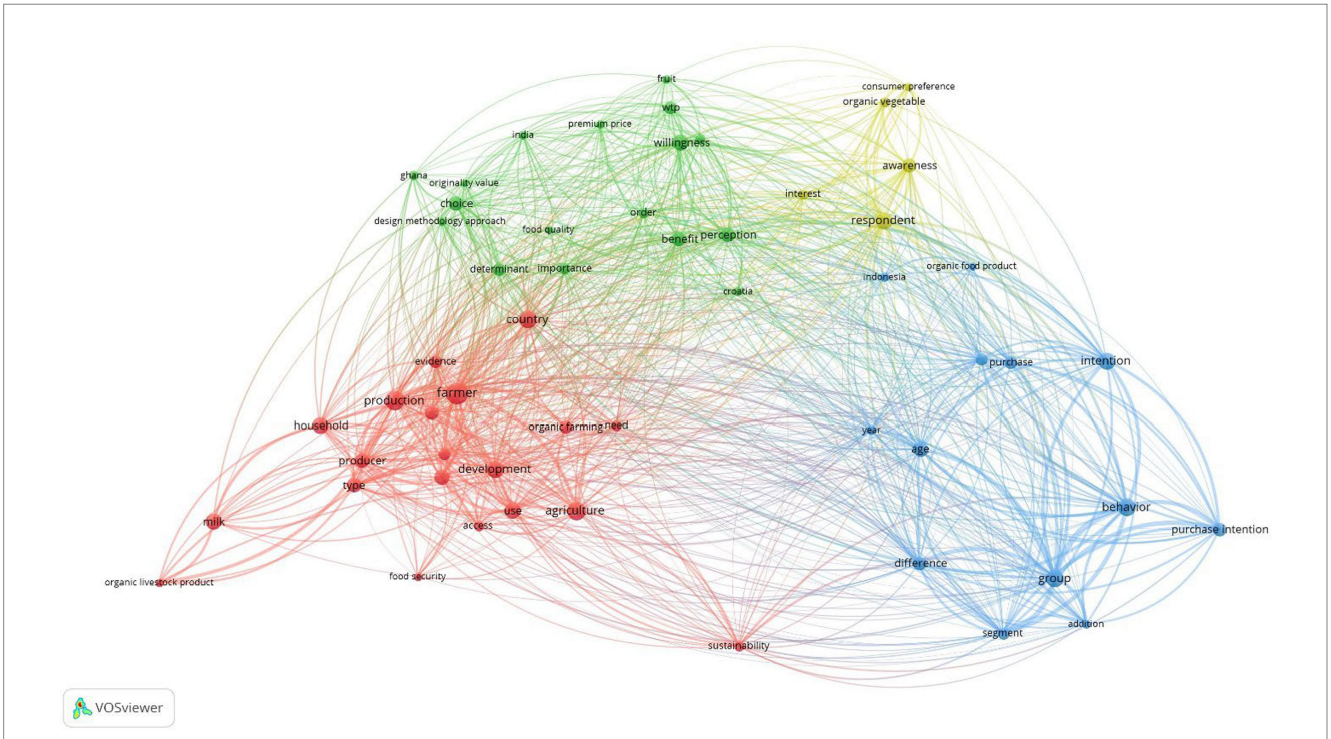


FIGURE 1
Bibliometric map identifying topics of interest in the scope of "organic food" and "income" articles in WoS database. Source: Own processing.

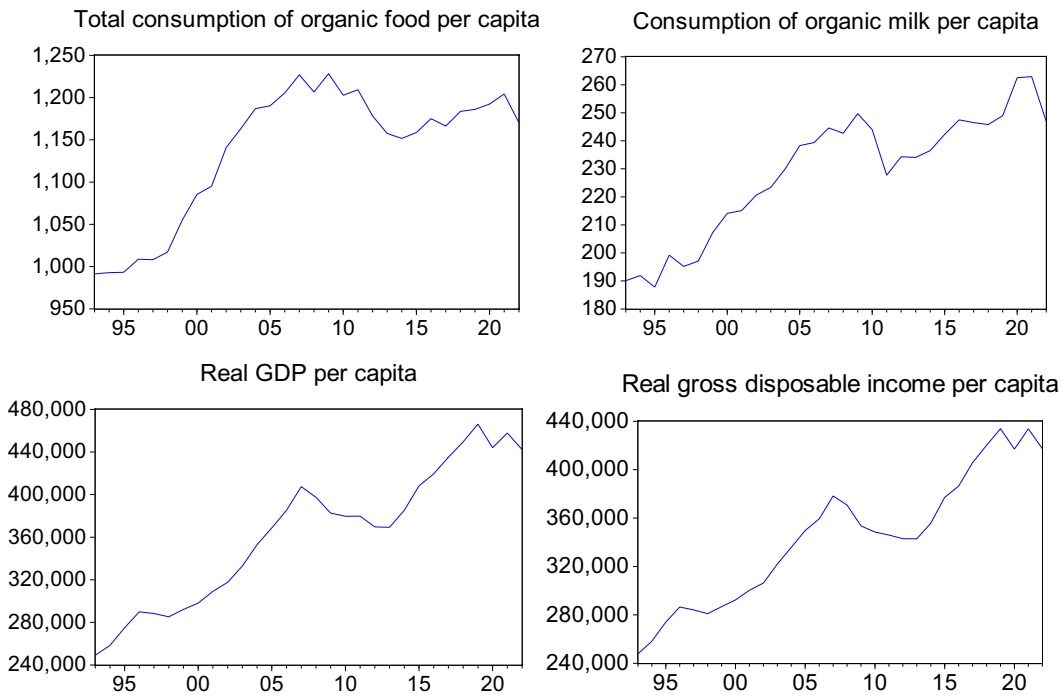


FIGURE 2
Evolution of the time series used to illustrate the 2008 turning point. Source: Own processing.

series of real GDP *per capita* is considered, as well as an indicator of real gross disposable income on a *per capita* basis. The source of these data is the database of the Czech Statistical Office (CZSO: Main Macroeconomic Indicators, 2023).

The mathematical description of the systematic aspects of the statistical relationship between real consumption of organic food and the selected indicators of real income was statistically analyzed using an error correction model. An error correction model is applied in this study for two reasons. First, all analyzed variables are non-stationary. Second, consumption and income are closely related in the long run due to budget constraints, from which it follows that these variables are cointegrated. Economic indicators with these two characteristics must be formulated as an error correction model (Engle and Granger, 1987). Moreover, as stressed by Jansen (1996), an error correction model can be regarded as a synthesis of other approaches focusing either only on the long-run relation (cointegration) or only on the short-term dynamics (regression models with differenced data).

Moreover, the presence of economic crises requires statistical breakpoint analysis to be applied. For this reason, instead of the commonly used ADF (Augmented Dickey-Fuller) tests (Dickey and Fuller, 1979) and Phillips-Perron tests (Phillips and Perron, 1988), the Perron (1989) stationarity test for time series with a breakpoint was employed. The breakpoint was statistically tested and demonstrated using Chow's (1960) stability test in all regression models used. The error correction model was therefore modified to include breakpoint analysis using auxiliary binary variables (Poliak et al., 2014).

The econometric estimation and testing of the error correction model with breakpoints was done using Engle and Granger's (1987) method. Dependent variables were chosen to be (1) total organic food consumption and (2) *per capita* consumption of dairy organic food. To examine the robustness of the results obtained, different income indicators were chosen as explanatory variables in different regression equations. Specifically, the indicator (1) of real GDP *per capita* and also the indicator (2) of real gross disposable income were considered.

4 Results

All time series used were tested for stationarity using the Perron (1989) test designed for time series with a breakpoint. The breakpoint was always set in 2008, given the outbreak of the global economic crisis in that year. The evolution of the time series used to illustrate the turning point at the outbreak of the global economic crisis is shown in the following figure (Figure 2).

The error correction model will be formulated in logarithms of the variables and in absolute differences of the logarithmic values. Therefore, the results of Perron's stationarity test of the time series are expressed for the logarithmic variables and their 1st differences. In the case of the original variables, the trend and level constants were used in the Perron test, and for the case of the differenced data, only the level constant was used in the test. The breakpoint was always set in 2008. The null hypothesis states that the relevant time series contains a unit root. The results are summarized in Table 1.[1]

The results in the table show that in all cases, the indifference data are non-stationary and also that transforming them using 1st differences has already ensured their stationarity. For this reason, an error correction model was chosen to model the relationship between

1 The symbols *, **, and *** indicate rejection of the null hypothesis at the 10, 5, and 1% significance levels, respectively.

TABLE 1 Results of Perron's stationarity test for the time series with a breakpoint in 2008.

Perron stationarity test		Undifferentiated data		1. differentiation of variables	
		Test criterion	*P*-value	Test criterion	*P*-value
Time series (in logarithms)	Real consumption of total organic food (*per capita*)	−0.52	≥ 0.5	−5.33	< 0.01***
	Real consumption of organic dairy foods (*per capita*)	−1.77	≥ 0.5	−6.66	< 0.01***
	Real GDP (per 1 inhabitant)	−0.08	≥ 0.5	−4.94	< 0.01***
	Real gross disposable income (*per capita*)	−2.47	≥ 0.5	−4.47	< 0.01***

Source: Own processing.

TABLE 2 Results of the stationarity test of the bias estimate $\hat{u}_t$ from long-run equilibrium using the ADF test.

Dependent and explanatory variable used		Test criterion	*P*-value
C_t…total consumption of organic food	Y_t…GDP	−2.58	0.012**
	Y_t…gross disp. Income	−2.69	0.009***
C_t…consumption of organic dairy foods	Y_t…GDP	−3.28	0.002***
	Y_t…gross disp. Income	−2.71	0.009***

Source: Own processing.

organic food consumption and a given income indicator to eliminate the problem of apparent regression in non-stationary time series and describe both the long-run equilibrium relationship between these variables and the short-run dynamics.

The error correction model will be formulated here with the dependent variable *total organic food consumption* and the explanatory variable *GDP*. A completely analogous model has also been formulated for all other combinations of dependent and explanatory variables.

The first step in the Engle and Granger (1987) methodology is the econometric estimation of the long-run equilibrium relationship between the original indifference variables (Eq. 1):

$$\ln(C_t) = \alpha_0 + \alpha_1 \cdot \ln(Y_t) + u_t, \quad (1)$$

Where C_t denotes the real total consumption of organic food in *per capita* terms,

Y_t represents real GDP *per capita*,

u_t is a random error with characteristics of the so-called white noise.

Due to the non-stationarity of the time series used, the econometric estimation of the regression equation is burdened with the problem of apparent regression. Parameter estimates $\hat{\alpha}$, $\hat{\beta}$ using the least squares method can therefore only be used to obtain an estimate of the deviation from the long-run equilibrium $\hat{u}_t$ (Eq. 2):

$$\hat{u}_t = \ln(C_t) - \hat{\alpha}_0 - \hat{\alpha}_1 \cdot \ln(Y_t). \quad (2)$$

To apply the error correction model, the variables of the model, $\ln(C_t), \ln(Y_t)$, need to be first-order cointegrated, i.e., the deviation from the long-run equilibrium $\hat{u}_t$ is stationary. In this case, stationarity was tested with the standard Augmented Dickey-Fuller (ADF) test, and the results are summarized in the following Table 2.

The results in the table show that the null hypothesis of the existence of a unit root of the variable $\hat{u}_t$ is rejected at the 5% significance level in all cases and even at the 1% significance level in three cases. Deviation from long-run equilibrium $\hat{u}_t$ is therefore a stationary variable in all cases considered, and the following error correction model can be applied (Eq. 3):

$$\Delta c_t = \beta_1 \cdot \Delta y_t + \beta_2 \cdot \hat{u}_{t-1} + \varepsilon_t, \quad (3)$$

Where

$$\Delta c_t \equiv \ln(C_t) - \ln(C_{t-1}),$$

$$\Delta y_t \equiv \ln(Y_t) - \ln(Y_{t-1}),$$

$\hat{u}_{t-1}$ represents the lagged deviation from the long-run equilibrium relationship,

ε_t is a random error with white noise properties.

Since the absolute difference of the logarithmic quantities corresponds approximately to the relative difference of the original non-logarithmic values $\ln(X_t) - \ln(X_{t-1}) \cong \frac{X_t - X_{t-1}}{X_{t-1}}$, the coefficients β_1, β_2 interpret the coefficients of relative elasticity. Parameter β_1 thus expresses by how much percentage C_t change if the value of Y_t changes by 1%. Similarly, the parameter β_2 indicates by how much percent it will change C_t if this consumption was 1% above its long-run equilibrium level in the previous period.

The standard error correction model (3) was tested for stability using Chow's (1960) breakpoint test (Table 3). The application of this statistical test showed a breakpoint at the 5% level of statistical

TABLE 3 Results of Chow's breakpoint test in 2008 for the error correction model (3).

Dependent and explanatory variable used		Test criterion (*P*-value)		
		F-statistics	Logarithm of the likelihood ratio	Wald's statistics
C_t…total consumption of organic food	Y_t…GDP	22.09 (0.000)***	29.79 (0.000) ***	44.19 (0.000)***
	Y_t…gross disp. Income	27.23 (0.000)***	33.89 (0.000) ***	54.46 (0.000)***
C_t…consumption of organic dairy foods	Y_t…GDP	3.37 (0.049)**	6.92 (0.032) **	6.74 (0.034)**
	Y_t…gross disp. Income	7.58 (0.003)***	13.78 (0.001)***	15.16 (0.001)***

Source: Own processing.

significance in 2008 for the parameter β_1. The results are summarized in the following table:

The results in the table show that the null hypothesis of no breakpoint in 2008 for the parameter β_1 was rejected in all regression equations examined at the 5% significance level, using all test criteria considered. The observed instability of the coefficient β_1 will therefore be explicitly modeled using auxiliary binary variables as follows (Eq. 4):

$$\Delta c_t = \beta_0 \cdot B_t \cdot \Delta y_t + \beta_1 \cdot (1 - B_t) \cdot \Delta y_t + \beta_2 \cdot \hat{u}_{t-1} + \varepsilon_t, \quad (4)$$

while the interpretation of the variables is the same as in the relation (3), the binary variable B_t is defined as follows:

$$B_t = \begin{cases} 1, \text{for } t < 2008, \\ 0, \text{for } t \geq 2008. \end{cases}$$

Results of the econometric estimation of the error correction model in the form (4) using the least squares method are summarized in Table 4 for all regression equations examined. In addition to the estimation of the parameters ($\beta_i, i = 0,1,2$), the *p*-value of the t-test of its statistical significance is also reported in parentheses for each estimate in the table. In the last column of the table, the coefficient of determination R^2 of the regression model is presented.

Statistical significance of the parameter β_0 according to the t-test proved to be significant even at the 1% significance level in the three regression equations considered. The null hypothesis $H_0 : \beta_0 = 0$ is therefore rejected in all these cases. Thus, before 2008, the explanatory variable Δy_t had a statistically significant effect on organic food consumption Δc_t . A 1% year-on-year increase in real GDP *per capita* led to a year-on-year increase:

- total real *per capita* consumption of organic food by 0.350 percentage points,
- real *per capita* consumption of organic dairy products by 0.518 percentage points.

By analogy, the 1% year-on-year increase in real gross disposable income *per capita* led to an annual increase:

- total real *per capita* consumption of organic food by 0.362 percentage points,
- real *per capita* consumption of organic dairy products by 0.514 percentage points.

In 2008, however, this statistical dependence of organic food consumption on real GDP disappeared, as demonstrated by the statistical insignificance of the parameter β_1 in all regression equations considered.

Parameter β_2 satisfies the *a priori* condition $\beta_2 \in (-1,0)$ in all regression relationships examined, according to which the consumption of organic food partially returns to its long-run equilibrium value if it deviates from this equilibrium in the previous period. In the case of the regression with total organic food consumption, the statistical significance of this adjustment mechanism toward equilibrium was found to be at the 5% level of statistical significance. The second regression equation with organic dairy consumption was even at the 1% significance level, while the strength of this mechanism proved to be significantly higher in this case. A deviation of total organic food consumption of 1 percentage point above the long-run equilibrium level in the previous period leads to a year-on-year decline in total organic food consumption of the order of 0.11 percentage points. In the case of the use of the explained variable consumption of organic dairy products, this year-on-year decline is in the range of 0.43–0.56 percentage points.

Determination coefficient R^2 in the regression equations came out to be in the range of 0.221–0.360 in all cases examined, which means that the estimated regression model of error correction of the form (4) can explain on the order of 22.1 to 36% of the total variability in the explained variable. This result can be considered satisfactory given that the variables are expressed in differences in this model. Coefficient of determination R^2 in regression Equations (1) describing the long-run equilibrium relationship was significantly better due to this fact (in the order of 0.71–0.92).

The estimated error correction model of form (4) was econometrically verified based on the analysis of the estimated residuals. Random errors were tested for autocorrelation in a correlogram analysis using the Q-statistic. The results are summarized in the following figure (Figure 3).

The figures show that all autocorrelation and partial autocorrelation coefficients are not statistically significantly different from zero, which is also confirmed by the Q-statistic and its *p*-values (denoted as Prob).

TABLE 4 Results of the econometric estimation of the error correction model (4) by the least squares method.

Dependent and explanatory variable used		Parameter estimation (*P*-value of *t*-test)			R^2
		$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	
C_t…total consumption of organic food	Y_t…GDP	0.350 (0.002)***	0.109 (0.369)	−0.117 (0.037)**	0.267
	Y_t…gross disp. Income	0.362 (0.004)***	0.082 (0.498)	−0.107 (0.019)**	0.221
C_t…consumption of organic dairy foods	Y_t…GDP	0.518 (0.003)***	0.067 (0.725)	−0.561 (0.002)***	0.360
	Y_t…gross disp. Income	0.514 (0.012)**	0.132 (0.501)	−0.433 (0.009)***	0.291

Source: Own processing.

The same conclusion about the absence of autocorrelation was also obtained by the Breusch–Godrey LM (Lagrange Multiplier) test of serial correlation (Breusch, 1978; Godfrey, 1978). The results are summarized in the following Table 5.

The results in Table 5 show that the null hypothesis of no autocorrelation was not rejected in all regression equations examined.

Next, White's (1980) test for heteroskedasticity of random errors was performed, and the results are summarized in Table 6.

The null hypothesis of homoskedasticity of random errors was not rejected, and this result is again valid for all regression equations considered.

The main contribution of the article is to fill a gap in the professional literature devoted to the investigation of the influence of income on the consumption of organic food. Macroeconomic analysis of the dependence of organic food consumption on income is practically non-existent in professional literature, and the article targeted this gap.

The attention was focused on the change in the aforementioned dependence after 2008. This change was proven by statistical tests. It was found and confirmed by formal econometric tests that before 2008, there was a statistically significant positive dependence of organic food consumption on income. At the same time, however, the hypothesis that this dependence disappeared after 2008 in connection with the global economic crisis was confirmed. This important information shows that the organic food market has not been too affected by the falling real incomes related to the economic crisis. Organic food, therefore, has an unquestionable place in the Czech market and plays a non-negligible role in the food market.

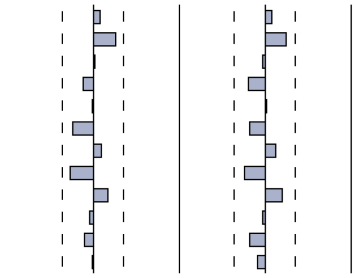
The obtained results turned out to be quite robust, as the mentioned conclusions turned out to be independent of the choice of a specific indicator of aggregate income or a specific indicator of aggregate consumption of organic food. The estimated regression models were also verified using a whole range of statistical and econometric tests—in addition to standard tests on parameters, these include unit root testing, breakpoint testing, and autocorrelation and heteroskedasticity tests. The obtained conclusions are therefore based on a high-quality regression model and rigorous statistical and econometric tests; in addition, the robustness of the obtained results against different specifications was demonstrated.

5 Discussion

The education of the population and systematic cultivation of the consumer role of its members seem to be more and more important parts of the sustainable development of society. One of the crucial issues of sustainable consumption (not only in general but especially in the scope of individual consumption patterns) has been detected in the scope of organic food production and consumption. However, despite the importance of this issue, there is no sufficient scientific attention paid to it. It is connected with two main facts: (1) there is no macroeconomic framework of the consumption detected (excluding the research of Liu et al., 2019 who have finally analyzed interest in organic food globally using data obtained from the Google search engine, and one of their conclusions is that organic food consumption is not correlated with GDP) and (2) when the national specifics of the market on the consumer level are taken into account, the income issue and spending habits are not considered as influenced by psychographic specifics of consumers.

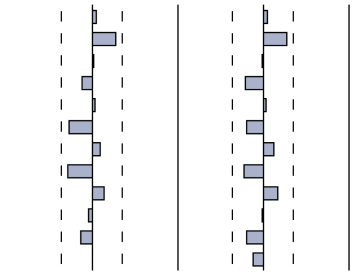
Thus, the huge potential of marketing implications on this specific market disappears, and the effectiveness of marketing activities is not sufficient. This is mainly because income is traditionally perceived as a variable with positive correlation to the spending on organic food—i.e., the higher the income, the higher the consumption, and vice versa (the same is also logically valid for real income, not only its nominal value). This original presumption has been based on the traditional perception of demand and the relation between price and quantity in the scope of the so-called income effect and effect of substitutes. However, in this case, subjectively perceived value sources should be considered. Thus, the scheme of demand does not follow standard rules, and in this case, the purchase of organic food is not affected by real income changes. Similarly, neither its affection by increasing price should be expected. The above-mentioned indicates specifically the high subjectively perceived value of this product category by its consumers. Moreover, others so far realized that research could indicate such a status. Xu et al. (2016) have stated that disposable income is an important factor influencing the willingness to pay a higher price. By applying the logic of an opposite statement, it could be concluded that the lower would be the real income, the lower would be the willingness

A Regression equation with C_t = total consumption of organic food and Y_t = GDP



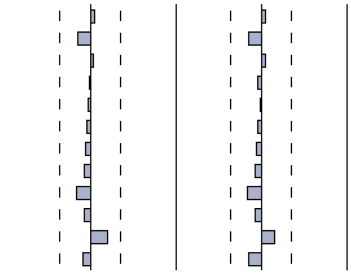
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.083	0.083	0.2200	0.639
		2	0.271	0.266	2.6716	0.263
		3	0.019	-0.022	2.6836	0.443
		4	-0.112	-0.199	3.1326	0.536
		5	-0.002	0.020	3.1327	0.680
		6	-0.242	-0.173	5.4204	0.491
		7	0.093	0.136	5.7756	0.566
		8	-0.285	-0.241	9.2620	0.321
		9	0.179	0.215	10.703	0.297
		10	-0.038	-0.021	10.771	0.376
		11	-0.102	-0.184	11.289	0.419
		12	-0.007	-0.098	11.291	0.504

B Regression equation with C_t = total consumption of organic food and Y_t = gross disposable income



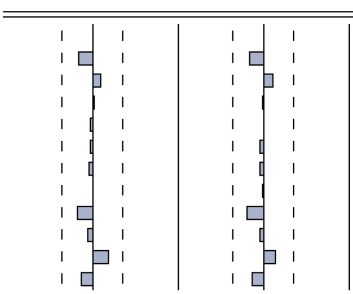
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.064	0.064	0.1313	0.717
		2	0.293	0.290	2.9866	0.225
		3	0.031	-0.001	3.0197	0.389
		4	-0.108	-0.213	3.4422	0.487
		5	0.037	0.049	3.4944	0.624
		6	-0.272	-0.203	6.3937	0.381
		7	0.101	0.127	6.8093	0.449
		8	-0.292	-0.223	10.463	0.234
		9	0.145	0.184	11.414	0.248
		10	-0.033	-0.006	11.466	0.322
		11	-0.138	-0.199	12.417	0.333
		12	0.004	-0.112	12.418	0.413

C Regression equation with C_t = total consumption of organic dairy products and Y_t = GDP



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.051	0.051	0.0851	0.770
		2	-0.152	-0.155	0.8505	0.654
		3	0.038	0.056	0.8991	0.826
		4	-0.012	-0.042	0.9041	0.924
		5	-0.031	-0.013	0.9392	0.967
		6	-0.033	-0.042	0.9828	0.986
		7	-0.050	-0.051	1.0831	0.993
		8	-0.068	-0.074	1.2817	0.996
		9	-0.157	-0.169	2.3859	0.984
		10	-0.069	-0.077	2.6116	0.989
		11	0.206	0.172	4.7316	0.943
		12	-0.096	-0.148	5.2161	0.950

D Regression equation with C_t = total consumption of organic dairy products and Y_t = gross disposable income



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.015	0.015	0.0070	0.933
		2	-0.166	-0.167	0.9291	0.628
		3	0.104	0.113	1.3063	0.728
		4	0.026	-0.008	1.3305	0.856
		5	-0.026	0.010	1.3556	0.929
		6	-0.030	-0.040	1.3919	0.966
		7	-0.043	-0.047	1.4659	0.983
		8	0.004	-0.003	1.4664	0.993
		9	-0.180	-0.196	2.9172	0.967
		10	-0.061	-0.041	3.0953	0.979
		11	0.199	0.150	5.0643	0.928
		12	-0.124	-0.127	5.8743	0.922

FIGURE 3
Autocorrelation (AC) and partial autocorrelation (PAC) functions of the estimated residuals in the regression models are considered (4). **(A)** regression equation with C_t= total consumption of organic food and Y_t = GDP. **(B)** regression equation with C_t = total consumption of organic food and Y_t = gross disposable income. **(C)** regression equation with C_t = total consumption of organic dairy products and Y_t = GDP. **(D)** regression equation with C_t = total consumption of organic dairy products and Y_t = gross disposable income. Source: Own processing.

TABLE 5 Results of the Breusch–Godfrey LM test for autocorrelation of the error correction model (4).

Dependent and explanatory variable used		Test criterion (*P*-value)	
		F-statistics	$n \cdot R^2$
C_t…total consumption of organic food	Y_t…GDP	1.61 (0.22)	3.41 (0.18)
	Y_t…gross disp. Income	1.85 (0.18)	3.87 (0.14)
C_t…consumption of organic dairy products	Y_t…GDP	0.44 (0.65)	1.00 (0.61)
	Y_t…gross disp. Income	0.44 (0.65)	0.88 (0.64)

Source: Own processing.

TABLE 6 Results of White's test for heteroskedasticity of the error correction model (4).

Dependent and explanatory variable used		Test criterion (P-value)	
		F-statistics	$n \cdot R^2$
C_t…total consumption of organic food	Y_t…GDP	1.46 (0.24)	6.98 (0.22)
	Y_t…gross disp. Income	1.00 (0.44)	5.17 (0.40)
C_t…consumption of organic dairy products	Y_t…GDP	0.28 (0.92)	1.66 (0.89)
	Y_t…gross disp. Income	0.39 (0.85)	2.26 (0.81)

Source: Own processing.

to pay more for organic products in the product category. This argument is also strengthened by the research provided by Yin et al. (2010), who stated that purchases of organic food are significantly influenced by income, trust in organic food, the degree of acceptance of its higher price, and consumers' concern for their health.

If income as a significant macroeconomic factor in the consumption of organic food has been considered previously, the research on the consumption has been managed and realized mainly in terms of national psychographic specifics (Kicova and Nadanyiova, 2015; Krizanova et al., 2015; Jankalova and Vartiak, 2017; Chen et al., 2022). Moreover, Aschemann-Witzel and Zielke (2017) literally stated that income plays only a negligible role compared to psychological factors. In light and shadow of our own research, we could agree with this theory in the wider sense of meaning. However, when stricter criteria of interpretation are applied, we could also state that income and perception are significantly influenced by the individual schemes of values created under specifics of national psychographic profiles. The specific position of the Czech consumer and its psychographic uniqueness, which has made our nationally oriented research reasonable, has been stated by Petljak et al. (2017), who identified the significant factors influencing the willingness of consumers in the Czech Republic and Croatia to pay a higher price for organic food. However, the macroeconomic analysis based on the time series approach is also missing in their research. Thus, our own research has developed their research basis of specifics of organic food consumption and willingness to pay more for this specific product category in terms of the Czech Republic and its market environment.

In our research, we have also followed current scientific trends in this issue—focusing on national and market specifics in terms of product category and country. Other trends, such as organic food products value sources which reflect the price and willingness to pay for them and overall consumer preferences, dedicated to prospective value sources of organic food products have been included in the study indirectly by discussing the psychographic effect of behavioral marketing inclusion when the relationship between organic food consumption and the income of consumption is discussed and interpreted.

Thus, we could conclude that our research significantly enriches the so-far formulated theory as it follows three of four detected scientific trends in this area, and it develops contemporary theory and practice of marketing management of organic food in terms of identifying the very strong phenomenon of subjectively perceived product value which deny the traditional rule of declining demand and provide a valuable platform for further research in this area. Moreover, it has the potential to be helpful in the process of state policy implementation. According to the Czech Ministry of Agriculture, the main issue is (1) to improve the sale of organic food; (2) to make it easier for eco-farms to access the market; (3) to build the domestic market fully competitive with foreign producers; and (4) to increase consumer awareness. However, these are just declaratory statements without any special activities that would support the fulfillment of these goals. Research outcomes are relevant to the last issue focused on consumer awareness. Here, it is just stated in the scope of the policy of the ministry that education should be more oriented on systematic awareness cultivation via specialized programs and public campaigns. As it is obvious from our research, consumption is not sensitive to real income development. It has been proven that the organic food market has not been affected significantly by the falling of real incomes related to the economic crisis. Thus, the importance of education

has been proved. In addition, it has been identified that a significant pillar of organic food consumption, which is relevant for producers—i.e., income does not form a relevant aspect of consumption in this category. Therefore, economic cycles do not have to be followed to ensure sustainability for businesses running in this sector. On the other hand, from a wider perspective, it could be started to discuss organic food as an elementary need in specific consumer segments. The importance is transmitted from the overall income aspect to the knowledge of these segments and their systematic widening.

6 Conclusion

The aim of this study is to analyze the dependence between income and organic food consumption. The dependence has been examined at the macroeconomic level using a time series of aggregate indicators. To describe the statistical dependence, the Error Correction Model (ECM) has been applied. Thus, it has been allowed to examine both the long-run equilibrium relationship between organic food consumption and income and its short-run dynamics. The standard ECM model has been further modified to include a breakpoint analysis with respect to the global economic crisis of 2008. In the context of the statistical breakpoint analysis, a second important objective has been set—to investigate how the dependence of organic food consumption on income changed after 2008 in the context of the global economic recession. To analyze the robustness of the results that were obtained, the total consumption of organic food and the consumption of dairy organic food were analyzed. In addition, to ensure the robustness of the obtained results, both GDP and gross disposable income were used in the analysis.

The obtained conclusions are based on a regression model and rigorous statistical and econometric tests. In addition, the robustness of the obtained results was demonstrated. It has been found and confirmed by formal econometric tests that before 2008, there was a statistically significant positive correlation between organic food consumption and income. At the same time, however, the hypothesis that this correlation would disappear after 2008 as a consequence of the global economic crisis was confirmed. Thus, it has been proven that the organic food market has not been affected significantly by the fall in real incomes related to the economic crisis. Based on these facts, it can be stated that organic food has an unquestionable position in the Czech market and plays a non-negligible role in the food market and its relevant consumption.

These findings are important for theory because they complement previous research and provide different perspective on the consumption of organic food and spending habits of consumers in specific conditions of the Czech Republic. First, they follow the trend of regionally focused research and prove the fact that the consumption of organic food should not be perceived as uniform and that the regional specifics relevant to the national psychographic profile of consumers should be taken into account as they are relevant not only to the subjectively perceived values of the organic food but also to the spending habits of the consumer. Second, they enrich the so-far formulated theoretical patterns of marketing management of organic food and create a platform for further research in this area.

The practical implications consist of the use of research findings in managerial practice. The application of the knowledge that results from one's own research is wide. Mainly, it radically changes the practice of marketing stimulation of the consumer and the planning and prognosis of demand in the scope of wider macroeconomic circumstances. Basically, as it has been proven that consumers are not sensitive to the real income value, they perceive organic food products as stable in the scope of their value perception. In other words, the organic character of products brings sufficient value to consumers, and their consumption does not change even if they face inflation with respect to the decline in their purchasing power. This fact is crucial for the management of such products as the sensitivity on price in case the real value of income would remain could be present as well. If so, there could also be present other phenomena—less need for communication support of the company. In such a case, the cost profile of the company would be significantly optimized.

The crucial limitation in our research is first its territorial validity, i.e., national and cultural specifics of consumers from the Czech Republic. So, the applicability of the research outcomes is justified only in specific conditions of this market. This means that it is not fully possible to apply research outcomes regardless of taking the specifics of the market into account. However, this limitation can be removed by repeating the research in the national conditions of other countries whose national specifics are not convergent to the national specifics of the Czech Republic. The Hofstede's national psycho-graphic profile model could be used for these purposes. However, it should be enriched by analysis of relevant macroeconomic indicators. Based on defined clusters of similar regions (both psychographic and macroeconomic characteristics would be included), the research should be primarily repeated within the same cluster where the Czech Republic is identified. Once the similarity in research outcomes has been detected, the following hypothesis could be formulated: there are inner cluster similarities in organic food consumption from the macroeconomic point of view. When reconsidering this limitation, the results of the research could be considered as relevant, and they could be subject to subsequent verification in the specific national environments. The geographic extension can be perceived as a prospective further direction of the research. Thus, the usability of research outcomes would be wider, and the conclusions could be applied in more complex circumstances of a globalized marketplace.

Similarly, prospective ways of future research extension in this area could be connected with the inclusion of qualitative analysis. Thus, the inclusion of the qualitative research method could partially enrich the process of understanding consumer behavior and the scheme of attitudes toward organic food consumption. In-depth interviewing with respect to the specific incorporation of a questionnaire survey could be applied. However, the strict macroeconomic character of the research should be followed. Otherwise, the research would not fulfill the scientific gap that has been identified in the scope of the macroeconomic aspect of the topic of organic food consumption, and it would just repeat the dominating concept of research—i.e., ″consumer-centric″ from the behavioral point of view.

However, there is still space for further discussions on the implementation of obtained research results on the marketing management patterns of specific grocery categories of organic food. Due to the need to transform consumption to its sustainable form,

this issue has great potential for further research. It would be beneficial to examine and compare the subjective perception of organic food in relation to the spending habits of consumers, for example, in the scope of different generational cohorts of consumers (as it could be understood from one of the detected trends of research in this area—i.e., area of demographic specifics in attitudes toward income spending in favor of organic food products) with respect to the individual categories of organic food (not only on organic milk).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JM: Conceptualization, Resources, Supervision, Visualization, Writing – original draft. SC: Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft.

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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.

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The origins and growth of the Meatless Monday movement

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Meatless Monday is a global movement that encourages people to reduce meat in their diets for their own health and the health of the planet. We conducted a comprehensive review of primary and secondary sources and archival material documenting the origins, historical roots, and growth of Meatless Monday and simultaneous developments in public health. Sources for the paper included publications of the US Food Administration and articles and media identified using searches of ProQuest Historical Newspapers, Newspapers.com Academic, ProQuest US Newsstream, ProQuest Canadian Newstream, ProQuest International Newsstream databases, and Google.com. Meatless Monday was conceived by the advertising executive and public health advocate Sid Lerner in 2003, inspired by the meatless days observed during World War I and II. Meatless Monday grew steadily from 2003 to 2023 through advocacy by food writers, talk show hosts, and celebrity chefs, and through participation by schools, cities, restaurants, corporations, and institutions worldwide. School systems began to observe Meatless Monday, such as Baltimore City Public Schools in 2009 and New York City Public Schools in 2019. Meat-Free Monday campaign was launched by Paul McCartney and his daughters in 2009 in the United Kingdom. The Humane Society of the United States became an advocate for Meatless Monday and helped institute it in >200 US school systems. From 2003 to 2023, Meatless Monday spread to over 40 countries and was observed in public schools in countries such as Brazil, Ireland, and Belgium. Findings regarding high meat consumption and its adverse effects on health, high greenhouse gas production and environment degradation, and problems with animal welfare under conditions of industrial food animal production emerged during the same period and influenced many to advocate Meatless Monday. Meatless days of World War I and II were driven by patriotic motivations to provide food for the US troops and the Allies in Europe, whereas motivations for observing Meatless Monday were largely related to concerns regarding personal health, the environment, and animal welfare. Meatless Monday grew from relatively humble origins to a highly recognized worldwide movement with wide appeal as a way to begin reducing meat consumption for personal and planetary health.

KEYWORDS

climate change, diet, greenhouse gas production, meat, protein, vegetarianism

1 Introduction

Food systems contribute to an estimated 30% of global greenhouse gas emissions (GHGe) (1). Livestock, which include primarily ruminant (cattle, lamb) and monogastric (pigs, chicken) animals, account for 14.5% of total human-induced GHGe (2) and 30% of global anthropogenic methane emissions (3). Beef is by far the food with the greatest climate footprint

(4, 5). A potential strategy to reduce GHGe and alleviate global warming is to reduce meat consumption and shift to primarily plant-based diets (6–10). A shift from meat to plant-based dietary patterns also reduces the risk of adverse chronic disease outcomes such as type 2 diabetes (11, 12), cardiovascular disease (12, 13), frailty (14), and mortality (12, 13, 15). Whether dietary recommendations or public health campaigns can convince people to decrease meat consumption remains unclear (16). Among the most visible public health strategies of reducing meat consumption has been Meatless Monday, a global movement that encourages people to reduce meat in their diets for their own health and for the health of the planet (17).

The Meatless Monday campaign was founded by the advertising creative director and public health advocate Sid Lerner (17). The Center for a Livable Future of the Johns Hopkins Bloomberg School of Public Health provided scientific and technical expertise to the campaign. The relationship between the Meatless Monday campaign and the Center for a Livable Future has been strong and continuous since its founding. Meatless Monday had its historical origins in meatless days that were observed in the US partly as a goodwill effort to provide meat for Allies in Europe during World War I and II. Over the last two decades, the reach and contributions of Meatless Monday have spread across the United States and worldwide. The definition of "meat" has varied over time. During World War I and II, "meat" meant beef, lamb, and pork (18). During the first years of the Meatless Monday campaign, "meat" included all livestock meat, i.e., chicken, pork, lamb, and beef (17). Around 2010, fish was also included in the term "meat" in materials distributed by the Meatless Monday campaign (Pamela Berg, personal communication).

This paper aims to address a gap in the literature regarding the history of the Meatless Monday campaign. The goal of this paper is to present the history of Meatless Monday since its founding in 2003, the history of meatless days in World War I and World War II, and the expansion of the Meatless Monday movement from 2003 onwards. The Meatless Monday campaign grew during parallel developments in public health, such as increased concerns about the link between red and processed meat with cardiovascular disease and cancer, new findings on climate change that identified livestock as a major contributor to greenhouse gas production, and alarm raised about animal welfare in "factory farms." The emerging findings on health, climate change, and animal welfare prompted many individuals and organizations to become advocates for Meatless Monday. We conclude with a discussion about the impact of the Meatless Monday campaign and gaps in research.

2 Methods

The historical sources for the paper included official publications of the US Food Administration and newspaper articles, online publications, newswires, and blogs identified using searches of ProQuest Historical Newspapers (19), Newspapers.com Academic (20), ProQuest US Newsstream (21), ProQuest Canadian Newstream (22), ProQuest International Newsstream databases (23) and Google.com using the terms "meatless monday," "meat-free monday," and "meatless day." The archive of the Meatless Monday campaign was also used as a source for blogs and newswires (24). The search was limited to the time range of January 1, 2002 to December 1, 2023. Most of the available newspaper and periodical databases are based upon publications from the English-speaking world, but articles in Spanish, Portuguese, and French were also searched. Meatless Monday is compared and contrasted with its antecedents of meatless days during World War I and II. The growth of the Meatless Monday movement is presented in the context of parallel developments in medicine, public health, environmental science, and animal welfare that were occurring during the same period. Examples are given where these parallel developments influenced attitudes about the implementation of Meatless Monday. A figure showing Meatless Monday activities from 2003 to 2023 was developed using ArcGIS Pro software (Environmental Systems Research Institute [ESRI], Inc., Redlands, California). Meatless Monday sites were geocoded with the ArcGIS World Geocoding Service (ESRI) and then displayed by the year the Meatless Monday program began. The country boundaries on the figure were obtained from the United Nations. The figure uses the Robinson projection. Meatless Monday programs and locations were provided by the Meatless Monday Campaign based upon news releases, blogs, newspaper articles, personal communications, blogs, and web searches. A table that summarizes the approaches to meatless days was created to make a historical comparison (25) between the period of World War I and II with the Meatless Monday campaign (2003–2023). The table is a subjective historical interpretation by the authors of the referenced works. It is meant to highlight similarities and differences between these two historical periods. Salient points of comparison were selected by the lead author (RDS) with two rounds of revisions consisting of additions by the coauthors. There were no discrepancies in agreement during the revisions, and adjudication was not required.

3 Sid Lerner and the concept of the Meatless Monday campaign

Meatless Monday was conceived by Sid Lerner in 2002 during a meeting with Alfred Sommer, Dean of the Johns Hopkins Bloomberg School of Public Health, and Robert Lawrence, the Director of the Center for Livable Future, Associate Dean, and Professor at the Johns Hopkins Bloomberg School of Public Health in Baltimore (Robert Lawrence, personal communication). At the time, Lerner thought that an important avenue in addressing the problems associated with industrial food animal production was to identify ways to help people reduce their meat consumption. He was especially concerned about an excess of saturated fat in the diet. He was also alarmed about his own health, as his doctor had started him on a statin to lower his cholesterol. "Everybody was talking about fat and cholesterol," said Lerner, "and meat and fat in the diet." "I asked Bob [Robert Lawrence], 'what is too much?' (26) Lawrence replied that the Surgeon General, US Department of Agriculture (USDA), and others advised that Americans "…were eating over 15% of what we ought to be eating of this fat heavy diet which led to heart disease, cancer, stroke and diabetes. So how do you cut down 15%?" asked Lerner. It occurred to him that 15% of 21 meals in a week is three meals, or one day's worth. "So make it simple," said Lerner, "just one day a week knock off the fat and meat in the diet. You sort of make a dent in it, as you should, but an easy way. Just one day a week to catch up on other good things that aren't meat in the middle of the plate. So that was the beginning of Meatless Monday" (27).

Lerner was an influential figure during the "Mad Men" era of advertising on Madison Avenue, overseeing advertising campaigns for well-known brands such as Texaco and Maxwell House and motivating Americans to purchase common household products such as toilet paper with the memorable "Please Do not Squeeze the Charmin" featuring Mr. Whipple (28). Lerner found inspiration for Meatless Monday from his childhood recollections of "Meatless Tuesdays" during World War II and its earlier roots in World War I (26). The practice of meatless days was widespread and familiar to nearly all families growing up during the world wars in North America and Europe (18). When the Meatless Monday campaign was launched in 2003, it was endowed with a rich historical record that demonstrated meatless days were feasible in the past.

4 Meatless days during World War I

This section refers largely to how meatless days began in the US during World War I. After World War I broke out in Europe in August 1914, the US remained neutral under President Woodrow Wilson. Food production in Europe became greatly compromised due to several factors. There was a shortage of farm labor, since sixty million men of the nations in.

conflict were diverted from farms to the military (18). There was diminishing availability of fertilizer and feed (18). Much of the farm and cattle-grazing land was devastated by fighting (18). Serviceable farm machinery became scarce (18). Food supplies for the Allies from Russia, Rumania, Bulgaria, Serbia, and Turkey had been cut off by the Central Powers (Germany, Austria-Hungary, Bulgaria, and the Ottoman Empire) (18). There was a shortage of animal feed due to poor harvests, loss of transport ships due to sinkings from German torpedoes, and diversion of ships to support the war efforts. Among both the Allies and Central Powers, meatless days were enforced to conserve food for their respective armies. Austria and Italy had two meatless days per week. Bulgaria had three meatless days per week (29). One meatless day per week was observed in England (30). Two meatless days per week were observed in France in 1917 and extended to three meatless days per week in 1918 (31).

After German submarines sank U.S. merchant ships, President Woodrow Wilson called for a declaration of war against Germany in a joint session of Congress on April 2, 1917. Upon entry into the war, President Wilson declared that the first task was to "supply abundant food" to the Allies (32). The food supply to the American people was generally produced in a surplus, except for sugar, vegetable oils, and coffee, of which imports were decreased during the war (33). In May 1917, President Wilson outlined a food control program, deemed necessary to provide an adequate distribution of food for the US civilian population, US military, and the Allies and to prevent exorbitant prices of food in the US, notably meat, sugar, and wheat, due to hoarding, speculation, and erosion of the balance between supply and demand. He appointed Herbert Hoover as Food Administrator, an apt choice since Hoover had previously organized the Committee for Relief in Belgium – which fed nearly nine million people in Belgium and German-occupied northern France – and had garnered strong experience with the logistics of food relief (34). As Food Administrator, Hoover was responsible for directing the US Food Administration. On August 10, 1917, Wilson signed the Food Control Bill, a law that created the Food Administration. J. Ogden Armour, the owner of Armour Company, the largest meatpacker in the US, advocated government control of all provisions so that the people of the US and the Allies would have enough food (35). Prior to any actions by the Food Administration, meatless days were promoted in some localities, such as Parkersburg, West Virginia (36), Chicago (37), and Jackson, Mississippi (38), and railroad companies in the US (39). Canada was also supplying meat to the Allies and declared two meatless days in May 1917 (40).

Since the Food Administration lacked the authority to ration foods, its efforts to conserve food and prevent food waste depended primarily upon the patriotic cooperation of the people to ensure its success (18). The slogan "Food Will Win the War" was announced by Hoover for the campaign to enlist every "housewife" in the US to participate in two meatless days by signing a conservation pledge card (41). October 9, 1917, was declared the first beefless Tuesday nationwide by the Food Administration, a measure that was widely observed across the country (42). The Hotel and Restaurant Conservation Committee of Food Administration agreed that restaurants and hotels would observe two meatless days weekly – Tuesdays and Fridays (43). In New York City alone, according to the Food Administration observation of meatless Tuesday saved 116 tons of meat in 1 week, with estimates that 300 tons of meat would be saved with scaled up participation (44). By November 1917, the Food Administration reported that one out of every three families in the US pledged support for their plan of voluntary food conservation (45). The food situation in Europe was becoming increasingly dire, and in early 1918, the Food Administration asked households across the US to pledge to observe a meatless Tuesday, a porkless Tuesday and Saturday, as well as a meatless meal each day (46). A humorous poem that poked fun at the Food Administration became well known across the US: "My Tuesdays are meatless, My Wednesdays are wheatless; I am getting more eatless each day. My home, it is heatless; My bed, it is sheetless…" (18).

The Food Administration advocated meatless days and the conservation of food through publication, posters (Figure 1), and advertising in newspapers, magazines, farm journals, trade journals, religious press, and libraries, a speakers' bureau, and distribution of placards, slides, and motion pictures to movie theaters (18). Movie

FIGURE 1
US Food Administration "Food will win the war" poster, for display in windows of partipating restaurants. New York American Lithograph Company, 1917. Library of Congress Prints and Photographs Division, Washington, DC. "Food will win the war" by New York: American Lithographic on Library of Congress, licensed under Public Domain.

stars, such as Douglas Fairbanks and Mary Pickford, appealed to the public to support meatless days (18). Textbooks, such as *Food Saving and Sharing* for young children (47), *Food Guide for War Service at Home* (48) aimed at high school students, and *Food and the War: A Textbook for College Classes* (49) were widely distributed across the country (18). The nutritionist Mary Swartz Rose gave advice to "patriotic housewives" in *Everyday Foods in War Time*, which included an appendix with mostly meatless recipes (50). Rose advised that meat was only one of many protein-rich foods and was "no better than milk or eggs" and could easily be replaced by peanut butter, navy beans, or split peas (50). Furthermore, she noted: "Meat is produced at the expense of grain, which we might eat ourselves. And the production of meat is a very wasteful process" (50). A cookbook, *Foods That Will Win the War* provided meatless recipes for the home kitchen (51). War gardening efforts that promoted home gardening across the country raised awareness about supporting the Allies and led to greater consumption of vegetables (52). By the spring of 1918, the meat supply was increasing, allowing the US to supply the Allies with meat and ease some restrictions at home (53). The Food Administration announced that meatless Tuesdays would continue but the meatless meal and porkless Saturday would no longer be required since hogs became more available (53). Meatless days were temporarily suspended for 30 days on March 29, 1918 and never reinstated (33). Instead, consumers were advised to voluntarily limit their purchases and consumption of meat. No specific limits of purchase and consumption were made in this general recommendation. World War I ended on Armistice Day, November 11, 1918, but food conservation was still advocated to alleviate the serious food shortage in Europe (54).

The Food Administration facilitated a nearly eight-fold increase of pork and nearly ten-fold increase of beef exported from the US to Europe during the war and early post-war period. In the 2 years, 1917–1919, 2,340,705 tons of pork and 902,116 tons of beef were exported to Europe compared with 298,115 tons of pork and 93,187 tons of beef exported to Europe in the 2 years, 1912–1913, before World War I (18).

5 Meatless days during World War II

Meatless days returned to Europe with the outbreak of World War II. Hitler invaded Poland in September 1939, after which France and Great Britain declared war on Germany. In order to save meat for the army, France imposed meatless days on Monday and Tuesday at the beginning of the war (55) and added a meatless day on Friday in December 1939 (56, 57). By the spring of 1940, Belgium was observing meatless days on Monday (58), and Italy instituted three meatless days per week (59). The typical English dinner of roast beef became a rarity (60). Early in 1941, Lord Woolton, Minister of Food for Great Britain, asked the people of the US to reduce their consumption of certain foods such as meat, so that the surpluses could be sent to Great Britain (61). The US announced in October 1941 that it would help feed one-quarter of the population of Great Britain with food shipments, including 1.5 billion pounds of pork and lard in 1942, without causing shortages at home (62) as the US meat supply was at an all-time high (63). The USDA predicted there was no need to return to the "meatless, wheatless, or otherless days" of World War I (64).

President Franklin Delano Roosevelt raised the idea in 1942 that if a meatless day were observed 1 day per week in the US, it would free up 30 to 40 ships that could be used for military purposes instead of transporting meat from Argentina, New Zealand, and Australia to the US (65). The International Stewards and Caterers Association responded by adopting a resolution for Meatless Tuesdays. The association had 2,100 members in twenty-one cities, including New York, Philadelphia, Boston, Pittsburgh, Detroit, Cleveland, Cincinnati, St. Louis, Denver, Chicago, San Francisco, and Los Angeles (66). One meatless day per week was adopted by federal cafeterias in Washington, DC, in September 1942 (67) and by the Los Angeles public schools (68). The mayor of New York City, Fiorello La Guardia, asked the hotels and restaurants to make Tuesday a meatless day (69). Los Angeles adopted meatless Tuesdays at restaurants, schools, hotels, and clubs, with reported near 100% compliance in 1942 (70).

The US issued a War Food Communique warning that "meat rationing to begin on or about February 1, 1943" (71). The flyer, distributed door-to-door across the country, declared "Food is a Weapon of War!" Appealing to patriotism, the communique urged people who were accustomed to eating more than 2 ½ pounds of meat per week to cut back their consumption so that more meat could go to the Allies and troops (71). A complicated system of meat rationing was instituted by the US government in March 1943 that involved a point rationing system of meat to restaurants and booklets of ration stamps to individuals for meat, i.e., beef, lamb, and pork (72). New York City continued to observe meatless Tuesday in 1943, along with Philadelphia, Los Angeles, Boston, and San Francisco, but the rest of the US largely did not observe meatless days (73). When a new record in US meat production was reached in 1944, the annual consumption of meat averaged 154 pounds per person, the highest level of consumption since 1909 (74). As meat supplies were rising, meatless Tuesdays ended in New York and other cities in September 1945 (74). World War II ended on September 2, 1945, but the US public was asked to keep conserving food for post-war famine relief in Europe. In 1947, a US Gallup poll reported that 22% of respondents observed meatless Tuesdays as urged by the government, while 38% of respondents indicated that they were planning to follow it (75).

The experiences from World War I and II showed that meatless days could be widely observed by a large proportion of the population in the US and other countries at the time using an appeal to patriotism and a greater good. A common theme in the appeal for meatless days was that ordinary people in the US could help the Allies in Europe, who were poor and suffering much more than the privileged Americans (18, 47–49, 54, 62). Later in 2003, when the Meatless Monday campaign began, many of the generation of older people who lived through World War II era still remembered the meatless days they experienced in their youth (18, 26).

6 Initial developments in the Meatless Monday movement

Sid Lerner established Meatless Monday as a nonprofit public health initiative with the mission of helping people reduce meat and saturated fat in their diet (26). He hired a small team of experienced advertising professionals to promote Meatless Monday to consumers as well as organizations who could utilize the concept to accomplish their own goals, as he strongly believed in marketing best practices in

public health (26). "There's no 'McDonald's Day' or 'Coca-Cola Day' because those guys are in your face all the time," said Lerner. "We have to put a new face, mentality and drive behind public health communications and promotions." (76). Lerner preferred "Meatless Monday" instead of "Meatless Tuesdays" since Monday was the day of the week when he thought people were most likely to change their behavior (26). He ensured that Meatless Monday, with its memorable alliteration, was free and open-source in order to facilitate its dissemination. Lerner envisioned Meatless Monday being much like a national holiday – no one owned it.

A Meatless Monday website (17) (Figure 2) was initiated to raise awareness about dietary recommendations (77) and to feature weekly meatless recipes to provide suggestions for alternatives to meat. Meatless Monday reached people with weekly periodicity and on a day when they were starting the week and most open to making healthy choices (78). Meat, as defined by the Meatless Monday campaign, included all livestock meat, i.e., chicken, pork, lamb, and beef. A year prior to the formal launch of the Meatless Monday campaign, Alfred Sommer, Dean of the Johns Hopkins Bloomberg School of Public Health [dean from 1990 to 2005], and Allan Rosenfield, Dean of the Columbia University Mailman School of Public Health, [dean from 1986 to 2008], elicited agreement from 28 deans of schools of public health to support Meatless Monday (79). Students in schools of public health across the US launched pilot campaigns on their campuses and in local communities from 2003 to 2006 (Pamela Berg, personal communication). Signs and posters and networking at national and international meetings extended the influence of Meatless Monday from 2003 to 2006 (Peggy Neu personal communication). As social media and internet websites grew from around 2005, the influence of Meatless Monday grew (Peggy Neu, personal communication).

In 2006, an online commercial food distributor, Fresh Direct, included Meatless Monday in its digital content (80). Boca Burger was the first food company to use Meatless Monday to promote their vegetarian products (81). Jenny Craig, Inc. added Meatless Monday to their weekly newsletter in 2007 (82). In 2008, Meatless Monday campaign staff attended the American College Health Association Meeting to promote the idea of Meatless Monday on college campuses, and several more campaigns were launched that year (Pamela Berg, personal communication).

In 2009, the Baltimore City Public Schools became the first school system in the country to observe Meatless Monday, a decision that was widely attacked by industry-aligned groups. The American Meat Institute countered with the falsehood that 75% of children were not getting enough protein (83). Michael Pollan, the food writer and health advocate, noted: "If Baltimore can pull this off, it will be a sign that the effort is worth making!" (84). Meatless Monday was subsequently taken up by entire school districts of other cities such as Boston, Buffalo, Detroit, Houston, Kansas City, Oakland, Philadelphia, Sarasota, and San Diego (85–87).

FIGURE 2
Meatless Monday campaign logo.

On Earth Day, April 22, 2009, Pollan endorsed Meatless Monday on the Oprah Winfrey Show and urged viewers to do the same. Oprah Winfrey subsequently cheered Meatless Monday on her show in February 1, 2011 and instituted Meatless Monday in the cafeteria of her Harpo Studios in Chicago (88). The food service company Sodexo, which provides meals for about 10 million people per day in the US, announced that they would offer Meatless Monday options on their corporate, healthcare, and college menus nationwide (89). The city of Aspen, Colorado, became the first city in the US to adopt Meatless Monday (90) and the following year, the Los Angeles City Council unanimously passed a resolution for making every Monday a Meatless Monday (91).

The Meatless Monday campaign began a full social media effort in 2009, disseminating teaching materials on how to implement Meatless Monday in cafeterias and providing meatless recipes on their website and through their newsletters (Peggy Neu, personal communication). Staff and researchers at the Center for a Livable Future were active in contributing materials for newsletters and blog posts (Peggy Neu, personal communication). The rise of food media, defined as discussions of food on social media and in newspapers and magazines, was a major driver of awareness for Meatless Monday (Peggy Neu, personal communication). Popular magazines and websites such as *Redbook*, *Women's Day*, and *Huffington Post Green* provided recipes for Meatless Monday (Peggy Neu, personal communication). The *Washington Post* began a weekly blog on Meatless Monday (Kim O'Donnel, personal communication).

A controversy about Meatless Monday erupted at the USDA in July 2012. An interoffice newsletter was circulated within the USDA that mentioned green (environmental) initiatives at the Washington DC headquarters. It was suggested that the department's cafeteria could participate in Meatless Monday, since "the production of meat, especially beef … has a large environmental impact … greenhouse gases and climate change are byproducts, as well as wasted energy resources." (92). In addition, high meat consumption was mentioned as not being good for personal health (93). The beef industry and politicians from beef-producing states raised an outcry, which prompted the USDA to declare publicly that they would not observe Meatless Monday in their cafeteria (92). The debate over Meatless Monday at the USDA was brought further to national attention by the late-night comedian Stephen Colbert on August 2, 2012, season 8. Although Meatless Monday was not established in the Washington office cafeteria of the USDA, the controversy raised greater awareness of Meatless Monday across the US.

Prominent celebrities and health advocates such as Yoko Ono, Kate Moss, Richard Branson, Robin Roberts of the US television show, "Good Morning America," and trainer Bob Harper of the US television show, "The Biggest Loser," expressed support for Meatless Monday (94). In 2012, a video promoting Meatless Monday, produced by The Humane Society of the United States, was selected out of 11,000 entries around the world for a Telly Award, the premier award, established in 1979, that honors video and television (95). Other prominent celebrities to express support for not consuming meat on

Monday included Beyoncé, Chris Martin, Reese Witherspoon, Tom Hanks, Rita Wilson, Orlando Bloom, Billie Eilish, and Ringo Starr (96). Meatless Monday received increasing attention from celebrity chefs, such as Katie Lee, Mario Batali, Wolfgang Puck, and John Fraser (97, 98). Over a 13-year period from 2005 to 2021, awareness of Meatless Monday increased from ~9% in 2005 to 38% by 2021 in a survey of a representative sample of US adults (99). The highest awareness rate was recorded in 2011, when 50% in the survey responded positively to the question, "Have you heard of Meatless Monday?" (100). Of those who were aware of Meatless Monday, 27% said that the campaign had influenced their decision to cut back meat (100). The New York City Public Schools began Meatless Mondays with the 2019–2020 school year (101). The Meatless Monday campaign, despite operating with an extremely limited advertising budget, spread on the merits of the idea and its uptake by the media and public.

7 Growing health concerns about high consumption of red and processed meat

When the Meatless Monday campaign began, total *per capita* meat consumption (beef, pork, poultry) in the US had increased by more than 60% from about 160 pounds per person in 1950 to more than 260 pounds per person by 2003 (102). Prior to 2003, public health experts were mostly focused on the relationship of saturated fats rather than meat consumption with cardiovascular disease (103). During the two decades that followed the founding of the Meatless Monday movement in 2003, new scientific reports linked high red and processed meat consumption with cardiovascular disease, diabetes, and cancer. High consumption of red and processed meat consumption was associated with an increased risk of stroke, coronary heart disease, and diabetes (105, 106). In 2016, the American Heart Association recommended to "limit intake" of processed meat (107). The dietary guidelines issued by the USDA continued to evolve from advice in 2000 to "Choose a diet that is low in saturated fat and cholesterol and moderate in total fat" (108) to include mention of the DASH Eating Plan in 2005 and 2010 in which a healthy diet pattern "… feature[s] less red and processed meat and more seafood than typical American diets" (109). In 2020, the *Dietary Guidelines for Americans* stated that dietary patterns with positive health outcomes were characterized by "lower consumption of red and processed meats," and that "About three-quarters of Americans meet or exceed the recommendations for meats, poultry, and eggs." (110).

In addition, higher dietary intake of red meat and processed meat was associated with greater risk of colorectal cancer (111, 112). In October 2015, the expert working group of the International Agency for Research on Cancer, the cancer agency of the World Health Organization, reviewed the scientific evidence and determined that the consumption of processed meat was "carcinogenic to humans" and that the consumption of red meat was "probably carcinogenic to humans" (112–115). The American Cancer Society issued guidelines in 2020 for a healthy dietary pattern that "limits or does not include red and processed meat" (116).

The link between red and processed meat with some types of cancer prompted some healthcare writers to recommend Meatless Monday to reduce the risk of cancer (117, 118). On NBC News, Allison Van Dusen, senior editor at the Mayo Clinic, touted the potential health benefits in heart disease and cancer risk of cutting back on meat through participation in Meatless Monday (119). The city of Vancouver observed Meatless Monday on June 10, 2013, partly to raise awareness about how scientific evidence showed that a diet high in processed and red meat increases the risk of colon cancer (104). The large US healthcare provider, Patient First, advocated Meatless Monday to reduce the chance of cancer and cardiovascular disease (120).

8 Meat production identified as major adverse cause of climate change

In 2006, the Food and Agricultural Organization (FAO) of the United Nations issued a seminal report regarding the impact of livestock production on the environment (121). Their analysis showed that the livestock sector accounted a substantial amount of greenhouse gas emissions (GHG) and global water use and was a major factor in deforestation and loss of species (121). The FAO report concluded: "… The impact of livestock on the local and global environment is so significant that it needs to be addressed with urgency. Information, communication and education will play critical roles in the promotion of an enhanced willingness to act. Consumers, because of their strong and growing influence in determining the characteristics of products, will likely be the main source of commercial and political pressure to push the livestock sector into more sustainable forms" (121). Further studies showed that the water footprint of beef production greatly exceeds the production of other major plant and animal foods (122).

An updated analysis by FAO showed that livestock, which include primarily ruminant (cattle, lamb) and monogastric (pigs, chicken) animals, account for 14.5% of total human-induced GHG emissions, with cattle contributing 65% of total livestock GHG emissions (123). In 2015, at the United Nations Climate Change Conference (Conference of the Parties [COP] 21), an international treaty known as the Paris Agreement was ratified to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels." If no changes are made to the current trends in global food systems, even with total reduction of fossil food emissions, it will not be possible to achieve the 1.5°C limit of the Paris Agreement (124). Scientists made suggestions how changes in food consumption could potentially lower GHG emissions. Simple dietary substitutions of chicken for beef would reduce GHG emissions by an estimated 48% and water use by 30% in US consumers (125). Substituting beef with beans in US diets could reduce GHG production even further and free up >40% of US cropland (126). In 2019, the EAT-Lancet Commission proposed a global reference diet, the planetary health diet, that was based on optimal nutrition for health and ecological sustainability (127). The planetary health diet emphasizes whole grains, plant proteins, fruits and vegetables, and modest amounts of meat and dairy (127). An analysis of country-specific dietary shifts in 140 countries by Kim and colleagues showed that adoption of a meatless day worldwide would reduce GHG and water footprints in high income countries but overall would be associated with a small global net increase in GHG and water footprints due to shifts from nutritionally inadequate diets in lower and middle-income countries (128). In the modeling of a meatless day diet, meat (defined as beef, pork, lamb, and

goat) was included in the six of seven days of the diet. The consumption of meat is low in countries such as India, Indonesia, and Pakistan, thus, in this model, a meatless day diet projected an increase in diet-related GHG production in countries with low consumption of meat (129).

The *Washington Post* blogger and cookbook author, Kim O'Donnel, got actively involved with Meatless Monday after she heard a speech delivered by UN climate expert and chairman of the Intergovernmental Panel on Climate Change (IPCC), Rajendra Pachauri, in which he said that the most important thing one could do for the planet is to reduce meat consumption (129). Paul McCartney decided to become involved with Meatless Monday after he read the 2006 report by FAO (121) regarding the large contribution of livestock production to greenhouse gas emissions (130). The 2014 IPCC report was a stimulus for reducing meat in the diet and inspired some to start with Meatless Monday (131).

9 Connecting public health, the environment, and animal welfare

The One Health movement, a collaborative effort of multiple disciplines to attain optimal health for people, animals and our environment (132), grew in prominence from 2003 to 2023. One Health emphasizes the interrelationships between human, animal, and environmental health (133). The American Veterinary Medical Association formed a task force on the One Health concept that resulted in a report, *One Health: A New Professional Imperative*, in 2008 (134). In 2009, a One Health office was established by the Centers for Disease Control and Prevention. Animal science specialists and veterinarians have emphasized that One Health is a platform for improving the welfare and health of animals raised in industrialized agriculture (132, 135).

In 2008, the Pew Commission on Industrial Farm Animal Production issued a report that assessed the industry's impact on the public's health, the environment, rural communities, and animal health and well-being. The report shed light on the industry's intensive practices in food animal production (meat, eggs and dairy), including the overuse of antibiotics, generation of highly concentrated hazardous wastes, confinement of farm animals, and the adverse environmental and health impacts on communities (136). To accommodate the industrial model, food producing animals and their environments are engineered to ensure high productivity. The animal welfare aspects of this report built upon earlier work, such as Ruth Harrison's *Animal Machines* (1964) (137), Peter Singer's *Animal Liberation* (1975) (138), and the Brambell report which codified what became known as the Five Freedoms, a minimal set of moral rights for farm animals to protect them against unnecessary suffering (139).

In 2016, the United Nations Committee on World Food Security addressed the environmental, economic, social and equity dimensions of the livestock component of agricultural systems. Recognizing the connections among farm animal welfare and other dimensions of agricultural development, the report recommended that action be taken to improve animal welfare and intensive livestock systems: "The biggest welfare wins can be achieved on farm, where animals spend most of their time. For example, moving from close confinement systems such as sow stalls (gestation crates) to group housing systems, and cage-free rather than battery cage layer hen production. Alongside legislative requirements in the EU, many large food companies now require commitments to phase in improved animal welfare in their supply chains, including major food service multinationals and producers" (140).

The Humane Society of the United States started a Meatless Monday initiative in 2011, when they hired Kristie Middleton. By 2016, there were 15 people working on the team, and they helped get 200 school districts to participate in Meatless Monday (141). When the University of Notre Dame adapted Meatless Monday in 2012, Kenny Torrella, coordinator at the Humane Society of the United States, remarked, "If each American chose meatless options just 1 day a week, more than a billion animals would be spared from factory farms each year …" (142).

10 Meatless Monday becomes a global movement

As global awareness of the environmental and health issues surrounding high meat production and consumption has grown since 2003, the value and relevance of Meatless Monday has increased as well. Meat-Free Monday campaign was initiated in the United Kingdom by Sir Paul McCartney and his daughters Mary and Stella in 2009 (143). The same year, Belgium launched Donderdag Veggiedag (Thursday Veggie Day) (144). With financial support of the Flemish government, vegetarian restaurants blossomed in the city of Ghent, and it soon became the reputed "veggie capital of Europe" (145). The Meatless Monday campaign, as "Segunda Sem Carne," was initiated in Brazil by the Sociedade Vegetariana Brasileira in 2009 (146). Meatless Mondays Australia was founded in 2009 by Deb Robbins and Vinita Chopra. They noted, "Meatless Monday Australia represents a creative, practical avenue for people around the world to help save the planet and its inhabitants. Not everyone can buy an eco-friendly car, some people may not have a garden, it may not be practical or safe for others to travel by public transport or on foot, but eating vegetarian meals 1 day a week can make a world of difference." (147). Meatless Mondays spread to over 40 countries (Figure 3), including the Philippines (148), Malaysia (149), United Arab Emirates (150), Singapore (151), and Israel (152).

The Norwegian Army adopted Meatless Mondays in 2013 (153). In order to raise consciousness about excessive meat consumption and soaring obesity rates in Argentina, the Casa Rosada, the presidential palace, instituted Meatless Mondays in 2017 (154). The Meatless Monday campaign conveyed the message "Less Meat = Less Heat" at the United Nations' Climate Change Conference (COP21) in Paris in December 2015 (155). Several Canadian universities, including McGill, Dalhousie, Queen's, and Langara College, adopted Meatless Monday (156). Colleges, high schools, and hospitals in Vancouver joined the Meatless Monday initiative in 2016 (157). In 2019, actors and celebrities, including Juliette Binoche, called for the adoption of "Lundi Vert" (Green Monday) as a meatless day in France (158, 159). The network of university restaurants across France started participating in 2019 by offering wider vegetarian options to fit the objectives of the "Lundi Vert" campaign (160). The Green Schools program, run by An Taisce, Ireland's leading national operator for environmental education programs, advocated Meatless Monday for secondary schools in Ireland (161).

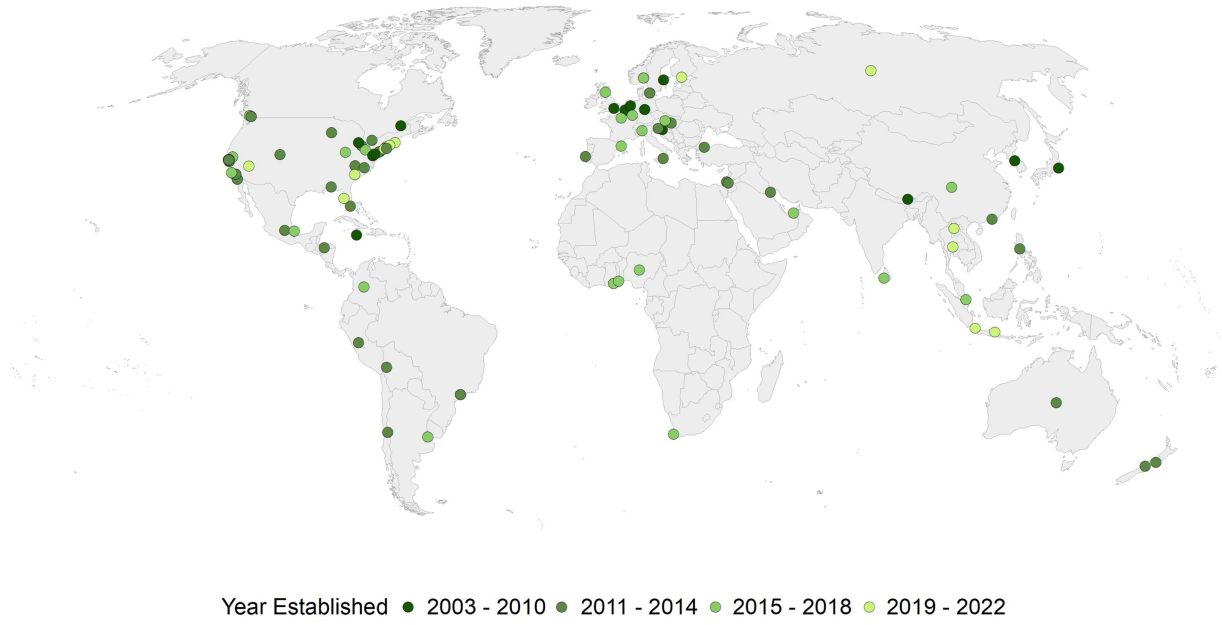

FIGURE 3
Global map of Meatless Monday activities, 2003–2022. Location of Meatless Monday activities in locations worldwide by time intervals in years specified.

11 Impact of the Meatless Monday campaign

Despite relatively high name recognition, there have been only a limited number of studies that have assessed participation in Meatless Monday or the impact of the Meatless Monday upon awareness of the health and environmental impact of meat consumption, attitudes toward meat consumption, or change in dietary habits. In France, a large cross-sectional survey showed that those who participated in "Green Monday" were more likely to be women, more educated, and with higher self-rated affluence compared with controls (162). A community survey of Meatless Monday participation in Bedford, New York showed that participants were more likely to be women and with higher income but no significant difference in education level compared with controls (163). Meatless Monday was evaluated for perceived message effectiveness in an online randomized study of 1,244 US adults aged 18 years and older (164). Subjects were randomized to control messages, Meatless Monday health-focused messages, or Meatless Monday environmentally-focused messages. Those exposed to the Meatless Monday messages showed greater intention to reduce meat consumption compared with the control group (164).

12 Future research

Future research could help address major gaps in knowledge regarding the impact of Meatless Monday on health, the environment, policymakers, and the food industry. The framing of the message about meat reduction can vary widely (165). What messaging by Meatless Monday has been the most influential? Behavior change is influenced by the need of people for information (166). Can the messaging of Meatless Monday be tested and improved to reduce consumption more effectively? Can response inhibition training (167) be applied to Meatless Monday to help people reduce their meat intake? The long-term effects of behavior change with Meatless Monday participants are not well characterized. For example, what proportion of participants in Meatless Monday eventually end up as flexitarians or vegetarians? What is the environmental impact when large school systems, such as New York City public schools as an example, observe Meatless Monday? What is the impact of large-scale implementation of Meatless Monday in public schools on food providers? What are the primary motivating factors for people to participate in Meatless Monday, and how does this differ around the world? Case studies could shed insight on underlying factors for either the success or failure of Meatless Monday initiatives and food policy around the world. If future research shows that participation in Meatless Monday leads to significant reductions in meat consumption, such dietary shifts have implications for health, the environment, and the food industry.

13 Discussion and conclusion

The concept of Meatless Monday was based upon meatless days in World War I and II when a large proportion of the US population widely practiced meatless days to conserve meat for the Allies and the troops. Based upon our historical review, we summarize the similarities and differences between the meatless days in World War I and II with the Meatless Monday campaign in terms of motivating factors, means of communication, scientific findings about meat, and other factors in Table 1. Antagonism to meatless days was relatively

TABLE 1 Approaches to meatless days in World War I and II and now.

	World War I and II	Meatless Monday campaign
World population	1.7 billion (1914) 2.0 billion (1939)	6.4 billion (2003) 8.0 billion (2023)
Meat definition	Beef, lamb, pork	Beef, lamb, pork, chicken
Motivating factors	Provide food for Allies Provide food for the troops Patriotism	Personal health Planetary health Animal welfare
Communication	Newspapers and magazines Signs and posters radio Door-to-door pledge campaigns	Newspapers and magazines Signs and posters Television Websites Social media
Local leadership	Mayors Restaurant associations	Mayors School administrations Food distributors
People of influence	Politicians Movie stars	Politicians Movie stars Rock stars Food writers Celebrity cooks Television talk show hosts
Scientific findings on meat	A source of protein that could be replaced by legumes	Consumption linked with heart disease, diabetes, cancer
Advice for households	Cookbooks Recipes in magazines	Cookbooks Recipes in magazines Recipes in social media
Antagonists	Not very vocal	Meat industry Politicians from meat-producing states

muted during World War I and II. The US meat industry, which has been a vociferous opponent of the current Meatless Monday campaign, uses an industrial animal model that did not exist during the first half of the twentieth century. With the Meatless Monday campaign, the motivations for observing a meatless day shifted to varied concerns about health, animal welfare, and the environment as seen, for example, in work by *Washington Post* food blogger Kim O'Donnel, involvement by Paul McCartney and the founding of Meat-Free Monday, and the involvement of the Humane Society of the United States in getting US public schools involved in Meatless Monday.

The strengths of this review are the involvement and contributions of three individuals who played a role in the early years of the Meatless Monday campaign (Peggy Neu, Pamela Berg, Shawn MacKenzie) and a comprehensive search of newspaper and periodical databases. A limitation of this review is that some parts of the world were not as comprehensively reported due to a focus on English, Spanish, Portuguese, and French and the paucity of newspaper and periodical databases in other languages and from low-and-middle-income countries and other parts of the world.

Meatless Monday grew steadily from 2003 to 2023 since its inception through advocacy by food writers, talk show hosts, and celebrity chefs, and through participation by schools, cities, restaurants, and institutions worldwide. During the same period, there were growing concerns about the environmental impact of meat production and adverse health consequences of high meat consumption. From numerous professional and scientific communities, several important findings and positions also contributed greater understanding of the impacts of high meat consumption and the practices associated with the industrial model. FAO linked livestock production with high GHG emissions. Hundreds of scientific papers showed that meat consumption increased the risk of cardiovascular disease, diabetes, and cancer. The World Health Organization issued a warning that processed meat was carcinogenic. US dietary guidelines emphasized a healthy dietary pattern that was high in fruit and vegetable and limited in meat consumption. International organizations expressed increasing concerns for farm animal welfare. Meatless Monday grew from relatively humble origins to a highly recognized worldwide movement that continues to raise awareness of healthy alternatives to meat consumption for personal and planetary health.

Author contributions

RS: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. PN: Investigation, Writing – review & editing. PB: Investigation, Writing – review & editing. JH: Methodology, Visualization, Writing – review & editing. SM: Funding acquisition, Writing – review & editing. RR: Conceptualization, Data curation, Project administration, Writing – review & editing.

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Factors that facilitate consumer uptake of sustainable dietary patterns in Western countries: a scoping review

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Objectives: This scoping review aims to describe factors that facilitate consumer-level transitions to more environmentally sustainable diets.

Methods: Using scoping review methods, four databases were searched for articles published in English examining facilitators to consuming an environmentally sustainable diet and focused on consumers, using data collected in Western countries, and were published between 2012 and 2022. Researchers extracted study characteristics and factors influencing adoption or uptake of sustainable foods or dietary patterns. Using this data, researchers conducted a thematic analysis to determine five main themes describing leverage points (modifiable) for dietary transitions.

Results: Results are reported per PRISMA guidelines: 21 studies were included with data from the U.K., U.S., Australia, and Europe. The results of this review indicate that values, knowledge, marketing, consumer-product relationships, and support networks, along with their respective subthemes, may be central drivers of consumer adoption of sustainable dietary patterns. Consumers are more likely to purchase and consume products which are familiar and appealing and align with their values. Cost, lack of knowledge, and lack of social support act as barriers to dietary change to more sustainable food choices. Income, education, ethnicity, sex, and employment were common individual-level characteristics identified as influential over likelihood of adopting environmentally sustainable dietary patterns. Individual-level characteristics create nuances in both likelihood to adopt, and the experience of barriers to adopting, sustainable dietary patterns.

Conclusion: Knowledge of leverage points and individual-level nuances is useful in informing strategies to facilitate transitions to more sustainable diets.

KEYWORDS

sustainable diet, dietary patterns, consumer, uptake, environmental sustainability, Western countries, scoping review

Introduction

The effects of human activity on climate change are well established and, as time progresses, the effects of climate change grow imminent (United Nations [Internet], n.d.-a) and increasingly unjust. If we fail to address this, temperatures could rise an additional three degrees by 2,100, pushing us into a climate system which is irreversible, unknown and unlikely to support food systems as we know them (United Nations [Internet], n.d.-a). Already, effects such as environmental degradation and increased frequency of natural disasters and extreme weather events (United Nations [Internet], n.d.-a) are impacting food systems (United Nations [Internet], n.d.-a) and the most acute and negative consequences are being borne by low and middle income nations who have contributed least to the problem. Food systems, and in particular highly industrialized, globalized food systems that dominate high-income Western nations, are a major component of humans' environmental impact (United Nations [Internet], n.d.-b). Approximately one-third of all human-caused greenhouse gas emissions are related to food, including agriculture and land use, refrigeration and food transport, and food waste (United Nations [Internet], n.d.-b). Therefore, it is important to consider dietary patterns in how we mitigate and adapt to climate change; in particular, the dietary patterns in Western nations.

Sustainable diets (SDs) consider both the health of the planet and the consumer. SDs are defined as "*diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.*" (Burlingame and Dernini, 2012, p. 7) Much of the available research on transitions to SDs focuses on the diet-environment relationship within this definition, and as a result figures prominently in this review. This includes research on dietary uptake of plant-based protein sources or other alternative proteins, such as fish and insects, as these options require less land and produce significantly fewer greenhouse gas emissions (Clark and Tilman, 2017). For similar environmental reasons, some research also examines *in vitro* or cellular meats, reducing food waste, choosing organic produce, and consuming seasonal fruit and vegetables.

Multiple factors contribute to the uptake of SDs (Paloviita, 2021). Therefore, researchers and practitioners have been working to understand and develop multifactorial strategies. For example, the Shift Wheel is a well-researched strategy document that proposes four complementary approaches for food businesses to use at a corporate level to encourage customers to choose more sustainable food products (Clark et al., 2020). Other strategies, such as nudging, choice architecture, and policy change have shown promising results at the population or individual level, to influence more sustainable choices (Ronto et al., 2022).

Health professionals, such as nutritionists, dietitians, physicians, etc., play a key role in facilitating dietary transitions through, for example, their work with individual dietary advice and population health promotion. Although helpful, the existing research about the roles of health professionals is largely conceptual in nature (Paloviita, 2021), or does not provide empirical evidence for specific strategies to promote SD uptake (Ronto et al., 2022). The purpose of this research is to review the evidence behind what factors and strategies facilitate the uptake of sustainable dietary patterns in Western nations. As a result of the available research, this review focuses on more environmentally sustainable dietary patterns. For brevity, SD will continue to be used to denote environmentally sustainable dietary patterns.

Methods

Design

A scoping review format for this research was used to do a broad search in an area where there are likely to be few publications (Arksey and O'Malley, 2005). Researchers used the search terms: (Food OR diet* OR nutr*) AND (sustainab* AND source) AND (transition OR facilitat* OR motivat* OR enable* OR obstacles OR barriers OR challenges OR support) AND (Australia* OR Canad* OR (United Kingdom or UK or England or Britain or Europe) OR (United States or America or USA or U.S). Databases included were: Medline, CINAHL, Nutrition and Food Sciences and PsycInfo. To guide systematic reporting of the results, researchers used the *PRISMA scoping review checklist* (Page et al., 2021). See Table 1 for the detailed search strategy. A forwards/backwards search strategy and expert consultation was also used to ensure literature important to answering this research question was not missed due to the constraints of the search terms.

Article screening

Primary research articles were included if (1) results related to the facilitation of SD uptake and (2) they studied Western countries (e.g., Canada, Western European countries, United States, Australia). Articles that did not address or consider the process of SD uptake and articles that took place in other countries were excluded. Reviews were also excluded. DistillerSR software was used by two independent researchers to screen and extract data. Three screening levels were created to screen the title, abstract, and full-text of articles and two screeners from the research team were assigned to each level. Four questions were used for each level to assess whether: (1) sustainability is a major concept, (2) the article focuses on food or diets, (3) the location of the study was considered a Western country, and (4) the study assessed factors that facilitate SD uptake. The research team did not specify what a sustainable food/dietary pattern was, but included those justified by the authors as more sustainable. Relevant review articles were retained as contextual literature but not included in the study.

Data collection and analysis

Data extracted on each of the articles was collected and collated collectively using an Excel spreadsheet. All researchers, with the exception of LC, JW and TE, extracted data on 3–4 articles. For each article, one researcher extracted data and cross checked with one additional team member if questions arose. From each article, researchers extracted data on the study design, country/countries where data collection took place, participant characteristics (see

TABLE 1 Database search strategy for article retrieval.

Date database was searched	Name of database searched	Number of articles retrieved	Limiters applied	Expanders applied
Sept 29, 2022	Medline	31	• English Language • Full Text • Year: 2012–2022	n/a
Sept 29, 2022	CINAHL	25	• Full Text • Abstract Available • English Language • Published between 2012 and 2022	• Apply related words • Apply equivalent subjects
Sept 29, 2022	Nutrition and Food Sciences	84	• English Language • Published between 2012 and 2022 • Type: Abstract • Item Type: Journal Article • Organisms: Man	n/a
Sept 29, 2022	PsycInfo	46	• Peer Reviewed • Published between 2012 and 2022	n/a

Search Terms (Food OR diet* OR nutr*) AND (sustainab* AND source) AND (transition OR facilitat* OR motivat* OR enable* OR obstacles OR barriers OR challenges OR support) AND (Australia* OR Canad* OR (United Kingdom or UK or England or Britain or Europe) OR (United States or America or USA or U.S). *The above search string was used for all databases.

Table 2), as well as key findings on factors that influence the uptake of sustainable diets (Table 3).

The research team then conducted a thematic analysis of factors influencing uptake of sustainable dietary patterns to make sense of potential leverage points, and used participant characteristic data where relevant to add nuance to the context in which those leverage points are most relevant. This thematic analysis is presented in the discussion of the results. No risk of bias assessment or quality assessment processes were used per scoping review methods (Arksey and O'Malley, 2005).

Trustworthiness

If any disagreement related to identification of the relevant literature, data collection and analysis was identified, the two researchers involved at each screening level would reach consensus through deliberation and consult the broader team if needed.

Results

Study characteristics

A total of 176 articles were identified for screening after duplicate records were removed. Twenty one studies were analyzed after the four-level screening; this included studies added from forward/backward searching and an expert in the field. Figure 1 details the article retrieval results (Page et al., 2021). Nineteen studies used a cross-sectional design (MacMillan Uribe et al., 2012; Vanhonacker et al., 2013; Grunert et al., 2014; Vainio et al., 2016; Hoek et al., 2017; Van Loo et al., 2017; Myers and Pettigrew, 2018; Grasso et al., 2019; Culliford and Bradbury, 2020; de Koning et al., 2020; Jodice and Norman, 2020; Vega-Zamora et al., 2020; Ali et al., 2021; Broeckhoven et al., 2021; Eustachio Colombo et al., 2021; Grasso et al., 2021; Hopkins et al., 2022; Mellor et al., 2022; Schiano et al., 2022), one was a randomized control trial (RCT) (Veltkamp et al., 2017), and one was a case study (Ramsing et al., 2021). The cross-sectional studies predominantly used qualitative surveys and interviews, although several used quantitative surveys (Grasso et al., 2019; de Koning et al., 2020; Jodice and Norman, 2020; Ali et al., 2021; Broeckhoven et al., 2021) or a combination of quantitative and qualitative surveys (MacMillan Uribe et al., 2012; Vainio et al., 2016). Four studies were conducted in the U.S (MacMillan Uribe et al., 2012; Grasso et al., 2019; Ramsing et al., 2021; Schiano et al., 2022),. three in Australia (Hoek et al., 2017; Myers and Pettigrew, 2018; Hopkins et al., 2022), and two in the UK (Culliford and Bradbury, 2020; Mellor et al., 2022). In addition, five studies were conducted in Northern and Western European countries, including Belgium (Vanhonacker et al., 2013), Finland (Vainio et al., 2016), The Netherlands (Veltkamp et al., 2017), Spain (Vega-Zamora et al., 2020), and Sweden (Eustachio Colombo et al., 2021). Six studies were carried out across multiple European countries (Grunert et al., 2014; Van Loo et al., 2017; Grasso et al., 2019; Ali et al., 2021; Broeckhoven et al., 2021; Grasso et al., 2021) and one was conducted globally (de Koning et al., 2020). Sample sizes ranged from 34 participants (Mellor et al., 2022) to 4,408 participants (Grunert et al., 2014). Methods of participant recruitment varied among studies; however, online recruitment via social media and emails was evident in the majority of study designs (Grunert et al., 2014; Hoek et al., 2017; Veltkamp et al., 2017; Grasso et al., 2019; de Koning et al., 2020; Jodice and Norman, 2020; Hopkins et al., 2022; Mellor et al., 2022). Other methods included specific market research agencies (MacMillan Uribe et al., 2012; Vanhonacker et al., 2013; Van Loo et al., 2017; Grasso et al., 2019, 2021; Schiano et al., 2022),street recruitment (Vega-Zamora et al., 2020) and paper advertisements (Myers and Pettigrew, 2018).

Types of sustainable foods/dietary patterns included in the literature

The types of sustainable foods or dietary patterns in the studies varied, including general SD choices or subtypes of SD choices. For instance, the majority focused on a combination of a broad range of food

TABLE 2 Summary of participant characteristics across 21 studies.

Author(s) and year of article	Sample size	Age	Sex	Socioeconomic Status (including income, education)	Race/Ethnicity	Data source country/ countries
Hoek et al. (2017)	944	Mostly 25–54 Median age: 40	Majority Female (65%)	Mostly medium-high education level and medium-high financial status	Representation from all states of Australia	Australia
Myers and Pettigrew (2018)	77	60+ (average = 73)	Mostly female ($n = 67$)	Not reported	Not reported	Australia
Hopkins et al. (2022)	601	18+ (mostly between ages 25–54)	Mostly female (76.2%)	Mostly higher education and higher income.	Not reported	Australia
MacMillan Uribe et al. (2012)	115	18 + (average of 42 years)	Mostly female (80.4%)	89% completed a bachelor's degree. 50% had a graduate or professional degree. 72.1% had made $60,000 or more.	Mostly non-Hispanic (92.2%) and/or White (95.2%)	United States
Jodice and Norman (2020)	575	Average of 53 years	54.5% female and 45.5% male	Majority had at least a college education. Over half were employed full-time. Over half making about $100,000/year.	Not reported	United States
Ramsing et al. (2021)	171	Majority (61%) 45–65	Mostly female (92%)	Majority College Degree or Higher (54%) and Majority have income of $100,000 USD+ (51%), Majority married (75%)	Majority Caucasian (85%)	United States
Schiano et al. (2022)	331	18–64 years, majority (75.2%) between 35–54	23.9% male, 76.1% female	Not reported	75.2% Caucasian, 17.2% Black, 4.8% Asian, 4.8% Latino/Hispanic, 1.2% other (check all that apply option so does not total 100%)	United States
Culliford and Bradbury (2020)	442	Mostly 25–54	Mostly female (66%)	Most with higher education (85%)	Not reported	United Kingdom
Mellor et al. (2022)	34	19–66 years, ($M = 34.06$, $SD = 83.27$)	64.7% female, 35.3% male	94% above high school, 6% at least high school; 53% employed, 41% students, 6% retired	Not reported	United Kingdom
Vanhonacker et al. (2013)	221	18+ Mostly 18–30 and 46–60.	Majority female (64%)	Mostly higher education level (77%), Well-off financial status (65%)	Flemish	Belgium
Vainio et al. (2016)	1,048	Majority aged 25–64 years (81%)	Almost half and half, but more females (58%)	Most (44%) had completed no more than secondary level education	Not reported	Finland
Veltkamp et al. (2017)	340	25–50	221 (65%) female, 119 (35%) male	Not reported	Not reported	The Netherlands
Vega-Zamora et al. (2020)	776	25–65	60% female, 40% male	50% university educated	Not reported	Spain
Eustachio Colombo et al. (2021)	42	10–11, 14–15, 18+	Equal male & female	Parents without postsecondary was 42% in School 1, 70% in School 2 and 60% in School 3	Not reported	Sweden
Grunert et al. (2014)	4,408	Varies by country, but mostly equally spread between 18 and 55+ years	Approximately equal proportion of male vs. female but variation between countries	Majority had no children. Predominantly a "medium" level of education (vocational or upper secondary). Social class divided among five levels, with the largest proportion in level highest level.	Not reported	United Kingdom, France, Germany, Spain, Sweden, Poland

(Continued)

TABLE 2 (Continued)

Author(s) and year of article	Sample size	Age	Sex	Socioeconomic Status (including income, education)	Race/Ethnicity	Data source country/ countries
Van Loo et al. (2017)	2,783	18–65	50% male, 50% female	Majority high education level and working full-time	Not reported	United Kingdom, Germany, Belgium, the Netherlands
Grasso et al. (2019)	1,825	55.9% between 65 and 69, 44.1% between 70 and 90	50.4% male, 49.6% female	59.6% below post-secondary, 40.4% post-secondary or above	Not reported	United Kingdom, the Netherlands, Poland, Spain, Finland
Ali et al. (2021)	291	18+	Mostly female	Highly educated	Not reported	Italy, Germany, Netherlands, Finland
Broeckhoven et al. (2021)	2,500	65+ (53.5% were 65 to 69 years old. 46.5% were 70years or over).	Mostly male (52.3%)	62.4% completed secondary education or lower education. Most (64.4%) had a household income of over €2000.	Not reported	The Netherlands, UK, Poland, Finland, Spain
Grasso et al. (2021)	2,478	85.4% between 65 and 74 years, remainder 75+	52.2% male, 47.8% female	62.2% below Bachelor level, 37.8% Bachelor or higher	Not reported	United Kingdom, the Netherlands, Poland, Spain, Finland
de Koning et al. (2020)	3,091	16+	59.2% females, 38.9% males, 1.9% preferred not to answer.	Not reported	Not reported	China, USA, France, UK, New Zealand, Brazil, Spain, Dominican Republic

and dietary pattern choices justified by the authors as being more sustainable, such as organic food, alternative protein sources, and eating less meat (MacMillan Uribe et al., 2012; Vanhonacker et al., 2013; Hoek et al., 2017; Veltkamp et al., 2017; Grasso et al., 2019; Culliford and Bradbury, 2020; Broeckhoven et al., 2021; Eustachio Colombo et al., 2021; Grasso et al., 2021) Three studies focused on the general uptake of plant-based protein (Vainio et al., 2016; Van Loo et al., 2017; de Koning et al., 2020), while some specifically focused on plant-based milk (Schiano et al., 2022), sustainable plant production methods (Ali et al., 2021), or the reduction of meat intake (Ramsing et al., 2021). In addition, one study focused on sustainable seafood consumption (Jodice and Norman, 2020), some studies explored entomophagy (Myers and Pettigrew, 2018; Hopkins et al., 2022), including the perspective of seniors (individuals over the age of 65) (Myers and Pettigrew, 2018), and a study explored algae consumption (Mellor et al., 2022). Organic food consumption (Vega-Zamora et al., 2020) and sustainable food labels (Grunert et al., 2014) were also explored by two other studies.

Participant characteristics as factors influencing uptake of sustainable dietary patterns

Participants were predominantly female, with only six studies (Grunert et al., 2014; Grasso et al., 2019; Broeckhoven et al., 2021; Eustachio Colombo et al., 2021; Grasso et al., 2021) using approximately equal proportions of male and female participants. The majority of studies examined participants between the ages of 18–64 years old with medium-to-high education and income levels. Notably, the majority of studies did not disclose race or ethnic representation. See Table 2 for participant characteristics.

Income, education, country of residence and sex were common individual-level factors identified as influential over likelihood of adopting SD. People with higher incomes were more likely to be educated on topics of sustainability such as entomophagy (Hopkins et al., 2022), and more willing to pay food premiums for "healthy," sustainable or organic food products (Veltkamp et al., 2017; Ali et al., 2021; Schiano et al., 2022). Contrastingly, they were also more likely to eat out (Jodice and Norman, 2020), and consume more meat than other consumers (Vanhonacker et al., 2013; Ramsing et al., 2021). Participants with higher education levels consume an increased variety of food; and are more willing to try alternative protein sources such as insects (Grasso et al., 2019; Hopkins et al., 2022). However, education level has been negatively related to interest in local foods (MacMillan Uribe et al., 2012). In addition, people with higher education levels may be more aware of environmental sustainability and health benefits of plant-based diets; and are willing to pay more for "healthy" and sustainable food products (Van Loo et al., 2017; Grasso et al., 2019; Culliford and Bradbury, 2020), though two studies challenge this. One study found no significant difference between education level and adoption of plant-based diets (Culliford and Bradbury, 2020), while another found that having lower education increased plant protein consumption (Vainio et al., 2016). Employment status was collected for three articles (Van Loo et al., 2017; Jodice and Norman, 2020; Mellor et al., 2022) but was not thoroughly assessed.

Ethnicity/race demographics were collected in three articles (MacMillan Uribe et al., 2012; Ramsing et al., 2021; Schiano et al., 2022) but were not directly mentioned in the discussion section of these articles. However, country of residence was a predictor of SD uptake in two studies. People living in Poland were more likely to eat plant-based protein sources and less likely to eat *in vitro* meat

TABLE 3 Key themes influencing uptake of sustainable diets.

Main themes	Sub themes (Factors)	Article (Authors, Year)
Knowledge	• Sustainability • Food safety • Health • Information source	Vanhonacker et al. (2013), Grunert et al. (2014), Van Loo et al. (2017), Myers and Pettigrew (2018), Jodice and Norman (2020), Ali et al. (2021), Eustachio Colombo et al. (2021), Ramsing et al. (2021), Hopkins et al. (2022), Mellor et al. (2022), Schiano et al. (2022)
Marketing	• Media influences • Point-of-purchase actions	MacMillan Uribe et al. (2012), Grunert et al. (2014), Jodice and Norman (2020), Grasso et al. (2021)
Consumer-product relationships	• Willingness to pay • Sensory appeal • Familiarity	Vanhonacker et al. (2013), Vainio et al. (2016), Hoek et al. (2017), Veltkamp et al. (2017), Myers and Pettigrew (2018), Grasso et al. (2019), Culliford and Bradbury (2020), de Koning et al. (2020), Jodice and Norman (2020), Vega-Zamora et al. (2020), Broeckhoven et al. (2021), Grasso et al. (2021), Eustachio Colombo et al. (2021), Hopkins et al. (2022), Mellor et al. (2022), Schiano et al. (2022)
Support networks	• Community groups • Friends and family • Social norms • Peer pressure	MacMillan Uribe et al. (2012), Vainio et al. (2016), Broeckhoven et al. (2021), Eustachio Colombo et al. (2021), Ramsing et al. (2021)

compared to those living in the UK (Grasso et al., 2019). In addition, people living in Poland were classified as 'medium' meat consumers compared to the Netherlands who were considered 'heavy' meat eaters (Grasso et al., 2021). Another article also determined that the Netherlands, Finland, and Spain were more likely to consume insect protein sources when compared to data collected from the UK (Grasso et al., 2019).

Sex was another common social demographic factor among all the articles. Female participants commonly expressed more disgust when asked if they would consume insect protein, cellular meats and *in vitro* meat-based protein sources (Myers and Pettigrew, 2018; Grasso et al., 2019; Hopkins et al., 2022). Males were more willing to eat insect species and products such as insect-based flour, chocolate-coated ants, crickets, ants, etc. (Hopkins et al., 2022). Females were found to be more accepting of meat alternatives when compared to males (Grasso et al., 2019), possibly due to increased awareness of food-related environmental and health consequences (MacMillan Uribe et al., 2012; Culliford and Bradbury, 2020). Females also perceived a larger environmental benefit with reducing food waste, choosing sustainable fish, choosing organic produce, and consuming seasonal fruit and vegetables (Culliford and Bradbury, 2020). Females are willing to pay more for 'healthy' and sustainable food options as they are more concerned about sustainability and reading food labels (Grunert et al., 2014; Ali et al., 2021). Finally, females are more likely to reduce meat consumption (Grasso et al., 2021) and adopt a plant-based diet because they tend to be more health conscious and are more likely to acknowledge environmental and public health benefits (Vainio et al., 2016; Van Loo et al., 2017; Grasso et al., 2019; Culliford and Bradbury, 2020).

Factors driving uptake of sustainable dietary patterns

Thematic analysis suggests a range of interrelated factors influencing uptake of sustainable dietary patterns. Five broader themes were identified, as seen in Figure 2: marketing, consumer-product relationships, knowledge, support networks and values. This latter theme served as a central theme as values also influence how the former themes may influence dietary patterns. At a more granular level, each theme included sub themes, or factors, driving uptake of SD.

Consumer knowledge of the food product included factors such as product sustainability, food safety considerations, and health considerations, as well as the perceived quality of the source of the information. Marketing, as a theme, captured actions which influence consumer attitudes and behaviors based on how products are advertised. This included the subthemes media influences and point-of-purchase techniques. Product-consumer relationships as a theme included factors such as willingness to pay a specific price, sensory appeal and familiarity. Finally, support networks, as a theme, included social factors such as community groups, friends and family, social norms and peer influence, all of which may impact how consumers interact with a product.

The values theme was conceptualized as central to the other four themes as values are the filter through which most other themes and factors are interpreted. For example, just as knowledge of a food or food product's healthfulness and sustainability may influence dietary patterns, whether this knowledge is acted on is influenced by whether those are important values held by the consumer. Similarly, values influence each of the other factors and themes identified.

These themes are discussed below in the context of the results related to participant characteristics to provide nuance to these relationships.

Discussion

Knowledge

This research suggests that knowledge remains one important component of uptake. Several articles identified the need for increased consumer knowledge about sustainable food choices (Vanhonacker et al., 2013; Jodice and Norman, 2020), to increase acceptance (Myers and Pettigrew, 2018). Even when consumers want to eat, or think they are eating sustainable food, they may lack the appropriate knowledge to properly identify sustainable foods (Jodice and Norman, 2020). By

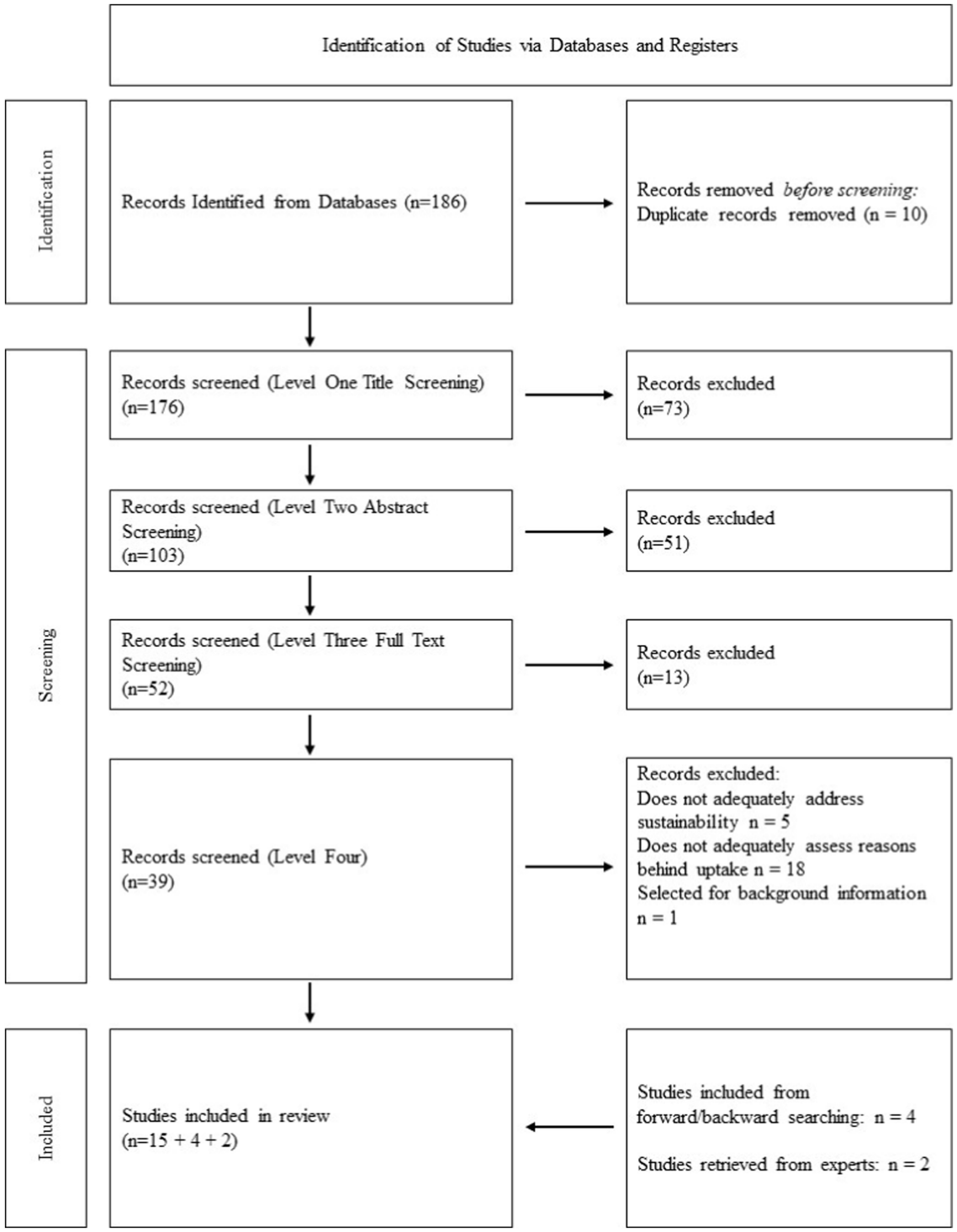

FIGURE 1
PRISMA flowchart depicting article retrieval process.

providing increased opportunity for learning, and practical tools like recipe ideas (Mellor et al., 2022) more consumers have become willing to eat sustainable food (Hopkins et al., 2022). This is particularly true if the sustainable alternative is similar to a product they are already familiar with (e.g., insect flour, see also Consumer-product relationships below) (Hopkins et al., 2022). One study suggests that campaigns promoting SDs should focus on raising awareness of the environmental benefit of prioritizing plant-based proteins and choosing organic produce; these findings suggest a knowledge gap in consumer understanding despite an awareness of packaging and food waste (Culliford and Bradbury, 2020) Knowledge that a product is food safe (Myers and Pettigrew, 2018) (e.g., safe even if novel food production methods) (Ali et al., 2021) also helped consumers to have greater acceptance of more sustainable foods/diets.

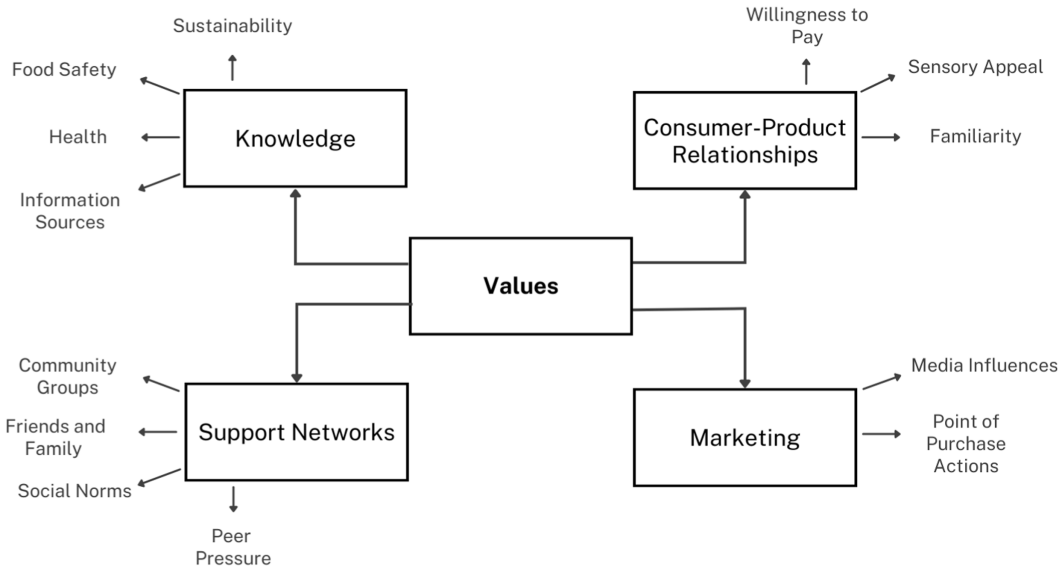

FIGURE 2
Mind map of key themes influencing uptake of sustainable diets.

Highly educated consumers may have more opportunities to learn about sustainability and transition to SDs (Grunert et al., 2014) compared to consumers who have lower education levels (Vainio et al., 2016). Some research singles out employees that work with food (i.e., kitchen staff) as less able to engage in sustainable dietary choices (Eustachio Colombo et al., 2021). In this study, kitchen staff were connected to the food system and wanted to make sustainable food choices, but their actual dietary choices did not reflect what they wanted to eat, possibly due to fewer opportunities or resources (Eustachio Colombo et al., 2021). These findings connecting knowledge, education level, as well as access to opportunities and resources, highlight the well-understood fact that agency is a mediating factor to translating knowledge to action for healthy and sustainable diets. Efforts to transition to sustainable dietary patterns at a population level will need to be informed by equity-based approaches (IPES-Food, 2017).

Consumers' preconceived ideas, or prior knowledge of sustainable food can impact their food choices. For example, when comparing the perception of sustainable foods to healthy foods, many consumers expected products perceived as sustainable to taste worse (Van Loo et al., 2017; Veltkamp et al., 2017). It may therefore be beneficial to use healthy and sustainable as interchangeable terms (Van Loo et al., 2017) promotion, with the rationale that foods and dietary patterns are not sustainable if they are not healthy (Broman and Robèrt, 2017). Lastly, as knowledge provision alone is insufficient (Grasso et al., 2021) there needs to be a combination of interventions in place to successfully implement dietary change. Additional factors to consider in such interventions are discussed below.

Marketing

Point-of-purchase actions describe what consumers are buying and what factors lead them to make these purchases at the time of purchase. Product packaging plays a large role in what consumers are buying. Yet the current sustainability labels are not playing a large role in point- of- purchase choices (Grunert et al., 2014). Placing instructions, cues or prompts for more sustainable product choice on packaging could encourage purchasing behaviors (Mellor et al., 2022). Health claims that include the term "sustainable" on product packages could also help persuade consumers to purchase sustainable foods (Vainio et al., 2016); however, food labeling is highly regulated in Western countries and would depend on government standards and approvals, which would take time to implement. Alternatively, third-party sustainability labels ("ecolabels") have been explored (Grunert et al., 2014). These are not federally regulated, but rather, are certifications obtained by organizations who set independent standards (e.g., Fair Trade International).

Mass media, including social media and television, can be helpful (social) marketing methods to provide reliable and valid information to consumers, since this is a primary source of consumer health information (Myers and Pettigrew, 2018; Schiano et al., 2022). It is important to acknowledge that consumers receive information from various sources. Thus, it would be impactful to disseminate information about SDs through multiple media sources. This approach is also vulnerable to dilution by the volume of information coming from available through the same media channels. This product marketing landscape is confusing for consumers with conflicting messages coming from, for example, food manufacturers and trade associations and in some countries without adequate regulatory oversight (Kraak, 2021).

Product-consumer relationships

Product-consumer relationships refer to how certain characteristics of a product, including willingness to pay, familiarity, and sensory appeal influence consumer actions. Pricing of products directly influences consumers' willingness to pay and this is related to consumer values. Nine of the 21 studies (Vanhonacker et al., 2013;

Vainio et al., 2016; Hoek et al., 2017; Culliford and Bradbury, 2020; de Koning et al., 2020; Vega-Zamora et al., 2020; Broeckhoven et al., 2021; Eustachio Colombo et al., 2021; Mellor et al., 2022) examine how willingness to pay higher prices for meat alternatives is moderated by factors such as consumer values, and how price can, in turn, moderate the strength of these values. Two studies found that consumers were more willing to consume alternative proteins than to pay for them (Vanhonacker et al., 2013; de Koning et al., 2020), while other studies illustrate some nuance: that consumers are usually less willing to pay a price premium for plant-based meat alternatives, but are more likely to try more sustainable meat options if priced at a lower cost. For example, the demand for kangaroo meat (as a replacement for beef) rose from 26 to 35% once the price was lower than that of beef (Hoek et al., 2017). However, despite this increase in demand, few participants were willing to try the kangaroo meat, highlighting that price is just one determinant among many. Willingness to pay for more sustainable food products is also moderated by household budgets, and therefore socioeconomic factors such as employment and income; however, these are not explored in the included literature. Theoretical work suggests that government-led price intervention can reduce environmental impacts of meat and dairy food sectors (Säll and Gren, 2015), and empirical evidence shows likely impact on consumer adoption of more sustainable dietary patterns. According to Cawley and Frisvold, taxes on sugar sweetened beverages, a category of foods with well-established negative health and environmental impacts, generally decrease purchasing or sales of these products (Cawley and Frisvold, 2023). Fiscal incentives to adopt more sustainable dietary patterns show promise, could support those who would choose more sustainable choice patterns but for whom price is a strong moderating factor.

Both sensory appeal and familiarity are related to consumers' willingness to consume and purchase alternative proteins. Familiarity with products was found to increase purchasing behavior (Jodice and Norman, 2020; Schiano et al., 2022) and dishes that closely mimicked familiar meat increased the likelihood of consumption (Broeckhoven et al., 2021; Eustachio Colombo et al., 2021). In agreement with this finding, consumers were also less willing to consume products that looked unfamiliar or contained unfamiliar ingredients (Grasso et al., 2019, 2021; Mellor et al., 2022). This was partly because consumers did not have knowledge on how to prepare unfamiliar ingredients, such as algae (Mellor et al., 2022). One study highlighted that some consumers are less willing than others to try new foods unfamiliar to them, which is a well-accepted phenomenon (Grasso et al., 2019). This factor is likely a contributor to why plant-based proteins (which are already common foods, such as legumes) were commonly accepted alternative proteins, as compared to more novel products.

Not only was familiarity of the product important to consumers, but it was also important that alternative proteins have an enjoyable taste, texture, and smell (i.e., sensory appeal) (Vanhonacker et al., 2013; Veltkamp et al., 2017; Myers and Pettigrew, 2018; Grasso et al., 2019; Broeckhoven et al., 2021; Eustachio Colombo et al., 2021; Grasso et al., 2021; Mellor et al., 2022). Often, ensuring sensory appeal for consumers involved alternative proteins that looked and tasted like meat and had the same texture as meat (Vanhonacker et al., 2013; Eustachio Colombo et al., 2021; Mellor et al., 2022). Many consumers were less willing to try insect- or single-cell-based alternative proteins (Vanhonacker et al., 2013; Myers and Pettigrew, 2018; Grasso et al., 2019; de Koning et al., 2020); however, sensory changes to these products, such as disguising insects through insect-based flour, or in other familiar foods as suggested by older adults (Myers and Pettigrew, 2018) could help overcome disgust (Myers and Pettigrew, 2018; Hopkins et al., 2022; Mellor et al., 2022).

Support networks

Social networks were identified as a key factor in dietary transition in multiple studies (MacMillan Uribe et al., 2012; Vainio et al., 2016;Eustachio Colombo et al., 2021; Ramsing et al., 2021). Social networks consider the social context in which meals are eaten as well as the pressure to conform to social norms. Strong and supportive social networks, including friends and family who eat similar foods and refrain from judgement, have been shown to be positive facilitators for sustainable food choices (Vainio et al., 2016). In addition, programs which provide built-in social support, such as membership in community-supported agriculture (CSAs), have been found to support sustained behavior change (MacMillan Uribe et al., 2012). Conversely, food preferences of friends and family within a consumer's social network can also be a barrier to behavior change (Eustachio Colombo et al., 2021; Ramsing et al., 2021), such as when friends and family are heavy meat consumers. One study of the Meatless Monday challenge highlights the value of community-based efforts in initiating and maintaining sustainable dietary patterns (Grasso et al., 2021). Adolescents are especially susceptible to peer pressure (Eustachio Colombo et al., 2021). If a teen's friend group declares their disdain for plant-based meals, the teen may feel less inclined to eat these foods (Eustachio Colombo et al., 2021). The importance of social networks provides the theoretical foundation of some action research to facilitate uptake of sustainable dietary patterns and food citizenship (Warner et al., 2013). This research suggests networks where consumers are able to support each other in their dietary choices may strongly influence uptake, and that current social norms can be influenced so that sustainable dietary choices become the norm.

Values

This major theme underpins the other five themes since individuals' values shape their knowledge acquisition, product-consumer relationships, and support networks as well as influence their response to marketing strategies. A few examples illustrate this relationship. While knowledge of what is more sustainable and healthy (e.g., legumes) influences behavior, consumers who also *value* sustainability and health were more likely to eat alternative proteins such as legumes (Vainio et al., 2016; Veltkamp et al., 2017; Mellor et al., 2022), as long as the decision was not overridden by other important factors, such as being accessible and easy to prepare. Furthermore, consumers who valued health and environmental sustainability were more likely to show initiative to seek out sustainable foods (Grunert et al., 2014; Culliford and Bradbury, 2020; Eustachio Colombo et al., 2021). Interventions aiming to transition consumers to sustainable dietary patterns must consider the values of consumers.

Another example of how values influence factors previously presented is that consumers will pay more for what they value. The price of a product was a large determinant of whether consumers would opt for the sustainable option. Along with convenience, these

factors are often reported as barriers to choosing sustainable products (Vainio et al., 2016; Hoek et al., 2017; Broeckhoven et al., 2021; Eustachio Colombo et al., 2021).

Strengths and limitations

This review uncovered strong thematic consistency in the literature, suggesting results that provide reliable insight into determinants of SD uptake. This scoping review relied on a wide range of reputable databases to minimize selection bias and multiple researchers involved in screening, extracting and analyzing the data to maximize reliability of the data. The studies included in this review relied on large sample sizes, increasing the validity of the results and themes emerging in this review. However, many of the studies in this review had sample populations with higher education, middle income, and mostly female participants, influencing the population-level generalizability of these study results.

Some of the available research relies on psychosocial theory and the assumption that intention to choose certain foods or dietary patterns increases likelihood of action. We recognize that there are intervening factors that disrupt this theoretical assumption, and these have been included in the Discussion section.

Conclusions and implications

The results of this review indicate a number of themes, knowledge, marketing, consumer-product relationships, and support networks, along with their respective subthemes, are central drivers of consumer adoption of sustainable dietary patterns, and that values are strongly influential on each of these themes, respectively. The themes identified in this research can be helpful to inform a multi-sector, multidisciplinary approach necessary to influencing uptake of sustainable dietary patterns (Springmann et al., 2018). The implications of this research are relevant to several sectors. In the private sector, and for the food industry specifically, modifications to product packaging claims such as sustainability or eco-labels and point-of-purchase incentives, including price reductions for sustainable products, will likely encourage consumer purchasing. For governments, food policy can amplify industry efforts; subsidies and taxes that incentivize purchasing on sustainability and dissuade less sustainable purchasing shows significant promise, though this area of food policy is nuanced. Adjusting policy and product packaging guidelines to standardize and ensure health/sustainability claims is also recommended. These efforts may influence consumers' openness and willingness to pay for, or try foods, as well as increase opportunities for greater consumer awareness and understanding of SD. For health professionals, such as dietitians, nutrition education focused on healthy and sustainable dietary patterns is helpful to increase access to evidence-based information that balances health and sustainability, and knowledge is still an important driver of behavior change. While knowledge is important, evidence points to creating supportive social environments as a strong lever for uptake and maintenance of more sustainable dietary patterns. At the community and institutional level, campaigns such as Meatless Mondays, which emphasize activities that are done together and normalize novel behaviors, can help spark social networks.

Dietary patterns that are inclusive of health, environmental, and economic sustainability will vary by geographic, temporal and cultural context (Willett et al., 2019); therefore the "one shoe fits all" approach is not applicable. Some combination of efforts will likely be needed in line with the understanding that values will mediate individual response to various intervention approaches.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SS: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. AG: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. RK: Writing – original draft, Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. AS: Writing – original draft, Conceptualization, Data curation, Investigation, Methodology. MM: Writing – original draft, Conceptualization, Data curation, Investigation, Methodology. DN: Writing – original draft, Conceptualization, Data curation, Investigation, Methodology. LC: Funding acquisition, Resources, Supervision, Writing – review & editing, Conceptualization. JW: Funding acquisition, Resources, Supervision, Writing – review & editing, Conceptualization. TE: Funding acquisition, Resources, Writing – review & editing, Conceptualization.

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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.

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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.2024.1333742/full#supplementary-material

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Simulation of the impact of changes in the volume of production and export of products on the food security of the country: on the example of Ukraine

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Changes in the production of agricultural products in Ukraine are analyzed. Forecasting of the volume of exports of agricultural products from Ukraine until 2027 was carried out. The following factors were taken into account: projected changes in real GDP in those countries that are the main importers of these products; reduction of cultivated agricultural land caused by military actions; forecasted changes in the population of Ukraine during the forecast period. It was concluded that there are no threats to Ukraine's food security caused by changes in the production and export of agricultural products. The research was based on a forecasting method, which made it possible to take into account retrospective information and a number of internal and external factors affecting the processes of production and export of agricultural products. The sources of information were the data of the International Monetary Fund and the State Statistics Service of Ukraine. The hypotheses of the study were confirmed, and the results showed that the volume of production of agricultural products will be sufficient to support the population of the country, while maintaining the previous proportion of exports. At the same time, there is a potential for growth of the share of products that Ukraine can export. The forecast volumes of export of Ukrainian agricultural products obtained can serve as a guideline for regulating exports, taking into account the issue of food security in Ukraine.

KEYWORDS

agricultural production, import of Ukrainian products, food, food security, Ukrainian export

1 Introduction

Food security is a certain indicator that gives predictions about the probability of hunger in different countries of the world. Today, a lot of attention is paid to the issue of fighting hunger (Horn and Ferreira, 2022). This is evidenced by the content of the Sustainable Development Goals (SDGs), among which Goal #2 is formulated as follows: End hunger, achieve food security

and improved nutrition and promote sustainable agriculture (https://ourworldindata.org/sdgs/zero-hunger). After all, global warming, natural disasters (floods, droughts, fires, and earthquakes), wars, and the rapid growth of the population are the cause of the imbalance of food security, which causes hunger, especially in developing countries. The Food and Agriculture Organization of the United Nations (FAO) notes that the share of undernourished people is an indicator of a country's food security. Research data indicates that the world population is growing and is projected to reach 9.2 billion by 2050 (Silva, 2018). This will lead to an increase in the demand for food. The author notes that it is necessary to increase agricultural production by ~60–70% in order to ensure adequate nutrition for the world population by 2050 (Our World in Data Team, 2023). In their study, scientists (Pawlak and Kołodziejczak, 2020) emphasized the role of agriculture (Bashynska, I.,) in ensuring food security in developing countries in the context of the problem of sustainable food production. Indeed, many sub-Saharan African regions are highly dependent on imported crops (e.g., rice and wheat) and agricultural inputs (e.g., fertilizers), which exposes such countries to a greater risk of food insecurity imbalances due to disruptions in the global supply chain (Koval et al., 2023) caused by the COVID-19 pandemic and the ongoing war in Ukraine (Ben Hassen and El Bilali, 2022).

State governments ensure that food products are available to all categories of the population, as well as that strategic food stocks are replenished in case of emergency situations (harvest failure, natural disasters, man-made disasters, military actions, etc.). International organizations, together with FAO (FAO et al., 2022), draw attention to the fact that the war in Ukraine disrupts supply chains and significantly affects the prices of grain, fertilizers and energy. In particular, in the first half of 2022, this led to a further increase in the price of food products in the world (Horn and Ferreira, 2022). Military conflicts can create a threat to food security, both in Ukraine itself and in other countries of the world where Ukrainian products are exported (Bochko et al., 2022, 2023). It is important to emphasize that it is Ukrainian agricultural products that play an important role in ensuring the food security of many countries. However, the war and the consequences of military operations created such conditions that became barriers to the normal operation of the country's agricultural sector. The specified circumstances may cause a decrease in the volume of production of agricultural products in Ukraine and its export to other countries of the world, as well as affect the food security of Ukraine.

Taking into account that agriculture has a much greater impact on reducing poverty and improving food security than other sectors of the economy, the purpose of the article is to investigate how the change in the volume of production and export of Ukrainian agricultural products affects the food security of Ukraine itself. At the same time, it is necessary to take into account that during the period of the Russian-Ukrainian war and after its end the economic conditions will continue to change not only in Ukraine, but also in other countries, including those that import a significant amount of Ukrainian agricultural products.

To achieve the set goal, the actual task is to forecast these volumes (for the period until 2027) taking into account changes in export directions, which are also caused by logistics problems, political and economic relations of importing countries with Ukraine. An important task from the point of view of the strategic vision of the development of the national economy of Ukraine and ensuring food security is forecasting the volumes of production and export of Ukrainian agricultural products, which in combination with the results of research previously conducted in the field of the agricultural sector (Dziurakh et al., 2022; Nagurskyy et al., 2022) will contribute to the solution of these problems.

2 Literature review

A large number of scientific works and practical research data indicate the growing interest of both scientists and practitioners in the development of issues that raise vital issues at the global level (Horin, 2020; Pawlak and Kołodziejczak, 2020; García-Díez et al., 2021; Shpak et al., 2021a,b; Tanveer et al., 2024; Verni et al., 2024). In order to achieve the goal of the research, the main attention will be focused on a more detailed study of such areas of problems as food safety; the relationship between agriculture and food security, as well as the key role of the agricultural sector of Ukraine in the formation of its food security, since this directly affects the food security of other countries at the global level.

2.1 Food security

Food security is considered a measure of population access to food (García-Díez et al., 2021). Scientists Lv et al. (2022) emphasized that food security is achieved when every individual has continuous physical, social, and economic access to an ample supply of safe, nutritious food that aligns with their dietary requirements and personal nutritional preferences, promoting active and healthy lifestyle. Often, researchers attribute food security to economic security. For example, Hrynyshyn (2020) argues that crafting a national development strategy involves taking into account various indicators of economic security, with particular emphasis on factors such as food self-sufficiency and food sovereignty. He suggests defining the food security system as a comprehensive framework encompassing organizational, economic, social, legal, informational, scientific, innovative, and ecological measures. These measures aim to safeguard the essential interests of individuals, communities, regions, and the state by ensuring the physical, economic, and social accessibility, safety, and quality of food products, as well as the stability of food supply and food sovereignty. Horin (2020) attributes food security to national and economic security and suggested considering a number of indicators that characterize food security. Among these indicators, she considers it expedient to take into account those that determine the actual state of food consumption by the country's population, compared to specific threshold criteria, the values of which are given in official government documents and statistical data. This is also stated in the *Methodology for calculating the level of economic security of Ukraine* (Ministry of Economic, 2013), where for the assessment of food security, calculations of indicators are provided, most of which are based on data from the statistical collections "Balances and consumption of basic food products by the population of Ukraine" and "Availability and income of grain and oilseeds to enterprises engaged in their storage and processing." By the way, in the previously mentioned *Methodology*

for calculating the level of economic security of Ukraine, food security is defined as the condition of food production within the country capable of meeting the nutritional needs of every member of society with food of suitable quality, under the condition that it is balanced and accessible to all members of society. The Law of Ukraine "On the National Security of Ukraine" does not directly refer to food security, but it is clear that it is an important element of the country's national interests, which provide for "safe living conditions and the wellbeing of its citizens," which must be protected "from real and potential threats" (Law of Ukraine on National Security of Ukraine, 2018) (Verhovna Rada, 2018). Most of the above definitions link food security with protection against internal and external threats. Food security is also about access to food under healthy economic conditions, so knowing the basic tools that guarantee the safety of these types of food is essential to achieve food stability and subsequent food security (Tanveer et al., 2024; Verni et al., 2024). Scientists developed the issue of food security and substantiated that it is important to have a balanced diet and access to different categories of food: meat, vegetables, fruits, dairy products, nuts, etc. (Amao et al., 2023).

2.2 The relationship between agriculture and food security

Food security, agricultural policy and economic growth are interrelated and interdependent processes (Breman, 2019). Agriculture provides the largest share of food resources and provides a critical number of ecosystem services (e.g., food supply; Podolchak et al., 2022a; Rehman et al., 2022). As such, agriculture is vital for food security and supports Sustainable Development Goal (SDG) particularly Goal 2, which aims to fight hunger. The analysis of scientific studies showed that in various regions of the world, in the context of increasing food and nutritional security, special attention is paid to the agricultural land system (Kniaz et al., 2023). Due to the importance of agriculture in the rural economy of both developed and developing countries, the sector can contribute to the creation of an enabling environment for increasing food security. Increasing the resilience of (rural) food systems can be ensured by the creation of smart agroclusters (Bashynska et al., 2022), and this can contribute to increasing the food security of households and communities in conditions of instability (García-Díez et al., 2021). Scientists (Lv et al., 2022) have shown that the main factors affecting food security are the area of arable land and limited water resources for land irrigation.

2.3 The key role of the agricultural sector of Ukraine in the formation of its food security

Since food security is directly determined by the state of the agricultural sector of a specific country, it is appropriate to assess food security, taking into account the functioning of this branch of the national economy. Regarding Ukraine, the agricultural sector remains among the leaders in its economy, which is due to the peculiarities of natural and climatic conditions and the structure of the country's economy. Approximately 2.9 million people were employed in this sector, of which ~80% were employed in the personal peasant economy, and almost every second employed rural person worked in the informal sector of the rural economy (Omotoso et al., 2022); the number of economically active rural population aged 15–70 was ~5.6 million people (Kukel et al., 2020). It is currently difficult to talk about these indicators due to significant migration phenomena, in particular internal population movements and forced emigration. Part of the problems associated with staffing of agricultural enterprises can be compensated for by implementing an innovative risk management system developed on the basis of the transfer of the best European technologies (Podolchak et al., 2022b). Nadvinichnyi (2018) noted that the regional organization of the agrarian sphere is largely determined by the "territorial-localization component" itself, as well as the features of the regional organization of the agrarian sphere (such as the specifics of the agrarian system, the level of production intensity, specialization, etc.). In the current conditions, it is also necessary to add the negative consequences of Russian military aggression, which are especially acute in the eastern and southern regions of Ukraine. It is important to preserve the territorial localization aimed at the development of the agricultural sector during the post-war reconstruction of Ukraine (Potcovaru and Majerová, 2022). From this point of view, it is important to pay attention to food security in Ukraine. After all, to ensure it, not only food stocks are necessary, but also their proper storage and balanced decisions regarding the export of agricultural products (Ostashko, 2022). The agricultural sector is one of the leaders in the economy of many countries, as it creates the basis for their economic growth. Each region in each country has its own unique sphere of social reproduction due to different resource potential, that is, fertile soils, favorable climatic conditions, etc. (Shpak et al., 2021a,b). Scientists of the Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine assessed the prospects for increasing agricultural production and strengthening the role of the agricultural sector in the national economy. In their monographic study (Borodina and Shubravska, 2018; Mordovtsev et al., 2022), two qualitatively different phases in the processes of production and domestic consumption of agricultural products in Ukraine are distinguished: during 2004–2008 there was an "intensification of import expansion," and in 2012–2016—"decrease in the level of import dependence," and for the next period these researchers predicted "increase in import dependence." We consider this forecast to be unlikely, but it requires additional research in order to justify possible scenarios of changes in the volume of export of Ukrainian agricultural products and the total volume of its production.

Mudrak (2022) investigated the impact of Russian military aggression on global and national food security. He revealed the trends of constant growth of the share of Ukrainian exports of certain types of agricultural products in world exports. She emphasized that the circumstances caused by the war worsen the state of providing other countries with sunflower oil, grain and other types of products supplied by Ukraine. However, his research lacks predictive estimates regarding future volumes of production and export of Ukrainian agricultural products. The strengthening of the limitations of logistics chains, which

affect the supply of food to other countries, is also evidenced by the research of other scientists, which revealed negative dynamics of the aggregated logistics efficiency index (Stetsiv, 2022).

The main factors in the decrease in the volume of agricultural production in Ukraine are the removal of a large part of the land from agricultural use due to temporary occupation and their littering with ammunition and remnants of military equipment, the destruction of infrastructure and damage to agricultural machinery. It is obvious that significant funds will be needed to restore this industry, including demining and clearing agricultural land; these works will take several years. Therefore, in forecast calculations for the nearest period, it is necessary to rely on the assumption that the volume of production of agricultural products will be smaller, compared to the period until 2022, in proportion to the decrease in the area of land suitable for processing and growing agricultural crops. The war has resulted in a roughly 22% reduction in arable land suitable for agriculture in 2022 (Movchaniuk and Diachenko, 2023). Even following the liberation of the occupied territories, it will take several years before these lands can be cultivated, as they will require demining and field clearing first. In the future, as they are freed and cleared, they will be used again for agricultural production (Viana et al., 2022).

The conducted analysis of literary sources became the basis for formulating the research hypothesis.

H 1: Ukraine's food security depends on the volume of production of agricultural products.

H 2: Ukraine's food security depends on the volume of exports of agricultural products.

3 Methodology and data construction

For reasonable forecasting of the agricultural production volume in Ukraine, it is necessary to use such a methodology that would make it possible to take into account retrospective information and a number of internal and external factors that affect the processes of production and export of agricultural products. Bogomazova (2012) suggested using two groups of methods for forecasting, depending on the content of the initial information. The first group includes methods of extrapolation and modeling, whereas the second deals with expert methods that involve taking into account the opinions of authoritative specialists (these methods are useful for forecasting in conditions of some uncertainty of the investigated processes). Expert methods sometimes involve qualitative rather than quantitative predictive visions. In our opinion, the results of forecasting should be exactly quantitative indicators that make it possible to compare the actual state of the process in the past and the predicted future state. Therefore, those indicators that are essentially qualitative should be expressed quantitatively. Information about factors related to military actions on the territory of Ukraine, for example, changes in the area of land available for agricultural use, is given in the publications of experts in the agrarian sphere.

The volumes of agricultural products of Ukraine expressed in actual prices (in hryvnias) practically coincide with those calculated in US dollars at the official average annual exchange rates in previous years (Figure 1). The volume of production of agrarian products had an increasing trend in recent years.

This research will use the forecasting method. In order to forecast the volume of production of agricultural products an assumption was made of their decrease in 2022 by 22% from the volume in 2021. This is approximately the same estimate given by experts in October 2022 (Neiter et al., 2022). According to this scenario, the reduction in production in 2022 should be calculated as the average value for the previous 5 years, reduced by 22% (the area of arable land has decreased by that much). The mathematical model of this forecast is described by the equation.

$$Q_{2022} = (1 - 0,22)*(Q_{2017} + Q_{2018} + Q_{2019} + Q_{2020} + Q_{2021})/5$$

According to the forecast for 2022, the volume of production of agricultural products in Ukraine is: Q_{2022} = (1–0, 22) * (26,609 + 31,161 + 32,602 + 33,118 + 49,331)/5 = 26,960 million dollars USA.

The forecast growth rates of Ukrainian agricultural production are taken as average to the previous ones, with the exception of the anomalous (record) year 2021. The rates calculated in this way are ~7.8% per year:

$$\begin{aligned} TQ &= [(1 - Q_{2018}/Q_{2017}) + (1 - Q_{2019}/Q_{2018}) + (1 - Q_{2020}/Q_{2019})]/3 = \\ &= [(1 - 31,161/26,609) + (1 - 32,602/31,161) + (1 - 33,118/32,602)]/3 \\ &= 0,078. \end{aligned}$$

The mathematical model for forecasting Ukrainian agricultural production volumes in 2023–2027 is described by the equation:

$$Q_N = Q_{N-1}*(1 + TQ).$$

In particular, for the period 2023–2027, the forecast values are:

$$\begin{aligned} &Q_{2023} = Q_{2022}*(1 + TQ) = 26,960*(1 + 0,078) = 29,063 \text{ million dollars USA;} \\ &Q_{2024} = Q_{2023}*(1 + TQ) = 29,063*(1 + 0,078) = 31,330 \text{ million dollars USA;} \\ &Q_{2025} = Q_{2024}*(1 + TQ) = 31,330*(1 + 0,078) = 33,774 \text{ million dollars USA;} \\ &Q_{2026} = Q_{2025}*(1 + TQ) = 33,774*(1 + 0,078) = 36,408 \text{ million dollars USA;} \\ &Q_{2027} = Q_{2026}*(1 + TQ) = 36,408*(1 + 0,078) = 39,248 \text{ million dollars USA.} \end{aligned}$$

The results of forecasting the volume of production of agricultural products in Ukraine for the period until 2027, expressed in US dollars, are shown in Figure 2.

At the time of writing, the State Statistics Service of Ukraine (2023) released estimates for the agricultural production volume in Ukraine in 2022, totaling ~29.4 billion USD. This indicates that the actual volume surpassed the forecasted value by ~8.7%.

It should be taken into account that as a result of the Russian invasion, the actual population of Ukraine at the end of 2022 decreased by ~8 million people (UNHCR, 2022), that is, by almost 20% compared to January 2022 (then, according to official data, the population of the country was more than 41 million people, excluding the Autonomous Republic of Crimea). This gives grounds for the assertion that the internal consumption of agricultural products will decrease accordingly. Therefore, according to the given scenario, the volume of production of agricultural products will be sufficient to provide for the country's

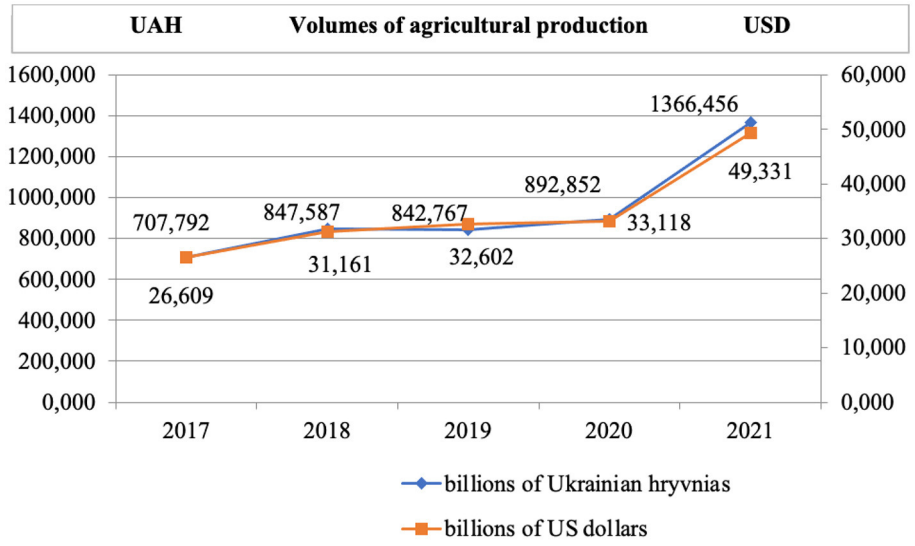

FIGURE 1
Volumes of agricultural production of Ukraine, expressed in billion Ukrainian hryvnias (left scale) and in billion US dollars (right scale). Source: calculated according to the State Statistics Service of Ukraine (2022).

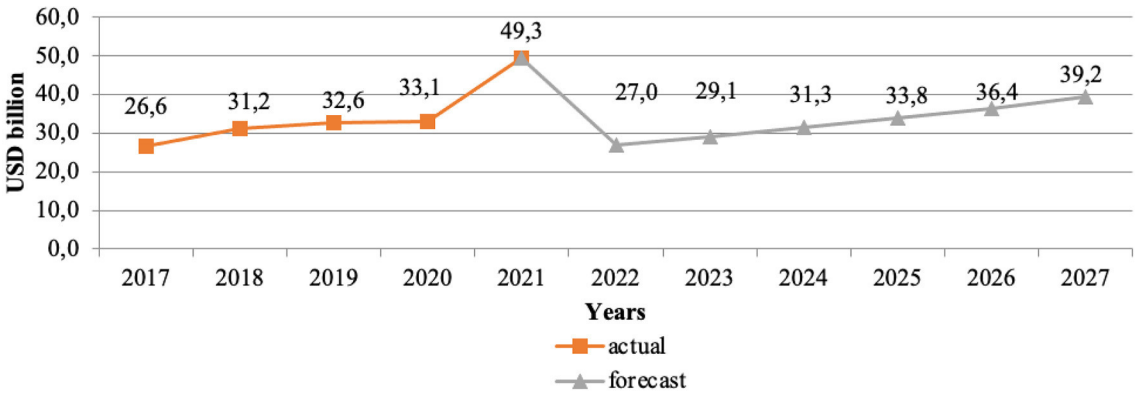

FIGURE 2
Actual (up to and including 2021) and forecast (from 2022) volumes of production of agricultural products in Ukraine (in billion USA dollars). Source: calculated by the authors.

population while maintaining the previous proportion of exports. At the same time, there is a basis for an increase in the share of products that Ukraine can export.

To forecast the volume of production and export of Ukrainian agricultural products, it is necessary to take into account not only the change in the area of cultivated agricultural land, but also the general state of the economies of the countries that import Ukrainian products. Information on gross domestic product (GDP) values and forecasts of their annual changes for the period until 2027 for the countries of the world are provided on the website of the (International Monetary Fund, 2022). Data on the dynamics of agricultural production in Ukraine and its export are available in the sources of the State Statistics Service of Ukraine.

In order to forecast the volume of export of Ukrainian agricultural products, assumptions regarding the state of the economies of the importing countries (changes in real GDP) and their shares in exports are taken into account. On this basis, the forecast values of average annual percentage changes in export volumes were calculated as the sum of products of percentage changes in real GDP of importing countries and their shares in the export of agricultural products from Ukraine. The forecast model uses the assumptions of analysts of the International Monetary Fund regarding annual changes in real GDP for the period until 2027 (Table 1).

Forecast calculations of the export of agricultural products were made according to two scenarios. Forecasting according to the first scenario covers two stages. At the first stage, expert assumptions were made regarding the shares of the main importing countries in the export of Ukrainian agricultural products ($dEXP_C$).For each year of the forecast period, annual percentage forecast changes in

export volumes (TE_N) were calculated as the sum of $dEXP_C$ and $dGDP_C$ products.

At the second stage, export volumes (Q_N) were calculated sequentially for each year of the forecast period, based on the forecast value of exports in the previous year (Q_{N-1}). The mathematical model for this scenario is described by the following expression:

$$Q_N = Q_{N-1} * (1 + TE_N).$$

The second scenario is based on the assumption that it will be possible to export a part of agricultural products, which will remain from the total volume of production, excluding the volume of domestic consumption.

TABLE 1 Forecast values of annual changes in real GDP of countries that are the main importers of Ukrainian agricultural products.

Country	Annual changes in real GDP (%) in the forecast period (dGDPc)				
	2023	2024	2025	2026	2027
Romania	2.1	2.8	3.6	3.8	3.8
China	5.2	4.6	4.1	3.8	3.6
Turkey	4.5	3.1	3.2	3.3	3.4
Spain	2.5	1.9	2.1	1.8	1.6
Poland	0.2	3.1	3.5	3.3	3.0
Netherlands	0.1	0.6	1.3	1.9	1.9
Egypt	3.8	3.0	4.4	4.7	5.1
Italy	0.9	0.7	0.7	0.2	0.3
Germany	−0.3	0.2	1.3	1.5	1.1
Hungary	−0.9	2.2	3.3	2.8	3.0

Source: compiled according to International Monetary Fund (2023).

4 Research results

In previous years, the share of exported agricultural products tended to increase in absolute numbers and decrease compared to the total volume of its production (Figure 3).

The peculiarity of the export of agricultural products is that products produced in the previous period can be sold in the current year. Therefore, in order to estimate the share of exports in the total volume of manufactured goods, it is advisable to calculate the corresponding ratio for several years. On average, the share of exports was 66% for the period 2017–2021.

The accession of Ukraine to the World Trade Organization and the implementation of the Association Agreement with the European Union (EU) provided additional opportunities for the development of the agricultural sector of the national economy of Ukraine, in particular for expanding the export of agricultural products to European countries. According to the results of 2021, Ukraine exported agricultural products in the amount of 27.7 billion US dollars, which is almost 25% more than the volume in 2020 (22.4 billion USD). Exports of agricultural products to EU countries and Great Britain increased by 12%: from 7.5 billion dollars USA in 2019 to 8.4 billion US dollars in 2021. The share of the EU in Ukrainian exports of agricultural products was 30.1% in 2021 (Makuha, 2022). Shares of exports to other countries are likely to remain at the level they were in 2021. The main importers of Ukrainian agricultural products in 2021 were China, India, Egypt, Turkey, Indonesia, a number of European countries, in particular members of the European Union (Figure 4).

The shares of countries in the export of Ukrainian agricultural products are calculated in proportion to the volume of exports to them. Due to the Russian occupation and blockade of Ukrainian ports in the Black Sea, the export shares to importing countries have changed. In 2023, the top 10 importers included Romania, China, Turkey, Spain, Poland, the Netherlands, Egypt, Italy, Germany, and Hungary (Table 2).

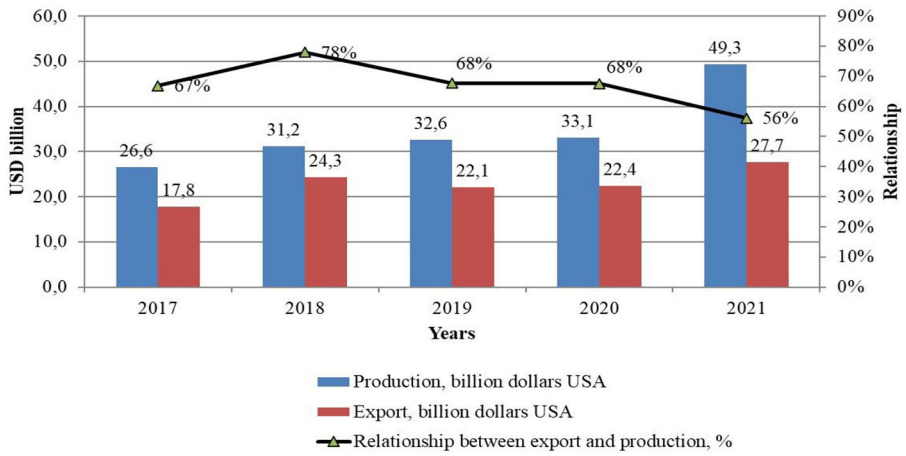

FIGURE 3
Dynamics of production and export of Ukrainian agricultural products and the relationship between them. Source: calculated by the authors.

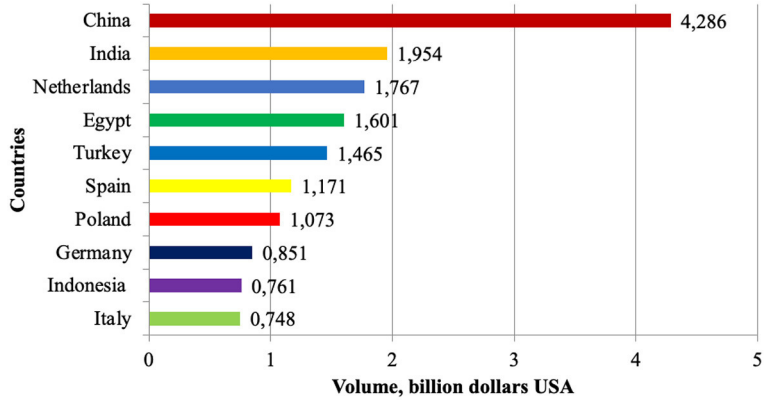

FIGURE 4
Export volumes of agricultural products of Ukraine to the largest importers in 2021 (billion USD). Source: summarized according to statistical data.

According to our assumption, these import shares (as listed in Table 2) will remain the same in the following years until 2027. For each year of the 2023–2027 forecast period, annual percentage forecast changes in export volumes (TE_N) were calculated based on the data from Tables 1, 2. For example, for 2023, TE_N was calculated as follows:

$$TE_{2023} = 19.0\%*2.1\% + 14.4\%*5.2\% + 13.1\%*4.5\% + 11.8\%*2.5\% + 11.1\%*0.2\% + 8.5\%*0.1\% + 7.2\%*3.8\% + 6.5\%*0.9\% + 5.2\%*(-0.3\%) + 3.3\%*(-0.9\%) = 2.35\%$$

The results of this stage are given in Table 3.

At the time of preparation of the article, the actual volume of exports of Ukrainian agricultural products for 2022 became known—in the amount of 23.4 billion dollars (UAEA, 2023). For the period 2023–2027, the forecast values of the export of Ukrainian agricultural products according to the first scenario are:

$Q_{2023} = Q_{2022}*(1+TE_{2023}) = 23.4*(1+0.0235) = 23.9$ billion dollars USA;
$Q_{2024} = Q_{2023}*(1+TE_{2024}) = 23.9*(1+0.0256) = 24.5$ billion dollars USA;
$Q_{2025} = Q_{2024}*(1+TE_{2025}) = 24.5*(1+0.0297) = 25.2$ billion dollars USA;
$Q_{2026} = Q_{2025}*(1+TE_{2026}) = 25.2*(1+0.0296) = 25.9$ billion dollars USA;
$Q_{2027} = Q_{2026}*(1+TE_{2027}) = 25.9*(1+0.0291) = 26.7$ billion dollars USA.

Further calculations have been carried out based on the second scenario (based on the assumption that it will be possible to export a part of agricultural products, which will remain from the total volume of production, excluding the volume of domestic consumption).

The average value of the share of Ukrainian agricultural products used for domestic consumption during 2017–2021 was 32.9%. This was ~(26.609 + 31.161 + 32.602 + 33.118 + 49.331)*0.329 = 11.372 billion dollars. US every year or about 277.4 USD. of the USA per resident of Ukraine yearly (considering the then population of 41 million people). This approach takes into account the need to support Ukraine's food security. At the same time, the projected changes in the number of the country's population, caused primarily by the expected return to Ukraine of fellow citizens from abroad, are taken into account. In 2023, the International Monetary Fund published demographic forecasts, according to which the population figures for Ukraine were projected as follows: in 2023—33.2 million, in 2024—33.7 million, in 2025—34.7 million, in 2026—35 million, and in 2027—35.9 million people (IMF, 2023). The assumption of changes in domestic consumption in proportion to the corresponding changes in the population of Ukraine, included in the second scenario of forecasting changes in the export of Ukrainian agricultural products, is shown in Table 4.

The remaining volume of domestically produced food can be exported. For example, in 2024, production is forecasted to be 31.3

TABLE 2 Export volumes of agricultural products of Ukraine to the largest importers in 2023.

N	Country	Volume (billion USD)	Share (%)
1	Romania	2.9	19.0
2	China	2.2	14.4
3	Turkey	2.0	13.1
4	Spain	1.8	11.8
5	Poland	1.7	11.1
6	Netherlands	1.3	8.5
7	Egypt	1.1	7.2
8	Italy	1.0	6.5
9	Germany	0.8	5.2
10	Hungary	0.5	3.3

Source: summarized according to statistical data.

TABLE 3 The results of the calculation of annual percentage forecast changes in the export of Ukrainian agricultural products.

Year (N)	2023	2024	2025	2026	2027
Annual percentage forecast changes in export volumes (TE_N)	2,35%	2,56%	2,97%	2,96%	2,91%

Source: calculated by the authors.

billion USD, so a volume of 22.0 billion USD can be exported (31.3–9.3). The results of forecast calculations of the volume of export of Ukrainian agricultural products under two scenarios are shown in Figure 5.

The second scenario takes into account the likely return of part of the population from abroad to Ukraine, leading to an increase in its total population. Therefore, in the coming years, the volumes of domestic consumption of agricultural products will increase. This will result in limitations on the volume that can be exported. However, due to the growth of agricultural production at higher rates than the population growth, export volumes may potentially increase. This growth (according to the second scenario) has higher rates than the first scenario. This is because the first scenario was based solely on changes in the economic situation of countries importing Ukrainian agricultural products.

The forecast volume of exports of Ukrainian agricultural products obtained under the second scenario can serve as a guideline for regulating exports, taking into account the issue of food security in Ukraine. With the return of Ukrainian refugees to Ukraine after the end of the war, domestic consumption of agricultural products will increase somewhat. However, at the same time, the area of lands suitable for cultivation after their clearing and demining will increase. Therefore, food security in Ukraine will remain satisfactory.

TABLE 4 Assumptions regarding changes in the volume of domestic consumption in Ukraine for the forecast period of 2023–2027 (based on changes in population).

Year	2023	2024	2025	2026	2027
Projected population size, million people	33.2	33.7	34.7	35.0	35.9
The volume of domestic consumption of agricultural products in Ukraine is billions of US dollars.	9.2	9.3	9.6	9.7	10.0

5 Discussion

The results of the above calculations showed that the forecasting of agricultural production volumes in Ukraine is based on the assumption of a decrease in 2022 (by ~22%) of land areas suitable for agriculture due to Russian military aggression. After 2023, the annual growth of agricultural production may be at the level of average growth rates (7.8%) until the record harvest of 2021. To forecast exports, changes in the economic status of the main importers of Ukrainian agricultural products and changes in domestic consumption are taken into account in proportion the projected population of Ukraine. During 2023–2027, changes in the volume of production of Ukrainian agricultural products, according to the calculations, will amount to ~29.1–39.2 billion US dollars. Export volumes during this period will also grow ~19.9–23.9–26.7–29.2 billion dollars USA.

In general, research on food security at the global level has shown that this indicator depends on the coherence of the work of various systems and sectors of countries (Tarasuk et al., 2019; Haghighi and Namdar, 2024). In particular, in China (Lv et al., 2022), the interdependence of agricultural, social and economic spheres explains the level of food security in the country. Scientists emphasize the need to develop agriculture and suggest reducing the development of agricultural land due to the expansion of cities; increase subsidies to encourage farmers to develop agriculture; improve the agricultural infrastructure and increased investment in agricultural development.

Mehrabi et al. (2022) presents the prioritization of threats to global food security from extreme events. Among the threats that have the strongest impact on global food security, the following are named: growing dependence on water resources, especially groundwater; droughts in Africa in regions south of the Sahara desert; heat and other extreme phenomena in the coastal regions of poor countries, where they eat mainly seafood; the simultaneous occurrence of extreme events that threaten the proper provision of water supply services (for irrigation), pest control, and the supply of feed for fish and livestock production; seizure of resources on land

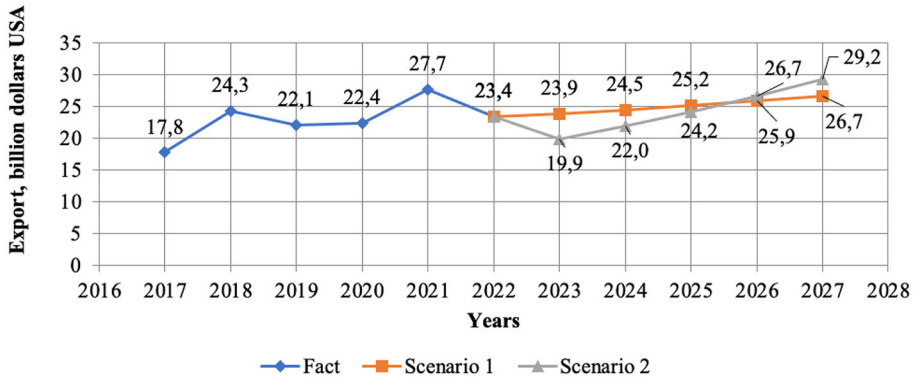

FIGURE 5
Export of Ukrainian agricultural products: fact (2018–2022) and two forecast scenarios (2023–2027), billion dollars USA. Source: calculated by the authors.

and at sea by powerful countries, and others. Military operations and their consequences are not mentioned in this study, but their impact due to the destruction of agricultural, logistical (Shpak et al., 2018) infrastructure should be taken into account.

In Ukraine, in addition to the above-mentioned main factors, it is necessary to take into account factors that have an indirect effect on food security, in particular the state of the energy infrastructure (Androniceanu and Georgescu, 2023), which is being destroyed as a result of hostilities on the part of Russia. In this context, an important strategic alternative to ensure sustainable development is the production of green energy (Androniceanu and Sabie, 2022). It is also necessary to consider the state and level of the shadow economy in public administration (Shpak et al., 2021a,b), which affects the development of the economy that shapes food security. All these and others factors have a significant impact on food security, since a study of changes in the indices of the global indicator of food security starting from 2018 shows that, along with its general decrease in the world by 1%, in Ukraine there was a tendency to increase by an average of 6% (Stetsiv, 2022), but with the start of a full-scale invasion in 2022, this indicator deteriorated sharply.

The results of the study proved that the main resource for the production of agricultural products in Ukraine is arable land. A large part of the territory of Ukraine becomes unfit for agricultural production due to the conduct of military operations there caused by the war Russian military aggression. After the liberation of the occupied territories, it takes a long time to return the agricultural lands to a condition suitable for their use for growing agricultural products. It will also be necessary to restore agricultural buildings and structures and to update the park of agricultural machinery. An additional negative factor is the decrease in the number of workers in the agricultural sector due to the fact that a large part of the population, including the rural population, left the temporarily occupied territories.

This research can be useful for various groups of people and organizations, in particular for:

- The government. The study can provide government agencies and authorities with important information to develop and implement effective policies and strategies to ensure food security in the country.
- Agricultural producers. Agricultural enterprises and farms can use research to plan their production and expand agricultural activities, according to the needs of the national market and export opportunities.
- The research community. Scientists and researchers can use the research results for further analytical work, as well as for improving methods and approaches to food security assessment.
- International organizations. International organizations such as the World Food and Agriculture Organization (FAO) can use data on food security in Ukraine to coordinate global efforts to ensure food security.
- Business and investors. Private companies can use food security information to make investment and business development decisions in the agricultural and food industries.

The limitation of the study is that the analysis of the impact of production volumes and export of products on the food security of Ukraine was carried out during the period of active hostilities, which is characterized by instability and unpredictability of further development and the state of the indicators that were taken as the basis of the study. The conducted research also has the following limitations: firstly, it does not consider the assumption of possible annexation of additional territories by the aggressor and the resulting decrease in agricultural land; secondly, the assumption about the return of Ukrainian refugees is hypothetical—as it is difficult to make a reliable forecast about future migration processes caused by war.

Further research should be devoted to identifying the relationship between changes in the population of Ukraine in the post-war period and the physical volume of domestic consumption and export of Ukrainian agricultural products.

6 Conclusions

Today, in the world society, great attention is paid to creating conditions for strengthening food security.After all, overcoming poverty and hunger is the second most important goal in the worldwide Millennium Development Goals.

The article analyzes changes in the production of agricultural products in Ukraine and develops forecasts for the volume of exports of these products from Ukraine until 2027. The presented analysis takes into account several factors, including projected changes in real GDP in countries that are the main importers of Ukrainian agricultural products, a decrease in processed agricultural land due to military actions and projected changes in the population of Ukraine over the next few years. Based on this analysis, it was concluded that there is no threat to Ukraine's food security caused by changes in the production and export of agricultural products.

The study confirmed the hypotheses and indicated that the volume of production of agricultural products in Ukraine will be sufficient to meet the needs of the country's population, without violating the previous export ratio. There are even reasons to increase the share of products that Ukraine can export. The forecasted export volumes obtained as part of the study can be used as an indication for export regulation taking into account food security issues in Ukraine. With the return of Ukrainian refugees to Ukraine after the end of the war, domestic consumption of agricultural products will increase somewhat. However, at the same time, the area of lands suitable for cultivation after their clearing and demining will increase. Therefore, food security in Ukraine will remain satisfactory.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

NS: Writing – review & editing. YM: Writing – original draft. YD: Writing – original draft. MG: Writing – original draft.

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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.

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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.2024.1361625/full#supplementary-material

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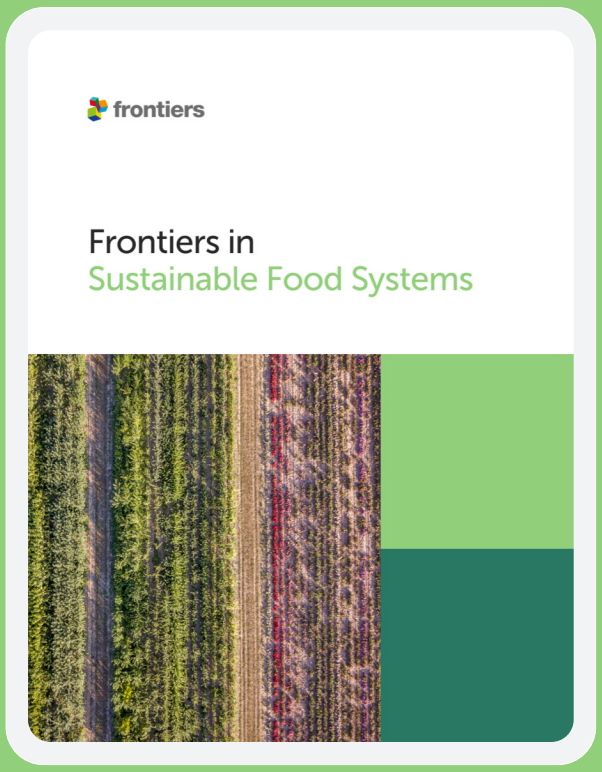

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