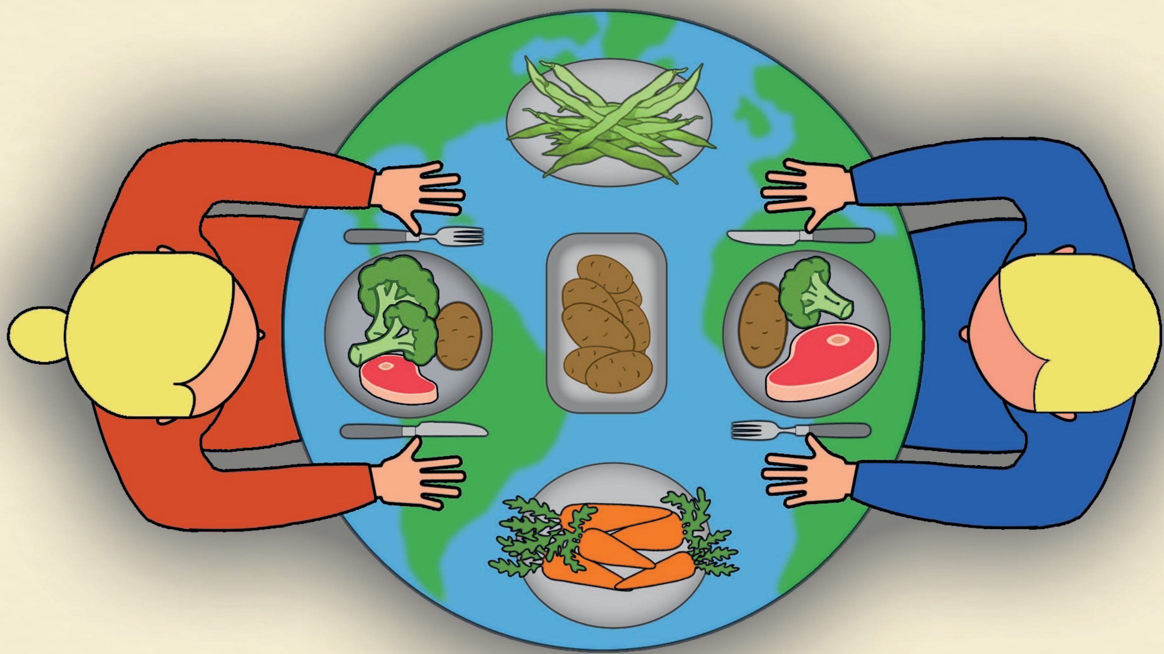
Healthy and Sustainable Diets

Bringing the consumer perspective to the table



Lenneke M. van Bussel

Propositions

1. An environmentally sustainable diet is both tasty and tasteless.

(this thesis)

2. The concept of sustainability is not useful yet to promote sustainable diets.

(this thesis)

3. Imperfect datasets are vital to perfectly understand data analysis.

4. Being a scientist and a human being are two different identities in the same person.

5. Chaos is a prerequisite for creating structural change.

6. Costs made due to theft of non-basic needs should always be recovered from the culprit.

7. Like car owners, E-bike owners should undergo road safety checks every 5 years.

Propositions belonging to the thesis, entitled

Healthy and Sustainable Diets: Bringing the consumer perspective to the table

Lenneke Marit van Bussel

Wageningen, 23 October 2023

Healthy and Sustainable Diets

Bringing the consumer perspective to the table

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Lenneke M. van Bussel

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Chapter 1

General introduction

Diet-related sustainability

Sustainable diets

Shifting towards sustainable diets is advocated as one of the strategies for sustainable life within the planetary boundaries. This shift contributes to mitigation of the adverse effects of our food production and consumption on the planet. Sustainable diets are defined by the FAO (2010) as "[those] diets which are nutritionally adequate, safe and healthy, while having a low environmental impact. These diets are also culturally acceptable, accessible, equitable, affordable, and economically fair, contributing to food and nutrition security and to healthy lifestyles for present and future generations." This definition demonstrates that dietary habits are shaped not only by individual or situational food choices, but also by citizens' food environment as part of the socio-cultural and economic context of the (trans)national food system (i.e. social and economic sustainability).

Rockström et al. (2009) defined nine different planetary boundaries, including climate change, ocean acidification, stratospheric ozone depletion, biogeochemical flow, global freshwater use, change in land use, biodiversity loss, atmospheric aerosol loading, and chemical pollution. All these planetary boundaries are related to the safe just space for humanity relative to the planet's system and to the planet's biophysical subsystems or processes (Rockström et al. 2009, Raworth 2017). These subsystems have tipping points. If these tipping points are exceeded, subsystems will acquire a new steady state, often with severe consequences for humans, such as deforestation and ice cap melting (Lenton et al. 2008). In order to estimate the impacts of our food production and consumption within these planetary boundaries, environmental sustainability indicators are used.

In sustainability research, the most frequently used environmental sustainability indicators are greenhouse gas emissions and land use (Jones et al. 2016). These indicators are estimated through life cycle assessment (LCA). LCA is a method to estimate the environmental impacts and land usage throughout the whole supply chain, from production to the consumer (Rebitzer et al. 2004). In order to estimate the impacts of diets, the emissions of carbon dioxide and other greenhouse gases are combined into one (environmentally sustainability) indicator and expressed as CO_2 equivalents (Hollander et al. 2017). Other environmentally sustainability indicators, such as water use, biodiversity loss, eutrophication, and acidification are less frequently used, mainly due to a lack of data or methodological challenges. Hence, we are currently highly dependent on environmental sustainability data to estimate the sustainability of our diet. To our knowledge, there are no clear indicators for economic and social sustainability, though economic and social sustainability are included in the FAO definition.

At present, the food system is held responsible for about one-third of the total greenhouse gas emissions emitted, or about 16 Gigaton CO_2 equivalents per year (Tubiello et al. 2021). The largest contributor to greenhouse gas emissions is carbon dioxide, but methane, nitrous oxide, and trace gases also contribute to greenhouse gas emissions (Ritchie et al. 2020). About 75 percent of these emissions are generated during agricultural production, pre-production or post-production activities, such as manufacturing, transportation, processing, and waste disposal. The remaining 25 percent is generated during agricultural expansion, including the transformation of natural ecosystems to make land suitable for agriculture or cropland (Tubiello et al. 2021). This change of land into agricultural land is concerned with deforestation, and ultimately biodiversity loss (Magioli et al. 2021).

In Europe, about 40% of the total land is currently used for agricultural purposes, of which the Netherlands is one of the top 5 leading countries in Europe with 54% of the total land used (Eurostat 2021). Fertilizers are used to maximize the crop yield; however, excessive fertilizer usage leads to eutrophication of marine and freshwater, and ultimately in deoxygenation and biodiversity loss (Jwaideh et al. 2022). Furthermore, fossil energy is used in production, transportation, processing, and within households for cooking. It has been estimated that in Europe, the energy use for the food system is 9.4 Exajoule per capita per year (Usubiaga-Liaño et al. 2020). Hence, greenhouse gas emissions, land use, and fossil energy use all contribute to the adverse effects on planetary health.

For the Netherlands specifically, the diet-related environmental impacts (based on greenhouse gas emissions) are between 3 and 6 kg CO_2 equivalents per person per day, depending on age and gender (Temme et al. 2015, Vellinga et al. 2019). Adults (18 years and older) have higher environmental impacts than children (aged 7-18 years) and males have higher environmental impacts than females (Temme et al. 2015). Greenhouse gas emissions could be reduced by 14% if consumers replace 30% of their animal-based foods with plant-based alternatives, which correspond to 0.4-0.8 kg CO_2 equivalents per person per day (Seves et al. 2017). As far as we know, other socio-demographic characteristics, such as education level, have not been linked to diet-related environmental impacts yet.

The environmental impacts are the highest for animal-based food groups, for example beef (34 kg CO_2 equivalents per kg), pork and chicken (13 kg CO_2 equivalents per kg) (Temme et al. 2015, Hollander et al. 2017, Vellinga et al. 2019). To protect the environment for present and future generations, it is crucial that consumers reduce the consumption of animal-based products and to shift towards more plant-based foods, including fruits and vegetables, legumes, and whole-grain cereals, which have a lower carbon footprint. To date, it is unclear how consumers perceive the term "sustainability" with respect to their food consumption.

Healthy diets

A shift towards more plant-based and less animal-based foods is not only beneficial for the planet but also for individual health. For example, diets with higher intakes of red meat and processed meat are associated with a higher risk of cardiovascular diseases, type 2 diabetes, and various types of cancer (Aune et al. 2009, Farvid et al. 2021, Papier et al. 2021). Moreover, the global intake of red and processed meat, saturated fat, sugar-sweet beverages, and salt is typically high in nutritionally low-quality diets (FAO and WHO 2019). In addition, high-quality diets are characterized by a high intake of fruit and vegetables, nuts, and whole grains cereals (FAO and WHO 2019), which are crucial for a healthy diet.

To support Dutch consumers towards healthier diets, Kromhout et al. (2016) formulated food-based dietary guidelines. These guidelines are evidence-based messages to guide consumers towards healthier consumption patterns. Not only health, but also environmental sustainability has been integrated into the food-based dietary guidelines by, for instance, the guidelines "limit the consumption of red meat, particularly processed meat", "eat at least 200 g of vegetables and at least 200 g of fruit daily", and "eat legumes weekly" (Kromhout et al. 2016). To quantify the healthiness of an individual Dutch diet, or the diet quality, Looman et al. (2017) developed a Dutch Healthy Diet index (DHD15-index), which is based on the individual adherence to the food-based dietary guidelines and the Wheel of Five. Compared to the Dutch National Food Consumption Survey 2012-2016, in 2019-2021, the consumption of fruits and vegetables is increasing, and the consumption of red and processed meat is decreasing (RIVM n.d.). Still, in 2019-2021, only 18% of the Dutch adults meet the afore mentioned dietary guideline of fruits and only 29% meets the dietary guideline of vegetables (RIVM n.d.).

If the Dutch population would adhere to the food-based dietary guidelines, it is estimated that life expectancy increases with 0.5 years, Quality Adjusted Life Years (QALYs) at birth increases with 0.7 years and the number of deaths in the coming 20 years decreases with 75 thousand (RIVM 2017). Moreover, unhealthy lifestyle factors, such as smoking, being overweight or obese, being physically inactive will decrease the total number of Disability Adjusted Life Years (DALYs) (May et al. 2015). Therefore, having a healthy diet and lifestyle are beneficial for healthy ageing.

To conclude, even though we have extensive knowledge on the influence of nutrition and diet quality on our health, the Dutch population does not meet to the Dutch food-based dietary guidelines, nor is their diet sustainable. To examine why the Dutch do not adhere to healthy and sustainable diets, this thesis focuses on the consumer perspective. More specifically, consumer perceptions of food-related sustainability and person-related determinants of sustainable food consumption are examined.

Consumer perceptions of food-related sustainability

Food choices

We make food choices several times a day: what to eat, when to eat, how much and with whom? These decisions are complex and are influenced by many factors. These factors include biological, personal, and social determinants, and experiences (Figure 1) (Furst et al. 1996, Steenkamp 1997, Shepherd 1999, Contento 2010). Biologically determined predispositions, including for example hedonic preferences of foods, are important for food choices. However, they may be influenced by prior experiences and personal factors. In addition, the environment facilitates or prohibits the ability of consumers to act on their biological preferences. Thus, choosing a meal or snack during the day is likely to be influenced by many factors.

The three levels of factors mainly defined in studying food choices are: factors related to the food (i.e. biologically determinant predispositions and experiences with food), factors related to the individual that makes the food choice (i.e. person-related determinants) and factors related to the environment (e.g., physical, social, cultural, or economic environment). Figure 1 provides a schematic overview of the factors that play a role at the different levels. For example, the biologically determined predispositions include taste preferences, taste properties of foods and sensory-specific satiety. The personal determinants include, for example, perceptions, attitudes, beliefs, knowledge, and socio-demographic factors. Last, the environmental determinants contain various factors related to the social environment (e.g., cultural practices), physical environment (e.g., food availability), economic environment (i.e. resources, time, and price), and informational environment (e.g., media). All these factors influence food choices, and consequently diet-related behaviours.

To examine the determinants of sustainable food choices, we chose determinants that are important in food choices and those that are measurable, namely taste and person-related determinants. In the next section, we will dive deeper into the taste properties, taste preferences and the person-related determinants of food choice.

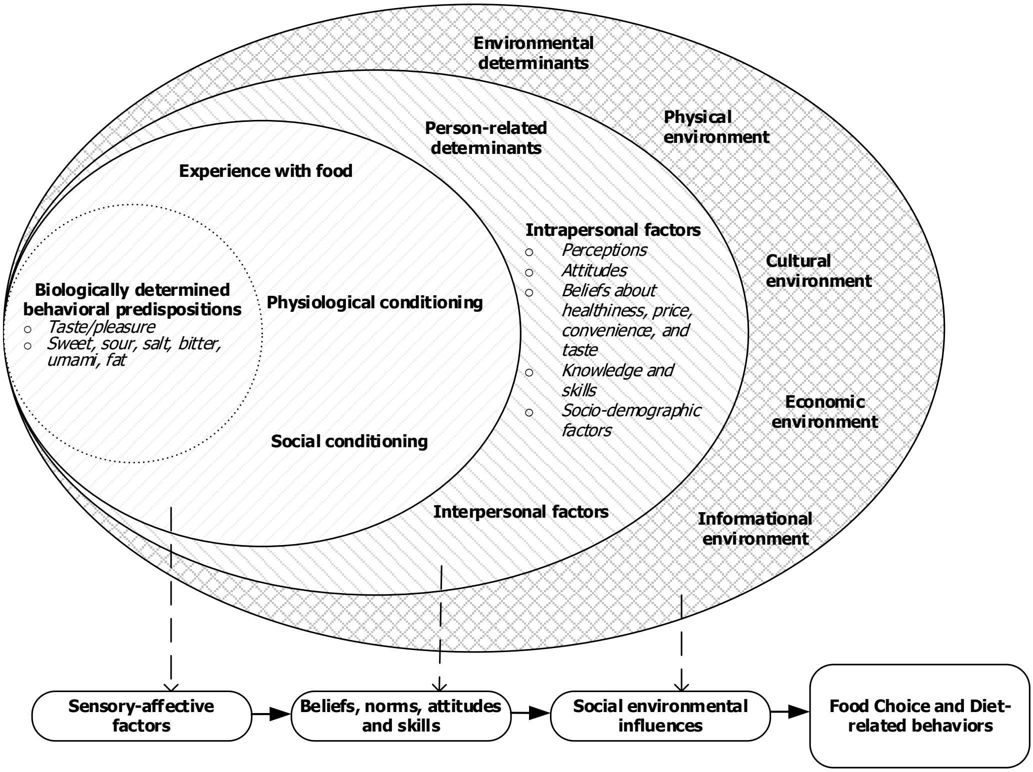

Figure 1 Social and environmental determinants that influence food choices and dietary behaviors at three levels. Factors related to foods include the biologically determined behavioral predispositions and experiences with foods (oval with diagonal line pattern to the right). Intrapersonal and interpersonal factors comprise the factors related to the individual (oval with diagonal line pattern to the left). The factors related to the environment include the physical, cultural, economic, and informational environment (oval with crossed line pattern). Adapted from Contento (2010). Factors tackled in this thesis are written italicized.

Taste properties of foods

Food choices are to a great extent determined by the sensory properties of foods (Drewnowski 1997). Sensory properties include the taste, texture, appearance, and smell of foods. Taste is known as one of the main drivers of food choice (Steptoe et al. 1995, Renner et al. 2012, Kourouniotis et al. 2016). Taste is distinct from the other sensory properties as it has an innate association with reward and aversion (Steiner 1977, De Graaf and Zandstra 1999). Taste properties may also play a role in the detection of nutrient contents, which may affect satiation, and finally the amount of foods consumed (Boesveldt and de Graaf 2017, Li et al. 2020). The five basic tastes are sweet, sour, bitter, salt and umami. Lately, fat sensation has been considered to be the sixth taste (Keast and Costanzo 2015). Humans are born with an innate preference for sweet tastes and an inborn dislike for bitter and sour tastes (Steiner 1977, De Graaf and Zandstra 1999). The origin of innate preferences and dislike of foods might be due to the caloric value of sweet tasting carbohydrates and the potential danger of bitter and sour tasting foods. A preference for salty tastes develops in early life, namely a few months after birth (Bernstein 1990). The fifth basic taste, umami, is related to glutamate, which is an amino acid, and is thought to represent the taste of proteins in foods (de Araujo et al. 2003). Taste preferences may change in a person's life due to experience over time and socio-cultural factors, such as culture, religion, age, gender, and race (Rozin 1996, Drewnowski 1997). This raises the question to what extent tastes play a role in sustainable food choices. Diets that are high in sugar, salt, and saturated fat (i.e. low-quality diets) might be higher in taste intensities than diets lower in these ingredients (Teo et al. 2018b). Studying the taste profiles of healthy and sustainable diets provides us with a deeper understanding of the taste properties of these diets, and may provide insights into the barriers and opportunities to shift towards more healthy and sustainable diets.

Taste preferences

Besides the taste properties of a food, also the liking of a food or pleasure derived from food, plays a role in food choices. As mentioned before, humans have an innate preference for sweet tastes and fat tastes, which are linked to the liking of sweet and fat tasting foods (Drewnowski 1997, Fernández-Carrión et al. 2022). Moreover, the innate, and automatic, aversion to bitter tasting foods is also linked to a dislike of these foods, including some vegetables (Appleton et al. 2019). However, it does not mean that all sweet foods are liked, nor that all bitter tasting foods are disliked. For instance, the liking of coffee or alcoholic beverages, which are bitter, can develop over time due to experiences (Appleton et al. 2019). The hedonic responses or taste preferences of foods are part of the affective component of an attitude, i.e. whether you like or dislike a food, and attitudes can also change over time due to experiences. It is therefore essential to consider the taste preferences of consumers when studying sustainable food choices and attitudes. In this thesis these preferences will be measured on a subconscious and conscious level.

Person-related determinants

Food choices are not only determined by sensory properties and food preferences, but also by other factors such as perceived healthiness, perceived (in)convenience, and price (Steptoe et al. 1995, Furst et al. 1996, Drewnowski and Monsivais 2020). These drivers have the potential to further explain sustainable food choice behaviour in consumers. The person-related determinants of sustainable food choices have not been extensively studied in previous research.

The question is, however, how the concept of sustainability connects to dietary food choices within consumers, consciously and subconsciously. To answer this question, we need to know how consumers perceive the term “sustainability”, especially sustainability related to foods. In addition to consumer perceptions, other factors such as attitudes and environmental knowledge could also play an important role in the consumption of sustainable foods. Differences in knowledge levels or attitude might shed light on the potential facilitators and barriers to sustainable food consumption.

Last, not only consumer perceptions, attitudes and knowledge could explain differences in healthy and sustainable food consumption, but also socio-demographic determinants. Social determinants are non-medical factors such as income level, education level or occupation status. These (social) determinants have an influence on health outcomes (WHO 2022) and affect health inequities (Petrovic et al. 2018). Social determinants are defined as “the absence of unfair, preventable or reversal health disparities between populations defined in social, economic, demographic or geographic terms” (WHO 2022). So far, the healthiness of the diet, i.e. diet quality, has been studied in various socio-demographic groups. For example, results of the Statistics Netherlands shows that higher-educated have higher life expectancy than lower-educated, both in men (82.8 vs. 77.0 years) and women (85.7 vs. 81.4 years) (Statistics Netherlands 2021). Moreover, the higher-educated have a better self-perceived health compared to the lower-educated (Statistics Netherlands 2022). In addition, other lifestyle factors, such as smoking, alcohol use and obesity, which are more common in lower-educated people, also play in a role in health equity (Peeters et al. 2003, Darmon and Drewnowski 2015). Generally, we can say, the lower the socio-economic position of a person, the unhealthier the lifestyle of that person is. In this thesis, we will mainly focus on education level, which also relates to knowledge levels. It is assumed that higher-educated have a higher income level (Galobardes et al. 2006), which in its turn increases the position that one occupies in society.

Conceptual model

An overview of the aspects that are addressed in this thesis is shown in Figure 2. As mentioned, this thesis focuses on diet-related environmental sustainability and the consumer’s perceptions of food-related sustainability. It is known that diets can be described in terms of diet-related environmental sustainability indicators (e.g., greenhouse gas emission, land use and fossil energy use) and of diet quality (i.e. adherence to the food-based dietary guidelines; healthy diet). To link diet-related environmental sustainability with consumer perceptions, it is important to deepen current knowledge of diet-related sustainability. Further integration of additional aspects of foods, such as the taste properties of healthy and sustainable diets, along with investigating socio-demographic factors like education in relation to sustainable diets, is necessary to gain a more comprehensive understanding of sustainable diets.

To achieve behavioural change among consumers, we need scientific data on the sustainability of their diet measured by biophysical sustainability indicators, but more so, we need to understand the perceptions of consumers with regards to food-related sustainability. This is especially needed to align policy recommendations with the consumer views. Unfortunately, little is known about current consumer perceptions of food-related sustainability. Perceptions entail all ideas, beliefs, and views that consumers have about food sustainability, this may include but not limited to the perceptions on local foods, organic foods, seasonal fruits and vegetables or plastic packaging. In addition, it is important to broaden our understanding of the consumer in relation to sustainable food consumption. In addition, it is essential to study the role of taste preferences, other potential facilitators and barriers (e.g., perceived healthiness, perceived inconvenience, affordability), and differences in socio-demographic characteristics in relation to sustainable food consumption.

Aim

The overall aim of this thesis is to determine the overlap and differences between diet-related sustainability as measured by environmental sustainability indicators and consumer's perceptions of food-related sustainability. This led to the following leading research questions:

1. What are the similarities and differences between the consumer's perceptions of food-related sustainability and the biophysical indicators of diet-related sustainability?
2. What are the taste properties of healthy and sustainable diets?
3. What are the consumers' taste preferences regarding sustainable foods?
4. Which person-related determinants are the potential facilitators or barriers to sustainable food consumption?

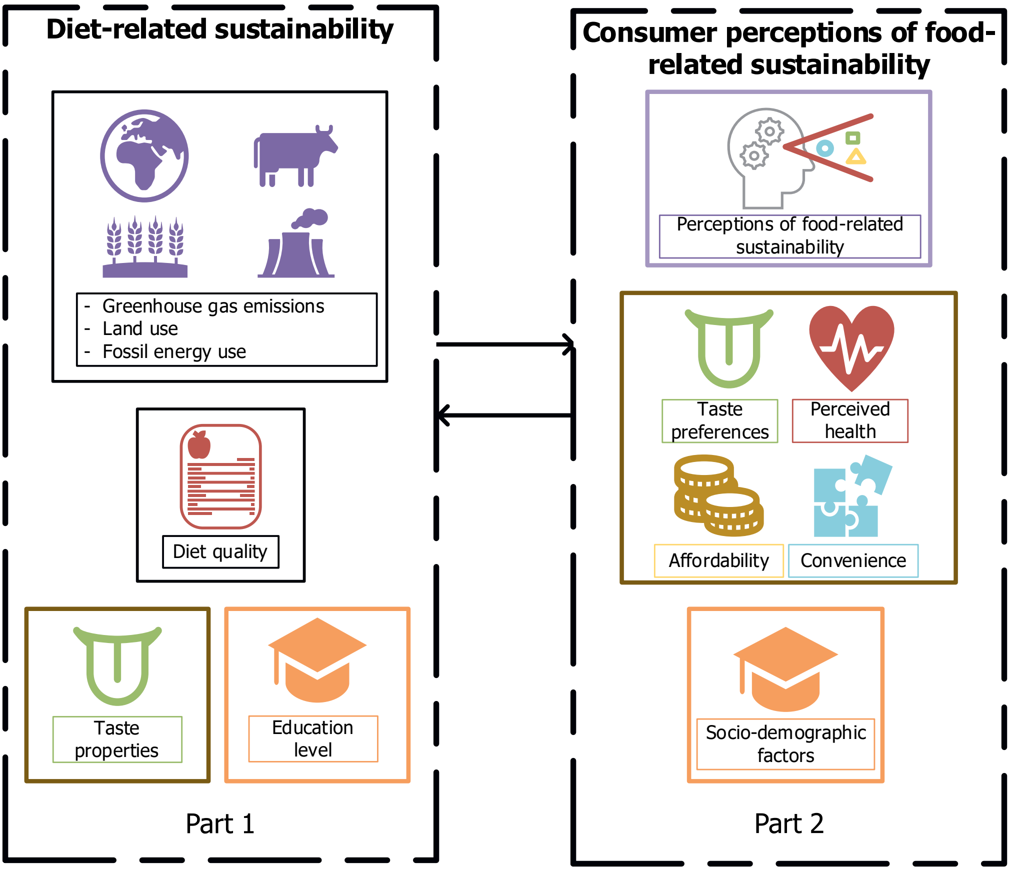

Figure 2 Thesis outline. The first part (chapter 2 and chapter 3) focuses on diet-related sustainability and the second part focuses on the consumer perceptions of food-related sustainability (chapter 4 to chapter 6).

Approach

To answer these research questions, we used existing food consumption data from observational studies, namely the Dutch National Food Consumption Survey (DNFCS 2007-2010) and the Nutrition Questionnaires plus study (NQ-plus, 2015). Environmental sustainability was estimated using Life Cycle Assessment (LCA) data and the taste properties of foods were extracted from a taste database (Mars et al. 2020) including 469 foods. In addition, a questionnaire was developed to collect new data from a representative sample of the Dutch population on the associations between sustainability aspects of foods and palatability, consumer perceptions related to food-related sustainability, attitudes, beliefs about sustainability attributes, food sustainability knowledge, and environmental responsibility.

This thesis is divided into two parts (see Figure 2). In the first part, the focus is on diet-related sustainability assessed with biophysical indicators, and in the second part the focus is on the consumer perceptions of food-related sustainability.

Part 1: Diet-related sustainability

In this part, the focus is on diet-related environmental sustainability. To answer the fourth question "Which person-related determinants play a role in sustainable food consumption?", in **chapter 2**, we study whether the healthiness and sustainability of diets differed among different education groups. For this question, we use data from the DNFCS 2007-2010. Environmental sustainability is measured using greenhouse gas emissions (GHGEs) and diet quality is assessed using the Dutch Healthy Diet index (DHD15-index). To provide more insights into the second research question "What are the taste properties of healthy and sustainable diets?", in **chapter 3**, the taste profiles of diets high and low on environmental sustainability and health are compared. For this question, data from the NQ-plus study are used. Using a taste database, foods are classified into six taste clusters, including fat, sweet/fat, sweet/sour, umami/salt/fat, bitter, and neutral tasting foods. We calculate the amounts of foods consumers consumed in each taste cluster, based on the actual amount and the contribution to energy intake. Diet-related sustainability is assessed using data on GHGEs, land use (LU), and fossil energy use (FEU). These indicators are combined into one environmental sustainability indicator to calculate the environmental impact of the diet. Similar to chapter 2, diet quality is assessed using the DHD15-index.

Part 2: Consumer perceptions of food-related sustainability

In the second part of this thesis, the focus is on the consumer perceptions of food-related sustainability. To answer the first question "What are the similarities and differences between the consumer's perceptions of food-related sustainability and the biophysical indicators of diet-related sustainability?", we need to know the consumer perceptions of food-related sustainability. **Chapter 4** provides a systematic overview of existent literature on consumer perceptions of food-related sustainability in high income countries. This literature review represents the perceptions of consumers in the whole supply chain, from production, and transportation, to the consumer, including waste, and reviews 76 articles. **Chapter 5** and **Chapter 6** provide information to answer the third and fourth questions "What are the taste preferences of consumers for sustainable foods?" and "Which person-related determinants are the potential facilitators or barriers to sustainable food consumption?". **Chapter 5** dives deeper into a consumer behaviour model, the Theory of Planned Behaviour, which describes how attitudes, subjective norms and perceived behavioural control influence the intention to consume sustainable foods. In **chapter 6**, we study the associations between taste preferences and food sustainability, both on a conscious and subconscious level. For these chapters, a questionnaire is developed and data from this observational study (N=988) are used to study potential facilitators and barriers to sustainable food consumption, namely food sustainability knowledge, sustainable food attributes (i.e. beliefs about palatability, perceived healthiness, perceived inconvenience, and affordability), and environmental responsibility as potential facilitators and barriers to sustainable food consumption.

In the general discussion (**chapter 7**), the main findings of this thesis and its implications are discussed, which are followed by recommendations for further research.

Part 1

Diet-related sustainability

Chapter 2

Education differences in healthy, environmentally sustainable and safe food consumption among adults in the Netherlands

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Abstract

Objective: To assess the differences in healthy, environmentally sustainable, and safe food consumption by education levels among adults aged 19-69 in the Netherlands.
Design: This study used data from the Dutch National Food Consumption Survey 2007-2010. Food consumption data were obtained via two 24-h recalls. Food consumption data were linked to data on food composition, greenhouse gas emissions (GHGe), and concentrations of contaminants. The Dutch dietary guidelines (2015), dietary GHGe, and dietary exposure to contaminants were used as indicators for healthy, environmentally sustainable, and safe food consumption, respectively.
Setting: The Netherlands
Subjects: 2106 adults aged 19-69 years
Results: High education groups consumed significantly more fruit (+28 g), vegetables (men +22 g; women +27 g) and fish (men +6 g; women +7 g), and significantly less meat (men -33 g; women -14 g) than low education groups. Overall, no education differences were found in total GHGe, although its food sources differed. The exposure to contaminants showed some differences between education groups.
Conclusion: The consumption patterns differed by education groups, resulting in a more healthy diet, but an equally environmentally sustainable diet among high compared with low education groups. Exposure to food contaminants differed between education groups, but was not above safe levels, except for acrylamide and aflatoxin B1. For these substances, a health risk could not be excluded for all education groups. These insights may be used in policy measures focusing on the improvement of a healthy diet for all.

Keywords: 24-h recall; Education level; Environmentally sustainable food; Food consumption; Food safety; Healthy food

Introduction

A healthy, safe, and environmentally sustainable consumption and production is important for human beings and the planet. In order to mitigate climate change, we need to consume and produce in a more environmentally sustainable manner. In the long term, the consumption of unsafe and unhealthy food might cause adverse health effects, varying from diarrhoea to several types of cancer (WHO 2019).

Several studies have described the relationship between education level and health-related behaviours, including dietary habits (Lopez-Azpiazu et al. 2003, Cardel et al. 2019). According to several studies, the highly educated consumed more healthy foods such as fruits and vegetables than low educated (De Irala-Estevez et al. 2000, Geurts et al. 2013). Little is known about education differences in other aspects of the diet, e.g., environmentally sustainability and food safety. Friedl et al. (2006) showed that people with a low education level consumed more foods that have a higher impact on the environment (e.g., meat products) compared to people with a high education level. In contrast, Reynolds et al. (2019) showed that the greenhouse gas emissions (GHGes) of the total diet were similar between income groups, although there were differences in types of meat. The relationship between education level and food safety is rather unknown. In previous Dutch National Food Consumption Surveys (DNFCS) differences in food consumption patterns between high and low-educated groups were observed (van Rossum et al. 2011); differences in food safety, environmentally sustainability, and healthy food consumption are therefore to be expected.

To decrease inequalities in health between education groups, insights are necessary into the underlying factors, such as healthy and safe food consumption. Food consumption is important for planetary health. More and more dietary guidelines target health as well as environmental aspects (Buttriss 2016, Kromhout et al. 2016). However, it is not yet known whether the environmentally sustainability of diets differs in different education groups, and thus whether such guidelines can be focused on the general population or should be specifically focused on specific subgroups of the population. This study aimed to describe the education differences in healthy, environmentally sustainable, and safe food consumption among adults aged 19 to 69 in the Netherlands.

Healthy food consumption was evaluated by the consumption of the components of the Dutch healthy diet index 2015 (DHD15-index), environmentally sustainable consumption by diet-related greenhouse gas emissions, and safe food consumption by exposure to a selection of contaminants present in food. Microbiological food safety was not addressed in this study.

Methods

In the present study, data from the Dutch National Food Consumption Survey 2007-2010 (DNFCS 2007-2010) were used (van Rossum et al. 2011). Details of the design and methodology of the DNFCS 2007-2010 have been described previously (van Rossum et al. 2011). Briefly, the study population consisted of people living in the Netherlands aged 7 to 69 years. The sampling frame was a representative consumer panel from which sex and age group stratified random samples were taken. Data were collected between March 2007 and April 2010. Representativeness of the Dutch population was monitored and adjusted during recruitment, regarding age groups, region, urbanization level, and education level. In total, all data of the adults from this survey were included in the present analysis (1,055 males and 1,051 females aged 19 to 69 years old). This age range was based on the age boundaries in the Dutch dietary reference values. The response rate for this age group was 70% (van Rossum et al. 2011).

Data collection DNFCS 2007-2010

The data collected within DNFCS 2007-2010 consisted of a questionnaire to obtain general information about the participants, including socio-demographic characteristics and lifestyle factors, and two non-consecutive 24-hour dietary recalls. The socio-demographic characteristics included working status, income, and highest obtained education level. Education level was categorized into low (primary school, lower vocational, low or intermediate general education), moderate (intermediate vocational education and higher general education), and high (higher vocational education and university). The lifestyle factors included alcohol consumption and general characteristics of the diet.

The 24-hour recalls were conducted as computer-assisted telephone interviews using GloboDiet software (©International Agency for Research on Cancer; previously called EPIC-Soft©). The GloboDiet classification consists of 17 main food groups (including 72 subgroups) (Slimani et al. 2011). Interviewers were trained dieticians and called unannounced (van Rossum et al. 2011). During these interviews, a detailed description of all foods (including beverages) and amounts consumed (using household measures, by weight or volume photographed from a delivered booklet) was collected. During the interviews also height and body weight were reported. The body mass index (BMI) was calculated by dividing the body weight (in kg) by height squared (in m^2). All reported foods were matched to codes of the Dutch Food Composition Database (NEVO 2011), the so-called NEVO codes.

Healthiness of the diet

We used the Dutch dietary guidelines 2015 of the Health Council and an overall score, the Dutch Healthy Diet index 2015 (DHD15-index) to score the diet on healthiness using the food intakes of the DNFCS 2007-2010 (see Table 1) (Kromhout et al. 2016, Looman et al. 2017). This index score is based on the Dutch dietary guidelines 2015 of the Dutch Health Council (see Table 1). The index is a summary score based on 15 single components, including fruit, vegetable, fish, wholegrain products, fats and oils, legumes, nuts, dairy intake, red meat and processed meat, sodium, coffee, tea, sweetened beverages, fruit juices, and alcohol. As described by Looman et al. (2017), some recommendations require a minimal intake (e.g., fruit, vegetables) or maximal intake (e.g., sodium), other recommendations an optimal intake (e.g., dairy products) or a replacement (e.g., fats and oils). For each recommendation, participants can proportionally score between 0 and 10 points, depending on the type of recommendation (minimum, maximum, optimal intake, or replacement). For instance, in the case of a minimum intake, a score of 10 points was allocated when the consumption was higher than or equal to the minimum intake (e.g., 200 grams of fruits per day); no consumption was given 0 points. In the case of a maximum intake, a score of 0 points was allocated when the consumption was higher or equal to the maximum intake (e.g., 6 grams of salt per day); no consumption was given 0 points. In the present study, the food intake relevant for each guideline was calculated as well as the DHD15-index per participant using the average of the two 24hRs.

GHGe of diets

For assessing the environmentally sustainability of food consumed, indicators such as the use of energy, water, and land, and the emission of greenhouse gases are typically used to assess the environmental impact (Marinussen et al. 2012, Fisher et al. 2013, Temme et al. 2014). Greenhouse gas emission (GHGe) has been used as an indicator for the overall environmental impact in multiple studies and consists of the emission of CO_2-equivalents (e.g., CO_2, NO_2, and CH_4) along the supply chain. In the present analysis, this indicator was used to assess the environmentally sustainability of food. The data and method were previously described in Temme et al. (2014). In summary, this was done by linking the values of the GHGe per NEVO code (Blonk dataset version 2014) to the food consumption data coded with NEVO codes. The GHGe data were calculated via life cycle assessment (Temme et al. 2014). All stages of a product's life, from primary production, processing, packaging, transportation, storage, preparation, and cooking were taken into account. Food waste was included by using food group-specific percentages for avoidable and unavoidable food losses throughout the food chain, including the consumer phase (Temme et al. 2014). The LCAs took into account the origin of foods as available on the Dutch market (e.g., share of imported foods) (van de Kamp et al. 2018a). In total, 254 food products in the Blonk database were previously extrapolated to 1595 consumed food products in the food consumption database to quantify GHGe. Extrapolation was used based on ingredient composition and similarities in the type of food or production methods. In the present analysis, the GHGes of the overall diet were calculated. In addition, the GHGe of several food groups were described.

Table 1 Components of the Dutch dietary guidelines 2015 and their definition in the present study (Kromhout et al. 2016).

Component	Description of guideline	Definition[a] (amount consumed)
Vegetables	Eat at least 200 g of vegetables daily	Vegetables (gram)
Fruit	Eat at least 200 g of fruit daily	Fruits (gram)
Cereal products	Replace refined cereal products by wholegrain products	Cereals and cereal products (gram)
Wholegrain products	Eat at least 90 g of brown bread, wholemeal bread or other wholegrain products daily	Wholegrain products within Cereals and cereal products (gram)
Legumes	Eat legumes weekly	Legumes (gram)
Nuts unsalted	Eat at least 15 g of unsalted nuts daily	Nuts unprocessed (gram)
Dairy products	Take a few portions of dairy produce daily, including milk or yogurt	Dairy products (gram)
Meat and meat products	Limit the consumption of red meat, particularly processed meat	Meat and meat products (gram)
Red meat		Sum of Fresh meat, Game, Processed meat and Offals (gram)
Processed meat		Processed meat (gram)
Fish	Eat one serving of fish, preferably oily fish, weekly	Fish and fish products (gram)
Fats	Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats and vegetable oils	Fats (gram)
Spreadable fat		NEVO codes with conditions (gram): ≤16 en% SFA, ≤1 en% TFA, Mono- and disaccharides ≤0.5g, sodium, ≤160mg within Fats
Sugar-containing drinks	Minimize the consumption of sugar-containing beverages	Beverages defined by sugar content, such as soda, ice tea, vitaminated water and sport beverages within Non-alcoholic beverages
Tea	Drink three cups of tea daily	Tea (gram)
Coffee[a]	Replace unfiltered coffee by filtered coffee	-
Alcohol	Do not drink alcohol or no more than 1 glass daily	Alcoholic beverages (gram)
Salt	Limit salt intake to 6 g daily	Sodium intake of all foods based on NEVO (mg)

Source: Health Council of the Netherlands (2015), Dutch dietary guidelines 2015 (Kromhout et al. 2016)

a No data was available on distinction between filtered or unfiltered coffee. This component was therefore excluded from the present analysis.

b The components of the dietary guidelines were all used in the calculation of the Dutch Healthy Diet index (2015, except for coffee).

Chemical food safety

Chemical food safety deals with a wide range of substances present in food, including pesticides, food additives, and contaminants. Contaminants are substances that are unintentionally present in food due to food processing (e.g., acrylamide, polycyclic aromatic hydrocarbons (PAHs), and 3-monochloropropane-1,2-diol (3-MCPD)), environmental contamination (e.g., dioxins, lead and cadmium), production by fungi present in foods (mycotoxins) or naturally present (e.g., nitrate and arsenic). Based on current dietary patterns, possible risks to public health are more frequently calculated for contaminants than for substances added by humans during food production or processing (Mengelers et al. 2017). The use of the latter category of substances such as food additives, pesticides, and veterinary drugs is legally regulated; these substances are only permitted if this does not constitute any risk to public health.

Food safety was evaluated concerning education level for a selection of contaminants, see Table 2. For some of these contaminants a potential health risk based on prior exposure assessments performed in the Netherlands could not be excluded (Geraets et al. 2014, Sprong et al. 2016, Boon et al. 2017). Furthermore, for the selected contaminants concentration data were readably available. Per contaminant, the main food products that may contain the contaminant are also described in Table 2.

Table 2 Overview of chemical compounds and food products in which they may occur.

Compound	Food products
Mycotoxins	
Aflatoxin B1 (Boon et al. 2009)	Nuts, peanut butter, maize, sunflower seeds, rice
Ochratoxin A (Boon et al. 2009)	Wheat, rye, raisins, nuts, biscuits, sunflower seeds
DON (Boon et al. 2009)	Wheat bread, wheat, biscuits, toast, pasta, maize
Process contaminants	
Acrylamide (Boon et al. 2009)	French fries, biscuits, crisps, Dutch spiced cake, peanut butter
3-MCPD (Boon and Te Biesebeek 2016)	Margarine and similar products, vegetable fats and oils, bread and rolls, fine bakery wares, preserved meat, gravy
Environmental contaminants	
Methylmercury (RIVM-RIKILT 2015)	Fish and shellfish, mushrooms, dried fruit
Lead (Boon et al. 2017)	Cereals, milk, fruit, meat, drinking water, vegetables, potatoes, eggs, rice
Naturally present	
Nitrate (Boon et al. 2009)	Potatoes, tap water, spinach, apple, banana, beetroot, cucumber, endive, green beans, cabbage, lettuce

First the average daily exposure to the different contaminants was calculated. Concentrations of aflatoxin B1, ochratoxin A (OTA), deoxynivalenol (DON), nitrate, and acrylamide were obtained from Boon et al. (2009) and EFSA (EFSA 2006, 2007, 2015, 2017b). The concentration data of methylmercury was obtained from RIVM-RIKILT (2015) and EFSA (2015), lead from Boon et al. (2012) and EFSA (2010) and 3-MCPD from Boon and Te Biesebeek (2016) and EFSA (2018). The mean middle-bound concentrations (samples with an analysed level below the Limit of Detection or Quantification were assumed to contain the contaminant at half the relevant limit value) per food product were used. The analysed foods were subsequently matched –unweighted- to the relevant products or subgroups (in total 72) of the GloboDiet classification. For instance, a concentration of 0.5 µg/kg (OTA) was assigned to biscuits (generic: subgroup biscuits), and a concentration of 10.7 µg/kg (OTA) was assigned to dried apricot (specific: product).

As differences in exposure to contaminants between education groups are only relevant if exposures result in potential health risks, the calculated exposures were compared to the relevant health-based guidance values (HBGVs) or a margin of exposure (MOE) was calculated. HBGVs are maximum intakes per unit of time, usually per day or week (such as the tolerable daily or weekly intake (TDI or TWI)). The calculated exposure must be higher than the HBGV for a potential health risk. MOEs are calculated by dividing lower limits of benchmark doses (BMDLs) by the calculated exposure. BMDLs are doses in toxicity studies in which a percentage (e.g., 1%, 5%, and 10%) increase in an adverse effect is observed. These BMDLs cannot be viewed as maximum acceptable intakes and are therefore evaluated via the calculation of a MOE. For a potential health risk, the MOE must exceed a minimum value, which can vary between 1 and 10,000, depending on the nature of the critical endpoint on which the BMDL is based. The HBGVs or BMDLs used in this study are listed in Table 3, including the minimum value of the MOE for a negligible health risk.

Data analyses

In order to calculate the differences in healthy, environmentally sustainable, and safe food consumption by education level, the mean consumption of components of the Dutch dietary guidelines 2015, and the mean emissions of CO_2-equivalents and mean exposure to contaminants over the two consumption days from the 24hRs was calculated per participant. For the contaminants, the mean exposure was divided by the self-reported body weight of the participant in kg, as both the HBGVs and BMDLs are expressed per kg body weight (Table 3).

Table 3 Health-based guidance values and BMDLs of various contaminants[a], including the minimum margin of exposure (MOE) for a negligible health risk, if relevant.

Contaminant	Type[a]	Value	Unit	Minimum MOE	Source
Aflatoxin B1	$BMDL_{10}$	170	ng/kg bw per day	10000	(EFSA 2007)
OTA	TWI	120[b]	ng/kg bw per week	-	(EFSA 2006)
DON	TDI	1	µg/kg bw per day	-	(JECFA 2011)
Acrylamide	$BMDL_{10}$	0.17	mg/kg bw per day	10000	(EFSA 2015)
3-MCPD	TDI	2	µg/kg bw per day	-	(EFSA 2018)
Methylmercury	TWI	1.3[b]	µg/kg bw per week	-	(EFSA 2012)
Lead	$BMDL_{10}$	0.63	µg/kg bw per day	1[c]	(EFSA 2010)
Nitrate	ADI	3.7	mg/kg bw per day	-	(EFSA 2017b)

[a] ADI, acceptable daily intake; BMDL, lower limit of the benchmark dose; $BMDL_{10}$, lower limit of the 95% confidence interval of the estimated dose with a 10% additional risk; TDI, tolerable daily intake; TWI, tolerable weekly intake

[b] For comparison with the calculated intakes per day, these health-based guidance values were divided by 7.

[c] The minimum value of the MOE for lead of one is related to a very low potential health risk.

The mean consumption and emission levels were used as dependent variables in an ANOVA to test on statistical significance between education groups. Education level was used as the independent variable. All statistical analyses were performed with SAS 9.3 (SAS Institute, Cary, NC). A weighting factor was used to correct for small deviances in sociodemographic characteristics (e.g., region, level of urbanization), season, and day of the week (van Rossum et al. 2011). It was known that men and women have different energy intakes, therefore the statistical analyses were performed separately for men and women (van Rossum et al. 2011). It was assumed that a p-value below 0.05 was statistically significant.

Results

On average, low-, moderate-, and high-educated men were on average 45 years, 43 years, and 46 years old, respectively ($p=0.002$). Low-, moderate-, and high-educated women were aged on average 49, 40, and 43 years, respectively ($p<0.0001$). The BMI of men did not differ between education groups (26 kg/m²; $p>0.05$). For women, the mean BMIs of low-, moderate-, and high-education groups were 27, 26, and 25 kg/m², respectively ($p=0.0007$) (see Table 4). The mean energy intake for men was 2687, 2638, and 2504 kcal for low-, moderate-, and high-education groups respectively ($p=0.008$). For women, the corresponding figures were 1915, 2001, and 1933 kcal respectively ($p>0.05$) (see Table 4).

Healthiness of the diet

Table 5 shows the results for healthy food consumption. For both men and women, the high education group consumed on average more vegetables and fruit than the low education group. Particularly, the consumption of fruit was approximately a quarter more in the high education group than in the low education group. In contrast, the lower education group consumed significantly more meat and meat products than the high education group (men: 148g vs. 115g, $p<.0001$; women: 93g vs. 79g, $p=0.02$). In line with this, the consumption of red meat was higher in the low education group than in the high education group. Finally, the salt consumption is lower in high-educated men compared to low-educated men (2995 mg vs. 3174 mg, $p=0.03$); the salt consumption of moderate-educated women is higher compared to low-educated women (2466 mg vs. 2330 mg, $p=0.02$). Altogether, for both men and women, the high education group has a higher overall DHD15-index score compared to the low education group (men: 59 vs. 53 points, $p<.0001$; women: 69 vs. 64 points, $p=0.0002$).

Some education differences were observed in men or women only. Among men, the consumption of wholegrain products was higher in the moderate and high education groups compared to the low education group (114g and 113g vs. 99g, $p=0.02$). Low-educated men consumed significantly more processed meat and sugar-containing beverages compared to high-educated men (processed meat: 69g vs. 48g, $p<.0001$; sugar-containing beverages: 344g vs. 265g, $p=0.04$). Among women, the consumption of cereals and cereal products was significantly higher in moderate-educated women than in low-educated women (190g vs. 167g, $p=0.0004$). Moreover, the consumption of non-alcoholic beverages and tea was significantly higher in high educated women compared to low-educated women (non-alcoholic beverages: 1990g vs. 1802g, $p=0.009$; tea: 390g vs. 283g, $p=0.01$).

Table 4 General characteristics (income, working status, age, BMI, intake of energy, proteins, fats and carbohydrates) for men and women aged 19-69 years by education level (weighted for sociodemographic factors, n=2,106, DNFCS 2007-2010).

	Men							**Women**						
	Low[a] (n=322)		Moderate[a] (n=487)		High[a] (n=246)			Low[a] (n=386)		Moderate[a] (n=448)		High[a] (n=217)		
Income	%		%		%		X^2 p-value	%		%		%		X^2 p-value
Low	44		42		14		<.0001	36		46		18		<.0001
Moderate	28		49		23			38		42		20		
High	6		34		60			23		31		46		
Working	%		%		%			%		%		%		
Yes	25		46		28		<.0001	27		46		27		<.0001
No	38		41		21			48		35		17		
	Mean	SE	Mean	SE	Mean	SE	ANOVA p-value	Mean	SE	Mean	SE	Mean	SE	ANOVA p-value
Age (year)	45	1	43*	1	46	1	0.002	49	1	40***	1	43***	1	<.0001
BMI (kg/m^2)	26	0	26	0	26	0	ns	27	0	26**	0	25***	0	0.0007
Energy intake (kcal/day)	2687	44	2638	32	2504**	46	0.008	1915	28	2001	26	1933	35	ns
Proteins (gram/day)	100	2	98	1	95	2	ns	74	1	76	1	74	2	ns
Fats (gram/day)	106	2	103	2	96**	2	0.005	75	1	77	1	74	2	ns
Carbohydrates (gram/day)	290	6	283	4	266**	6	0.006	209	3	226***	3	214	4	0.002

Significantly different from low education group with *p<0.05, idem with **p<0.01, idem with ***p<0.001.
SE, standard error; ANOVA, analysis of variance
[a] low, low education group; moderate, moderate education group; high, high education group

2

Table 5 Components of Dutch dietary guidelines 2015 (in gram/day) for men and women aged 19-69 years by education level (weighted for sociodemographic factors, season, day of the week, per age-sex group, n=2,106, DNFCS 2007-2010).

	Men (n=1,055)							**Women (n=1,051)**						
	Low[b]		**Moderate[b]**		**High[b]**		**F-test**	**Low[b]**		**Moderate[b]**		**High[b]**		**F-test**
	Mean	SE	Mean	SE	Mean	SE	p-value	Mean	SE	Mean	SE	Mean	SE	p-value
Vegetables	124	5	125	6	146**	7	0.002	120	4	128	6	147***	7	0.001
Fruit	85	6	98	8	113**	9	0.01	111	6	116	9	139**	10	0.02
Cereals and cereal products	233	6	240	8	230	9	ns	167	4	190***	6	180	7	0.0004
Wholegrain products	99	5	114**	6	113*	7	0.02	77	3	79	4	83	5	ns
Legumes	5	1	2*	1	3	1	0.04	2	1	3	1	4	1	ns
Nuts unsalted	1	1	2	1	2	1	ns	2	0	2	1	2	1	ns
Dairy products	411	18	411	23	412	26	ns	331	13	339	17	340	20	ns
Cheese	37	2	38	3	42	3	ns	34	2	35	2	32	3	ns
Meat and meat products	148	5	133*	6	115***	7	<.0001	93	3	88	4	79**	5	0.02
Red meat	129	5	114*	6	95***	7	<.0001	79	3	72	4	66**	5	0.02
Processed meat	69	3	65	4	48***	5	<.0001	39	2	39	3	34	3	ns
Fish and fish products	16	2	17	3	22	3	ns	14	2	15	2	21	3	ns
Fats	34	1	33	1	29**	2	0.006	23	1	22	1	20	1	ns
Spreadable fats	15	1	13	1	14	1	ns	10	1	9	1	10	1	ns
Non-alcoholic beverages	1632	43	1695	55	1748	62	ns	1802	38	1864	52	1990**	61	0.009
Sugar-containing drinks	344	23	330	29	265*	33	0.04	225	16	265	21	195*	25	0.01
Tea	164	20	189	26	198	29	ns	283	22	317	30	390**	36	0.01
Alcoholic beverages	314	31	356	39	299	44	ns	105	11	93	15	107	18	ns
Salt (mg sodium)	3174	59	3190	76	2995*	86	0.03	2330	42	2466*	57	2314	67	0.02
DHD-15 index	53	1	55	1	59***	1	<.0001	64	1	65	1	69***	1	0.0002

Significantly different from low education group with *p<0.05, idem with **p<0.01, idem with ***p<0.001.
a percentage
b low, low education group; moderate, moderate education group; high, high education group

Table 6 Greenhouse gas emission (in kg CO2e/d) for main contributing food groups and for the overall diet for men and women aged 19-69 years by education level (weighted for demographic factors, season, day of the week, per age-sex group, n=2,106, DNFCS 2007-2010).

	Men (n=1,055)							**Women (n=1,051)**						
	Low[b]		Moderate[b]		High[b]		F-test	Low[b]		Moderate[b]		High[b]		F-test
	Mean	SE	Mean	SE	Mean	SE	p-value	Mean	SE	Mean	SE	Mean	SE	p-value
Meat and meat products	1.75	0.08	1.61	0.11	1.56	0.12	ns	1.18	0.06	1.10	0.08	1.09	0.09	ns
Beef	0.61	0.08	0.60	0.10	0.69	0.11	ns	0.53	0.05	0.44	0.07	0.54	0.09	ns
Dairy products	0.99	0.04	1.01	0.04	1.06	0.05	ns	0.85	0.03	0.90	0.04	0.85	0.04	ns
Cheese	0.45	0.03	0.47	0.03	0.51	0.04	ns	0.42	0.02	0.44	0.03	0.39	0.03	ns
Milk and yoghurt[a]	0.49	0.02	0.48	0.03	0.48	0.04	ns	0.38	0.02	0.39	0.02	0.40	0.03	ns
Fish	0.07	0.01	0.08	0.01	0.11	0.02	ns	0.06	0.01	0.07	0.01	0.10**	0.01	0.03
Eggs	0.04	0.00	0.04	0.01	0.04	0.01	ns	0.03	0.00	0.04*	0.00	0.03	0.01	0.0007
Cereals and cereal products	0.24	0.01	0.25	0.01	0.24	0.01	ns	0.17	0.01	0.20***	0.01	0.18	0.01	0.0002
Bread	0.14	0.00	0.14	0.00	0.13	0.01	ns	0.10	0.00	0.10	0.00	0.10	0.00	ns
Vegetables	0.16	0.01	0.17	0.01	0.20**	0.01	0.003	0.16	0.01	0.17	0.01	0.20**	0.01	0.02
Fruiting vegetables	0.07	0.01	0.07	0.01	0.09*	0.01	0.04	0.07	0.00	0.08*	0.01	0.09**	0.01	0.02
Non-alcoholic beverages	0.46	0.01	0.45	0.02	0.43	0.02	ns	0.41	0.01	0.41	0.01	0.44	0.02	ns
Fruit juices	0.06	0.01	0.06	0.01	0.08*	0.01	0.01	0.05	0.01	0.06	0.01	0.07*	0.01	0.05
Soft drinks	0.16	0.01	0.14	0.01	0.10***	0.01	0.0001	0.10	0.01	0.11	0.01	0.09	0.01	ns
Alcoholic beverages	0.23	0.02	0.26	0.03	0.25	0.03	ns	0.11	0.01	0.10	0.01	0.13	0.02	ns
Overall	4.92	0.10	4.80	0.13	4.80	0.15	ns	3.75	0.07	3.77	0.10	3.79	0.12	ns

Significant different from low educated group with *p<0.05, idem with **p<0.01, idem with ***p<0.001.
GHGe, greenhouse gas emission; SE, standard error
[a] Milk including milk beverages
[b] low, low education group; moderate, moderate education group; high, high education group

Table 7 Exposure to contaminants (µg or mg/kg bw/day) for men and women aged 19-69 years by education level (weighted for sociodemographic factors, season, day of the week, per age-sex group, n=2,106, DNFCS 2007-2010).

	Men (n=1,055)							**Women (n=1,051)**						
	Low[c]		Moderate[c]		High[c]		F-test	Low[c]		Moderate[c]		High[c]		F-test
	Mean	SE	Mean	SE	Mean	SE	p-value	Mean	SE	Mean	SE	Mean	SE	p-value
Aflatoxin B1[a]	0.0004	0.00	0.0005	0.00	0.0006	0.00	ns	0.0003	0.00	0.0005**	0.00	0.0005*	0.00	0.003
OTA[a]	0.02	0.00	0.03	0.00	0.03	0.00	ns	0.04	0.00	0.05	0.00	0.06***	0.00	<.0001
DON[a]	0.05	0.00	0.05	0.00	0.05	0.00	ns	0.05	0.00	0.05**	0.00	0.06*	0.00	0.01
Acrylamide[a]	0.33	0.01	0.35	0.01	0.31	0.01	ns	0.32	0.01	0.30	0.01	0.29	0.01	ns
3-MCPD[a]	0.49	0.02	0.43*	0.01	0.39***	0.02	0.002	0.43	0.02	0.40	0.01	0.37	0.02	ns
Methylmercury[a]	0.11	0.00	0.11	0.00	0.12	0.01	ns	0.11	0.00	0.12	0.00	0.13***	0.00	0.002
Lead[a]	0.33	0.01	0.35	0.01	0.35	0.01	ns	0.32	0.01	0.35**	0.01	0.40***	0.01	<.0001
Nitrate[b]	1.47	0.06	1.38	0.04	1.52	0.07	ns	1.48	0.06	1.33*	0.04	1.62	0.08	0.001

Low education level used as the reference group
SE, standard error; 3-MCPD, 3-monochloropropane-1,2-diol; DON, deoxynivalenol; OTA, ochratoxin A
[a]µg/kg bw/day; [b] mg/kg bw/day
[c] low, low education group; moderate, moderate education group; high, high education group

GHGe of the diet

The overall GHGes and the GHGe of food groups that contributed most to total GHGes are shown in Table 6. The food groups that contributed most were mainly animal-based products, including meat products, dairy products, fish, and eggs. Besides these food groups, some plant-based food groups contributed to the total GHGes, including cereal products, vegetables, and (non-)alcoholic beverages. Overall, the GHGe for both men and women did not differ between education groups. However, the sources of GHGe were different between education groups. The GHGe through the consumption of vegetables and fruiting vegetables was approximately a quarter higher in the high education group compared to the low education group. Moreover, the GHGe via the consumption of fruit juices was about 33% higher in high-educated men and 40% in high-educated women compared to the low-educated. The GHGe of meat consumption did not differ between the high education group and the low education group.

Also for GHGe, some education differences were observed in men or women only. Among men, the GHGe of the consumption of soft drinks was higher in low-educated men compared to high-educated men (0.16 vs. 0.10, p=0.0001). Among women, the GHGes via the consumption of eggs and cereals and cereal products were higher in moderate-educated women compared to low-educated women (eggs: 0.04 vs. 0.03, p=0.0007; cereals and cereal products: 0.20 vs. 0.17, p=0.0002). In addition, the GHGe via fish consumption was also higher in the high education group than in the low education group (women: 0.10 vs. 0.08 in kg CO_2-equivalents/day, p=0.03).

Exposure to contaminants

The results in Table 7 show that the mean intake of 3-MCPD was significantly higher in low-educated men compared to high-educated men (0.49 vs. 0.39 µg/kg bw/day, p=0.002). For women, the mean exposure to methylmercury was significantly higher in high-educated women compared to low-educated women (0.13 vs. 0.11 µg/kg bw/day, p=0.002). Moreover, high-educated women had also a higher intake of lead (0.40 vs. 0.32 µg/kg bw/day, p<.0001), aflatoxin B1 (0.0005 vs. 0.0003 µg/kg bw/day, p=0.003), DON (0.06 vs. 0.05 µg/kg bw/day, p=0.01) and OTA (0.06 vs. 0.05 µg/kg bw/day, p<.0001) compared to low-educated women. The mean intake of nitrate was higher in low-educated women than in moderate-educated women (1.48 vs. 1.33 mg/kg bw/day).

Compared to the relevant health limits, the mean intake of acrylamide and aflatoxin B1 of all education groups resulted in margins of exposure that were lower than the minimal level above which the health risk was negligible. For the other contaminants, the mean intakes were either lower than the relevant HBGVs or resulted in margins of exposure that were sufficiently high in all education groups (see Table 3).

Discussion

This is the first study that simultaneously describes differences in healthy, environmentally sustainable, and safe food consumption across education groups in the same population. We expected differences in food consumption patterns between high and low education groups, and therefore we expected differences in food safety, environmentally sustainability, and healthy food consumption in high education groups compared to low education groups. The results show education differences in several indicators of healthy and environmentally sustainable food consumption. Differences in education level are both favourable and unfavourable in the domains of healthy and environmentally sustainable food consumption. Overall, the high-educated had higher adherence to the Dutch dietary guidelines compared to the low-educated. The high education group consumed more fruits and vegetables and less meat and fats than the low education group. In addition, no differences were found between the greenhouse gas emission of the high education group and the low education group. Regarding contaminant exposure, among men, the mean intake of 3-MCPD was estimated to be lower in the high education group compared to the low education group. Among women, the mean intakes of methylmercury, lead, aflatoxin B1, DON, and OTA were estimated to be higher in the high education group compared to the low education group. The mean intakes in all education groups were lower than the relevant HBGV or resulted in margins of exposure that were sufficiently high, except for acrylamide and aflatoxin B1.

The total GHGe did not differ between education groups, However, the contributing food groups differed between the high and low education groups due to different food consumption patterns. These results are in line with the results of Reynolds et al. (2019). In the present study, the consumption of fruit, vegetables, and fish was higher in the high education group compared to the low education group. Therefore, the GHGe of these food groups was higher in the high education group. In contrast, the consumption of meat was lower in the high education group. The GHGes due to half-and-half minced meat, pork meat, and processed meat consumption were significantly lower in high-educated men compared to low-educated men. For women, the GHGes of processed meat consumption was significantly lower in high-educated women. In this way, the overall effects on GHGes are diminished. For food safety, differences in the intake of contaminants could also be explained by differences in food consumption patterns. High-educated men had lower consumption of margarine than low-educated men. As margarine was one of the main contributors to the intake of 3-MCPD, the mean intake of this process contaminants was estimated to be lower in the high education group compared to the low education group. The consumption of fruits and vegetables was significantly higher in high educated women compared to low-educated women. Fruits and vegetables contribute both to the intake of lead, therefore, the mean lead intake was estimated to be higher in the high education group compared to the low education group.

Previous research has already shown that high education groups consume more fruit and vegetables than low education groups (De Irala-Estevez et al. 2000). In line with the present analysis, Darmon and Drewnowski (2008) found that high education groups consumed more fish (Denmark, the Netherlands, and France), whereas low education groups consumed more fats (Denmark, the Netherlands). A study by Hulshof et al. (2003) showed that high education groups consumed fewer potatoes and meat than low education groups (the Netherlands) (Geurts et al. 2015).

With respect to environmentally sustainable food consumption, greenhouse gas emission was used as an indicator. Insufficient data were available on water use and energy expenditures as well as other environmental aspects (Aldaya et al. 2012). Additional research is needed to estimate the impact on e.g., water use and energy expenditures and how this may affect the results. Data was available on land use (Marinussen et al. 2012); however, previous studies showed that greenhouse gas emission and land use are highly correlated and lead to similar conclusions (Temme et al. 2013). Also in other studies, greenhouse gas emissions are often used as an indicator of environmentally sustainability (Jones et al. 2016).

In relation to safe food consumption, only indicative intake estimates were calculated to obtain mean intake levels of contaminants in the different education groups. These mean intakes were estimated by linking concentration data and food consumption data to food subgroups, thus ignoring the variation in contamination levels within these food groups. However, all contaminants examined in this study exert their possible adverse effect on health over a longer period of time, from years up to life long. For this type of assessment, mean concentrations are usually used because it is assumed that fluctuations in concentrations will level out in the long run. Personal preferences for certain (brands of) foods that may contain higher mean levels of contaminants were not considered in this study.

Previous research has studied the intake of contaminants via food in the Netherlands in more detail and based conclusions on food safety on the whole population intake distribution (Geraets et al. 2014, RIVM-RIKILT 2015, Boon and Te Biesebeek 2016, Sprong et al. 2016, Boon et al. 2017). The mean intake estimates of the different contaminants in the present analysis show a similar trend compared to these studies. The intakes of aflatoxin B1 and acrylamide resulted in intakes with insufficiently large margins of exposure in all education groups (see Table 7). The percentages of individuals that did not exceed the

MOE of 10000 in aflatoxin B1 were 73%, 80%, and 82% for low-, moderate-, and high-educated men, respectively, and 73%, 78%, and 84% for low-, moderate-, and high-educated women, respectively. For acrylamide, the corresponding percentages ranged from 98% to 99% in all education groups, in both men and women. For these two contaminants, a possible health risk could not be excluded. For the other contaminants, the mean intakes of all education groups were below HBGVs or resulted in insufficiently high MOEs (see Table 7). However, based on the mean intakes, it is not possible to conclude if there is a public health concern for these contaminants. For that, the whole exposure distribution should be considered. For lead and OTA, a possible health concern could not be excluded in previous studies at the upper part of the exposure distribution (Sprong et al. 2016, Boon et al. 2017).

In this study, only a selected number of contaminants were taken into account. Due to the differences in food consumption patterns in the low education compared to the high education group, it is likely that the intake of other chemicals may also differ between the education groups. However, no data was directly available for these analyses. If these food consumption differences will also result in differences in safe food consumption, it needs further research.

The Dutch National Food Consumption Survey (DNFCS) 2007-2010 represents the consumption of Dutch adults aged 19 to 69 in the Netherlands. A weight factor was used to correct for small deviances in representativeness for the Dutch population. Food consumption was assessed by two 24-hour recalls per participant and on average energy intake was underreported. The proportion of low reporters on energy intake was 17%, whereas the proportion of high reporters was 1.5% (van Rossum et al. 2011). This was not taken into account. Furthermore, the energy intake of high-educated men was lower compared to low-educated men. In the present analysis, the food consumption data were not adjusted for energy intake. Energy intake might explain some of the differences found between the education groups. Nevertheless, this study aimed to describe the differences in healthy, environmentally sustainable, and food safety in education groups. Further research is needed to examine the factors that explain these differences.

We used the mean intake of two 24hRs as a measure of dietary intake, which is subject to day-to-day variation. On the group level, the within-person variation tends to be cancelled out, and only the precision of the mean intake estimates is affected. With the sample size of over 2000 men and women in DNFCS 2007-2010 relevant differences can be observed.

To decrease inequalities in health between education groups, insights were necessary into different aspects of food consumption (e.g., healthy, environmentally sustainable, and food safety). Besides education level, other factors such as lifestyle factors (e.g., smoking), obesity, and the price of the diet might also play a role in these inequalities (Peeters et al. 2003, Darmon and Drewnowski 2015).

Both the databases on food safety (concentrations used) and on environmentally sustainability were based on rough estimations. It is possible that the exposure to food contaminants was overestimated (by using extrapolation) and underestimated for environmentally sustainability. The database for environmentally sustainability includes uncertainties about shares and amounts of fertilizers and variability in the energy inputs during processing steps, which may underestimate the environmentally sustainability. However, these uncertainties and variabilities are related to the nature of the data affecting food safety values and environmental variables so that results breakdowns by population groups are equally subjected to bias. Therefore, comparison between population groups is possible. Future research is required to reduce uncertainties and includes variability in dietary model estimates.

Overall, this is the first study that provides an insight into education differences in healthy, environmentally sustainable, and safe food consumption. The consumption patterns differed by education groups, resulting in a more healthy diet, but an equally environmentally sustainable diet among the higher education group compared to lower education groups. Exposure to food contaminants differed between education groups, but was not above safe levels, except for acrylamide and aflatoxin B1. For these substances, a health risk could not be excluded for all education groups. The results suggest that healthy, environmentally sustainability and safe food consumption should be considered in policy measures and should also be addressed by other researchers. Hence, the insights of this study may be used in policy measures focusing on the improvement of a healthy, safe, and sustainable diet for all.

Chapter 3

Taste profiles of diets high and low on environmental sustainability and health

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Abstract

To mitigate the effects of climate change, we need to shift towards a more sustainable and healthier diet. This presumably affects the taste and texture of the diet. We assessed the taste profiles of current diets, of healthier and more sustainable diets and of less healthy and less sustainable diets in a Dutch adult population (n=1380) in the Nutritional Questionnaire Plus study. The Dutch Healthy Diet index and the pReCiPe-score were used to create tertiles by healthiness and sustainability of diets respectively. Based on the lowest and highest tertiles of these two indicators we constructed four subgroups. For each participant, we calculated the proportional contribution of taste clusters (n=6) to the total daily energy intake (en%) and the total amount consumed (gram%) using a taste database including ~469 foods. The six taste clusters consisted of 1) neutral, 2) salt, umami, fat, 3) sweet, sour, 4) sweet, fat, 5) fat and 6) bitter tasting foods. ANOVA was used to evaluate the differences between subjects in the extreme tertiles. Results show that participants who have a healthier and more sustainable diet consumed less food products from the taste cluster 'umami, salt, fat' (16.1 en%) and 'bitter' (17.1 gram%) and more products from the taste cluster 'neutral' (41.9 en%) compared to participants that have a less healthy and less sustainable diet (umami, salt, fat: 25.6 en%; bitter: 29.0 gram%; neutral: 33.0 en%). Therefore, taste profiles should be taken into account when proposing menus and diets that are healthier and more sustainable.

Keywords: environmental sustainability, health, taste

Introduction

Worldwide, there is an increasing concern to mitigate the effects of climate change; including the emissions of greenhouse gases (GHGEs). The GHGEs have increased in the past decades by 75% (Metz et al. 2007), and they are expected to increase even more in the future (Olivier et al. 2005, van Vuuren et al. 2008). At the same time, it is predicted that the population will increase to 9 billion people in 2050. In order to feed the world in 2050 and to retain the environment from depletions and droughts, we need to produce and consume foods in a more sustainable way. We, as consumers, need to shift towards more sustainable dietary patterns. These diets have been defined by the FAO as follows: Diets which are nutritionally adequate, safe and healthy, while having a low environmental impact. These diets are culturally acceptable, accessible, equitable, affordable and economically fair, contributing to food and nutrition security and to healthy lifestyles for present and future generations (FAO 2010).

At this moment, the food production system accounts for 15-28% of the total GHGEs (Garnett 2011). The highest contributor to these GHGEs are animal-based products, and in particular meat products. The GHGEs of animal-based products are generally higher compared to plant-based products. Therefore, to shift towards a more sustainable diet it is important to increase the proportion of plant-based compared to animal-based products (Sabaté and Soret 2014, Hoek et al. 2017). Besides the environmental sustainability of a plant-based diet, it is suggested that a plant-based diet is also healthier compared to an animal-based diet. Research has shown that a higher consumption of meat products, and especially processed meat is associated with stroke, diabetes and colon cancer (Gezondheidsraad 2015). Thus, a shifting towards a higher plant-animal ratio might have some health benefits compared to a meat-based diet.

Shifting towards a more plant-based diet will affect the taste and texture of the diet. Taste is an important determinant of food choices and might therefore play a role in the acceptability the diet. Taste may also play an important role in signalling nutritional content, having both an effect on satiation and food intake (Griffioen-Roose et al. 2012). To study the role of taste in diets, it is key to quantify the taste qualities of foods and drinks consumed within a population. Consequently, taste profiles can be used to describe dietary intakes on the base of taste qualities (van Langeveld et al. 2018). Whereas food composition tables are worldwide available, databases on taste intensities are only limited in their number (Martin et al. 2014, Lease et al. 2016, Cox et al. 2018). To our knowledge, no research has been done assessing the taste profile of a diet with regard to its sustainability aspects. Therefore, this study is the first study that aimed to assess the taste profiles of the current diet, of healthier and more sustainable diet and of less healthy and less sustainable diet in Dutch adults. In addition, this study aimed to explain how taste clusters differ in diets high and low on health and sustainability (H&S) in Dutch consumers using food consumption data in food groups.

In the current study, we combined a taste database – including taste intensities (sweet, sour, bitter, umami, salt) and fat sensation of 469 commonly consumed foods – with the food intake data from the Nutritional Questionnaire (NQ) plus study. Furthermore, we linked data on sustainability indicators (greenhouse gas emissions, land use and fossil energy use) to the food intake data and calculated the adherence to the Dutch dietary guidelines as a health indicator. As a result, we were able to describe the taste profiles of the current diet, and diets that were high and low on health and sustainability.

Methods

Study population

The Nutrition Questionnaire plus (hereafter abbreviated as: NQplus) study consists of 2048 participants. Details of the methodology and design are described by Brouwer-Brolsma et al. (2018). Briefly, the study population consisted of people living in Wageningen and its surrounding cities aged 20 to 77 years. Inhabitants were selected randomly from municipality registers of Wageningen, Renkum, Ede (n=30,000) and Arnhem (n=15,000) using electronic invitations (Brouwer-Brolsma et al. 2018). Furthermore, all households in Veenendaal (n=25,000) were send an invitation letter. If participants were interested to join the study, they could register online. People were excluded if they were not able to make their own decision, as well as if they had an inadequate command of the Dutch language. Data were collected between May 2011 and February 2013. The NQplus study was approved by the Medical Ethics Committee of Wageningen University (ABR nr: NL34775.081.10). All participants gave written informed consent. The study was conducted in line with guidelines in the declaration of Helsinki.

The inclusion criteria of the present analysis were based on the availability of two 24 hour recalls (24hRs). Of the total study population of 2,048 participants, 1,603 participants recorded their dietary intake using two 24hRs. Moreover, to account for underreporting, the ratio of reported energy intake and BMR was calculated per participant using the Schofield equations to estimate the BMR from weight and height (EFSA 2017a). The lower 5% of the EI:BMR ratio was assumed to underreport their consumption, and were excluded from analysis (n=80). In addition, participants were excluded from data analysis when height or weight was not reported (n=143), resulting in a total of 1,380 participants for analyses.

Dietary assessment

Multiple 24hRs were collected at baseline of the NQplus study of which the first two were used for the present analyses. Overall, the days of the week, including weekend days, were equally distributed and seasons were representative for the year. The 24hRs were self-reported using web-based software (Compl-eat^{tm}). The five-step procedure of the software is a validated tool to increase the accuracy of the recall (Meijboom et al. 2017). Portion sizes were assessed using standard household measures, standard portion sizes, volumes or grams. Recalls were checked by trained dieticians on extreme portion sizes.

Assessment of taste profiles

To assess the taste profiles of individual diets an extensive database was used. The design of this sensory database has been described in detail elsewhere (Teo et al. 2018a). In brief, 469 food items from different food groups were scored on the five basic tastes (sweet, sour, bitter, salty and umami). A modified Spectrum^{tm} method was used to assess the tastes (Teo et al. 2018a, Teo et al. 2018b). Six clusters of foods were then identified by means of hierarchical clustering. The six food clusters were labelled according to the dominant taste values of that specific cluster. This resulted in the following six taste clusters: 1) neutral, 2) salt, umami, fat, 3) sweet, sour, 4) sweet, fat, 5) fat and 6) bitter tasting foods. Food products included in each of the taste clusters can be found in the appendix of Teo et al. (2018).

Foods that were not tested by the trained panel were classified in the taste clusters using similar nutritional values of similar GloboDiet food groups (van Rossum et al. 2016). For example, the trained panel assessed the taste intensities of different meat and meat products (including poultry, beef and pork). These products were all assigned to the taste cluster 'salt, umami, fat'. Meat products that consisted of poultry, beef or pork were therefore, if not tested, assigned to the taste cluster 'umami, salt, fat'. Foods that were not consumed in isolation or not consumed frequently by the Dutch population or did not contribute to energy intake were not classified. These foods consist of herbs and spices, soy products, vegetarian products, and preparations (van Langeveld et al. 2018). Overall, only 1 percent of the energy consumed was included in these product categories. The taste clusters were predefined at the start of the study.

In the present study, we assessed the taste profiles based on the average of 24hRs. The contribution of foods to the different taste clusters was expressed in two ways. First, we calculated the proportional contribution of each of the six taste clusters to the individual daily energy intake. Secondly, we calculated the proportional contribution of the amount of foods (g) from each of the six taste clusters for each individual, standardized for a 2000kcal diet. Standardization for energy was performed in both approaches using the residual method, i.e., the residuals obtained from a linear regression of diet-related environmental impact on energy-intake (Willett et al. 1997). Moreover, the food products in the taste clusters were divided on the base of the food form of the food product (e.g., foods or drinks). Food products were categorized as drinks when they were beverages or soups.

Indicator of a healthy diet

We used the Dutch Healthy Diet index 2015 (DHD15-index) to score the diet on healthiness (Looman et al. 2017). This indicator is based on 15 components, including fruit, vegetable, fish, wholegrain products, fats and oils, legumes, nuts, dairy intake, red meat and processed meat, sodium, coffee, tea, sweetened beverages, fruit juices and alcohol. As described by Looman et al., 2017, some recommendations require a minimal intake (e.g., fruit, vegetables) or maximal intake (e.g., sodium), other recommendations an optimal intake (e.g., dairy products) or a replacement (e.g., fats and oils). For each recommendation, participants can proportionally score between 0 and 10 points, depending on the type of recommendation (minimum, maximum, optimal intake or replacement). In the present study, the DHD15-index was calculated per participant using the average of the two 24hRs.

Indicator of a sustainable diet

In the present study, we will focus on environmental sustainability. For this purpose, the environmental impact of the diet was assessed using greenhouse gas emissions (GHGEs), land use (LU) and fossil energy use (FEU). These three indicators are commonly used to assess the environmental impact of a diet (Jones et al. 2016). GHGEs involve the emission of CO_2-equivalents along the supply chain, including carbon dioxide (CO_2), nitrogen dioxide (NO_2) and methane (CH_4). LU includes the occupation and transformation of land agriculture. FEU involves the depletion of fossil energy sources. These three sustainability indicators (GHGE, LU, FEU) can be summarized into a simplistic impact score, which is called the pReCiPe score (Tyszler et al. 2014). The equation of the pReCiPe score is as following:

pReCiPe = 0.0459*GHGE+ 0.0439*LU+ 0.0025*FEU (Tyszler et al. 2014)
in which GHGE, LU and FEU are expressed in kg CO_2-equivalents / kg, m^2*year / kg and MJ / kg, respectively

To estimate the pReCiPe score in the Dutch population, life-cycle assessments (LCA) were performed by Blonk Consultants for 203 food items (Blonk Consultants data set version 2013). All stages of the supply chain, from production to cooking at the home environment, including wastage of food products were taken into account. Emissions related to incineration of food waste were not taken into account. In total, 203 food products were analysed using the LCA to value 1273 food products for the present analysis. Extrapolation was used based on ingredient composition and comparable food products and adjusted for difference in packages and/or preparation methods. The pReCiPe score was calculated per participants using the average of two 24 hour recalls. In the present study, about 90% of the energy intake was covered by the pReCiPe score. Wheat flour, sunflower seeds, sesame paste, wheat bran and peppermint are the main sources of missing data on energy intake.

Other data
The food consumption data from the NQplus study were classified using the GloboDiet food groups (Slimani et al. 1999). Besides the dietary assessment, demographic characteristics (e.g., educational level) and lifestyle factors (e.g., body mass index (BMI), smoking status) were collected at baseline. Educational level was categorized into three categories, namely low (none, lower or lower vocational), medium (intermediate, intermediate vocational) and high (higher vocational or university). Smoking status was categorized in current, former and never smoking groups.

Data analysis

As described above, the taste profile, the DHD15-index and the pReCiPe score were calculated for each participant. For the DHD15-index and pReCiPe score, sex-specific tertiles were created to represent extreme subgroups of the study population. The highest tertile of the DHD15-index was defined as high on health, whereas the lowest tertile was defined as low on health. The lowest tertile of the pReCiPe score was defined as high on sustainability, and the highest tertile was defined as low on sustainability. As a results, four subgroups were created: 1) high on sustainability, high on health (S_{high}-H_{high}, n=206); 2) high on sustainability, low in health (S_{high}-H_{low}, n=114); 3) low on sustainability, high on health (S_{low}-H_{high}, n=106); and 4) low on sustainability, low on health (S_{low}-H_{low}, n=188).

Data were analysed using SAS version 9.4. (SAS Institute, Inc). ANOVA was used to test for differences in tastes between the four subgroups. Subsequently, Tukey was used as post-hoc test. Data was provided as means ±sd, unless otherwise stated. P-values <0.05 were considered statistically significant.

Results

Population characteristics

Overall, the mean (±sd) age of the population was 53 (±12) years; 54% of the participants were male, the majority (64%) had a high educational level and 52% never smoked (Table 1).

In the subgroups, GHGE-scores were lower in the S_{high} subgroups (2.6 kg CO2-eq/d) compared the S_{low} subgroups (4.7-5.5 kg CO2-eq /d). Similar trends were found for land use and fossil energy use. DHD15-scores were higher in the H_{high} subgroup (5.6-5.7 points) compared to the H_{low} subgroups (3.5-3.7 points). There were no differences in energy intake between the subgroups (p=0.32), but the amounts of foods consumed did differ (2336-3143 g/d) (p<.001). BMI was lower in the H_{high} subgroups (25 kg/m^2) compared to the H_{low} subgroups (27 kg/m^2) (p<.001). Further analysis showed (not shown) that taste profiles did not differ in normal weights compared to overweight subjects.

Food groups

Subgroups high on health consumed more fruits, vegetables, legumes, whole grain products and tea compared to subgroups low on health and these subgroups consumed less solid fat and sugar sweetened beverages compared to subgroups low on health (Table 2). Subgroups high on sustainability consumed less meat products and poultry, eggs, coffee and soups than subgroups low in sustainability.

Food groups and taste clusters (contribution to energy intake)

The taste cluster 'neutral' was the largest contributor to the total energy content of the diets in the total study population (Figure 1). This cluster comprises the food groups bread (16.2 en%), cereals and cereal products (6.2 en%), vegetables (2.2 en%), eggs (1.3 en%) and some individual foods from other food groups (14.0 en%).The second largest taste cluster, 'salt, umami, fat', contains several animal-based food groups, such as meat and meat products and poultry (7.7 en%), cheese (5.5 en%), and fish (1.8 en%), but also food groups like nuts, seeds and snacks (3.4 en%) and soups (1.5 en%). The taste cluster 'sweet, sour' consisted of fruits and the taste cluster 'fats' consisted of fats, oils and savoury sauces and savoury bread spreads. The taste cluster 'sweet, fat' contains the food groups pastry and biscuits, sugar, sweets and sweet sauces and milk and milk products and the taste cluster 'bitter' consisted mainly of alcoholic and non-alcoholic beverages (Figure 1). Figure 1 is based on energy intake, therefore non-caloric foods will not be representative in the figure.

Table 1 General characteristics of the total study population, and across the four subgroups, based on combinations of healthiness (DHD15-index) and environmental impact (pReCiPe score) of dietsa‡ (mean + SD).

	Total	S_{high}[c] H_{high}[e]	S_{high} H_{low}[f]	S_{low}[d] H_{high}	S_{low} H_{low}	p-value
	n=1,380	n=206	n=114	n=106	n=188	
Gender, men (%)	54	56	50	45	60	ns
Age (y)	53±12	53±12	50±13	53±11	54±11	ns
BMI (kg/m^2)	26±4.0	25±4[g]	27±5[h,i]	25±3[g,i]	27±4[h]	<0.001
Education level (%)[b]						
High	64	68	56	72	64	ns
Low						
Smoking (%)						<0.001
Never	52	63	55	54	40	ns
Current	9	6	6	2	13	ns
Amount consumed (g/d)	2741±694	2708±623[g]	2336±609[h]	3143±733[i]	2744±675[g]	<0.001
Energy (kcal/d)	2004±572	2032±628	1973±632	1965±497	2080±598	ns
GHGE (kg CO2-eq /d)	3.7±1.7	2.6±0.7[g]	2.6±0.8[g]	4.7±1.4[h]	5.5±2.3[i]	<0.001
FEU (MJ/kg /d)	31.0±9.2	25.9±5.9[g]	24.6±7.0[g]	36.9±10.0[h]	37.2±9.7[h]	<0.001
LU (m2*year/kg /d)	4.3±2.3	2.9±0.9[g]	2.9±1.0[g]	5.4±1.8[h]	6.7±3.2[i]	<0.001
pReCiPe-score (points)	0.44±0.20	0.31±0.08	0.31±0.09	0.54±0.15	0.64±0.26	<0.001
DHD15-index	4.6±0.9	5.7±0.6[g]	3.7±0.5[h]	5.6±0.5[g]	3.5±0.5[h]	<0.001

[a] subgroups are based on sex-specific tertiles of DHD15-index and pReCiPe score
[b] high educational level: higher vocational or university
[c] high on sustainability, indicating a low environmental impact; [d] low on sustainability, indicating a high environmental impact
[e] high on health, indicating a high adherence to the Dutch dietary guidelines; [f] low on health, indicating a low adherence to the Dutch dietary guidelines
[g,h,i] results from Tukey; same letters indicate that these means are the same
GHGE: greenhouse gas emissions; FEU: fossil energy use; LU: land use; DHD15-index: Dutch Healthy Diet index 2015
‡ An ANOVA was performed using the variables by subgroups. If the overall effect was significant ($p<0.05$), a post-hoc test was performed (Tukey)

Table 2 Food consumption (in g/d) per food groups of the total population (NQplus, n=1380), and across four subgroups, based on combinations of healthiness (DHD15-index) and environmental impact (pReCiPe score) of diets; standardized for a 2000kcal diet[e].

GloboDiet food groups	**Overall n=1380 Mean**	**S_{high} H_{high} n=206 Mean**	**S_{high} H_{low} n=114 Mean**	**S_{low} H_{high} n=106 Mean**	**S_{low} H_{low} n=188 Mean**	**p-value**
Fruit (excl. juices)	93±111	122±110[a]	39±73[b]	195±164[c]	45±68[b]	<.001
Vegetables	148±127	164±128 [a]	89±123[b]	222±174[c]	123±111[b]	<.001
Potatoes	70±76	71±80	68±81	67±76	67±75	ns
Nuts, seeds and snacks	20±26	21±25	20±26	18±22	17±25	ns
Legumes	7±25	15±37[a]	1±8[b]	12±35[a]	2±10[b]	<.001
Soy products and vegetarian products	13±54	26±81	11±44	10±51	11±48	<.05
Cereals and cereal products	59±74	63±79	43±63	56±68	55±66	ns
Bread	146±65	164±73[a]	163±68[a]	135±66[b]	135±69[b]	<.001
Whole grain	129±80	163±78[a]	118±79[b,c]	140±89[a,b]	100±73[c]	<.001
Refined grain	79±79	73±88[a,b]	90±81[a]	53±63[b]	92±73[a]	<.001
Meat, meat products and poultry	91±67	39±42[a]	77±54[b]	94±62[b]	145±70[c]	<.001
Red meat	40±49	10±22[a]	24±35[b]	48±44[c]	87±61[d]	<.001
Processed meat	35±40	17±25[a]	45±42[b]	27±39[a]	49±45[b]	<.001
Milk and milk products	291±203	291±189 [a]	241±202[a]	360±223[b]	252±191[a]	<.001
Cheese	32±27	32±26	26±23	32±27	34b±29	ns
Eggs	15±25	12±22[a]	9±18[a]	16±30[a,b]	20±27[b]	<.001
Fish	19±40	20±39[a]	5±16[b]	32±53[c]	10±32[b]	<.001
Savoury bread spreads	7±15	8±13	7±12	6±13	8±19	ns
Pastry and biscuits	40±39	44±40[a,b]	51±47[a]	38±32[a,b]	35±38[b]	<.001
Sugar, sweets and sweet sauces	23±21	33±25[a]	23±18[b]	22±20[b,c]	17±17[c]	<.001
Fats, oils and savoury sauces	31±24	29±25	32±20	27±24	29±22	ns
Solid fat	8±10	6±9[a]	12±11[b]	5±10[a]	11±11[b]	<.001
Liquid fat	12±12	13±13[a]	12±13[a]	12±11[a]	8±10[b]	<.001
Soups	68±114	28±64[a]	27±69[a]	123±158[b]	87±116[c]	<.001
Alcohol and non-alcoholic beverages	1572±712	1528 ±687[a,b]	1456±642[a]	1726±822[b]	1551±664[a,b]	<.05
Sugar sweetened beverages	119±160	80±122[a]	203±229[b]	44±81[a]	149±157[c]	<.001
Alcohol	12±15	7±10[a]	10±14[a,b]	12±14[b]	20±19[c]	<.001
Coffee	461±336	373±289[a]	427±380[a]	466±281[a,b]	552±331[b]	<.001
Tea	386±439	550±506[a]	210±279[b]	647±561[a]	187±282[b]	<.001

a,b,c,d results from Tukey; same letters indicate that these means are the same
e subgroups are based on sex-specific tertiles of DHD15-index and pReCiPe score
‡ An ANOVA was performed using the variables by subgroups. If the overall effect was significant ($p<0.05$), a post-hoc test was performed (Tukey)

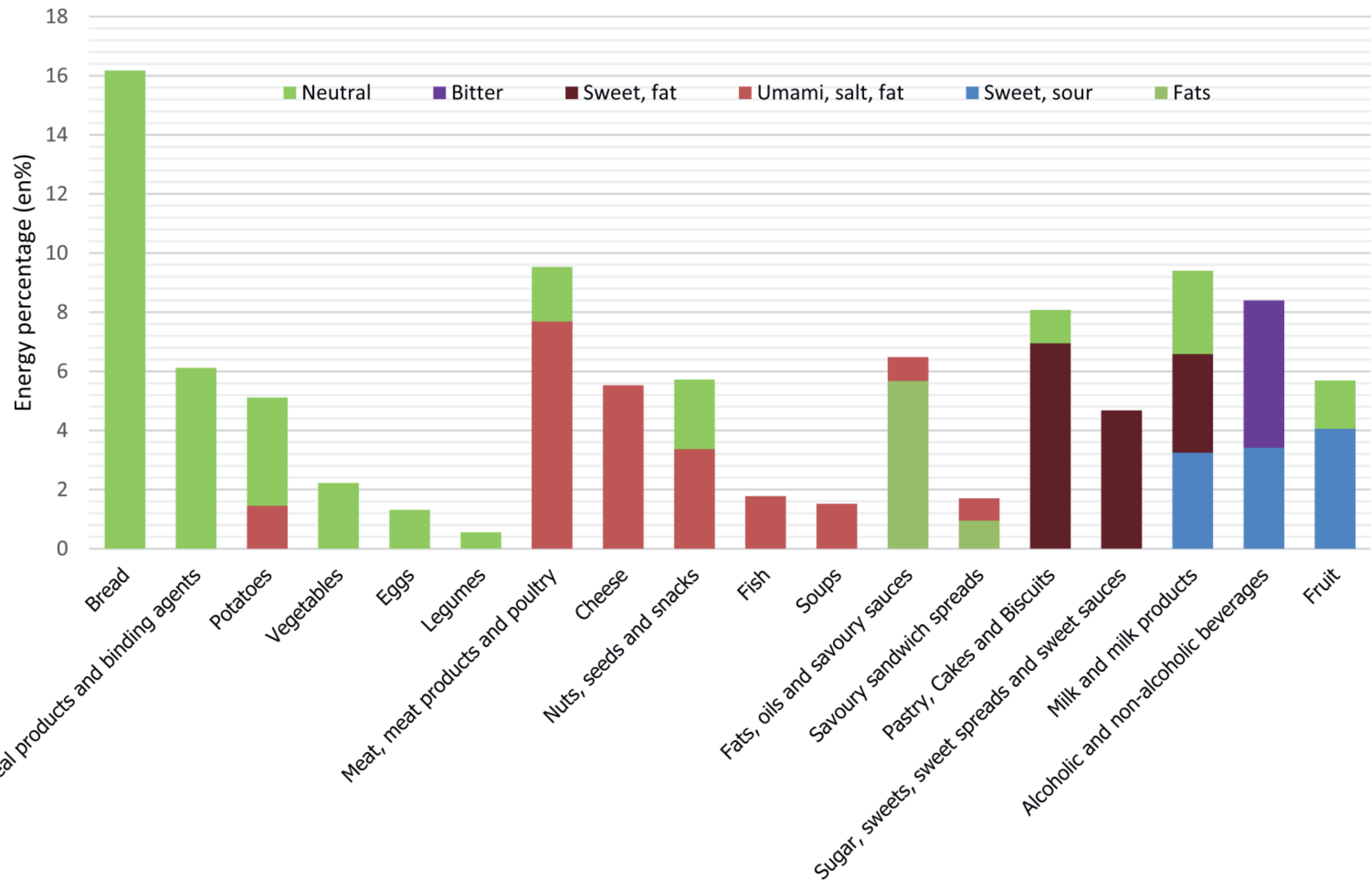

Figure 1 Percentage of energy intake per GloboDiet food group, expressed by the six taste clusters (n=1380)[1]. Note that non-caloric foods are not representative in this figure.

Contribution of taste clusters to energy intake

Foods

The $S_{high}H_{high}$ subgroup consumed more foods with a neutral taste (41.9 en%) than the S_{low}-H_{high} subgroup (35.9 en%), the S_{high}-H_{low} subgroup (33.8 en%) and the S_{low}-H_{low} subgroup (33.0 en%) (p<.001) (Figure 2). Moreover, the S_{low}-H_{low} subgroup had a higher contribution to energy intake in the taste cluster 'umami, salt, fat' (25.6 en%) compared to the other subgroups (18.6 en% (S_{high}-H_{low}), 18.4 en% (S_{low}-H_{high}) and 16.1 en% (S_{high}-H_{high})). Furthermore, the subgroups high on health consumed more foods from the taste cluster 'sweet, sour' ($S_{high}H_{high}$ 6.3 en%; S_{low}-H_{high} 9.2 en%) than the subgroups low on health (S_{high}-H_{low} 3.3 en%; S_{low}-H_{low} 3.0 en%) (p<.001).

Drinks

The S_{high}-H_{low} subgroup (5.0 en%) and the S_{low}-H_{low} subgroup (4.3 en%) consumed more drinks with a sweet, sour taste than the S_{low}-H_{high} subgroup (3.5 en%) and $S_{high}H_{high}$ subgroup (3.1 en%) (p=0.004). In addition, the S_{low}-H_{low} subgroup (8.1 en%) consumed more drinks with a bitter taste than the other subgroups (p<.001).

Contribution of taste clusters to amounts consumed

Foods

The $S_{high}H_{high}$ subgroup consumed more foods with a neutral taste (20.2 gram%) than the S_{low}-H_{high} subgroup (18.0 gram%), the S_{low}-H_{low} subgroup (16.8 gram%) and the S_{high}-H_{low} subgroup (16.7 gram%) (p<.001) (Figure 3). Moreover, the S_{low}-H_{low} subgroup (8.4 gram%) had a higher contribution to the total amount consumed in the taste cluster 'Umami, salt, fat' compared to the other subgroups (6.2 gram% (S_{high}-H_{low}), 5.5 gram% (S_{low}-H_{high}) and 4.7 gram% (S_{high}-H_{high})) (p<.001). Furthermore, the subgroups high on health ($S_{high}H_{high}$ 8.1 gram%; S_{low}-H_{high} 10.0 gram%) consumed more foods from the taste cluster 'sweet, sour' than the subgroups low on health (S_{high}-H_{low} 4.3 gram%; S_{low}-H_{low} 4.4 gram%) (p<.001).

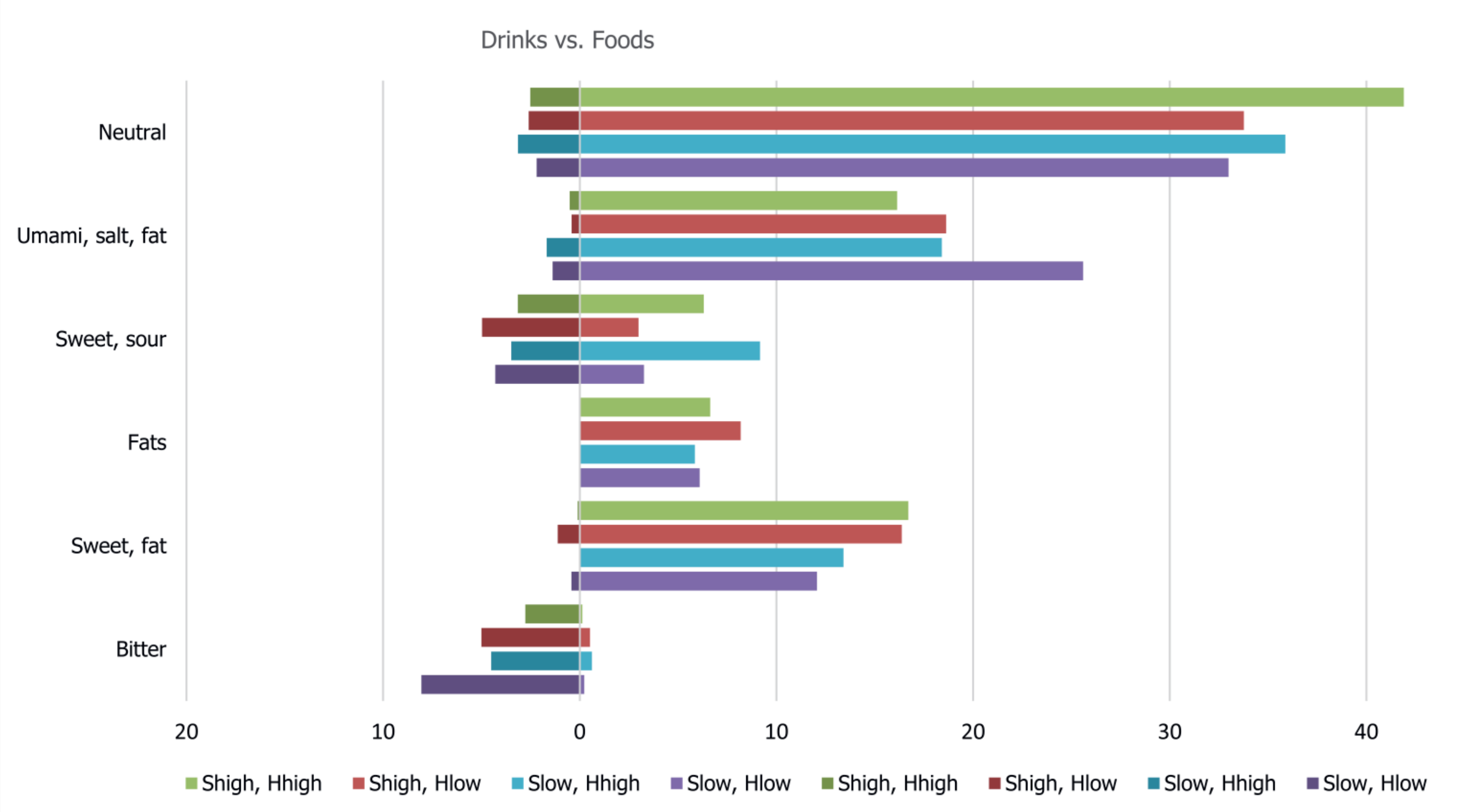

Figure 2 Contribution of taste clusters to energy intake, expressed as energy percentage, standardized to a 2000 kcal diet for both drinks (left) and foods (right) using extremes of four subgroups, classified on the basis of the DHD-tertiles and pReCiPe-tertiles from the NQplus study[1]. Note that non-caloric foods are not representative in this figure.

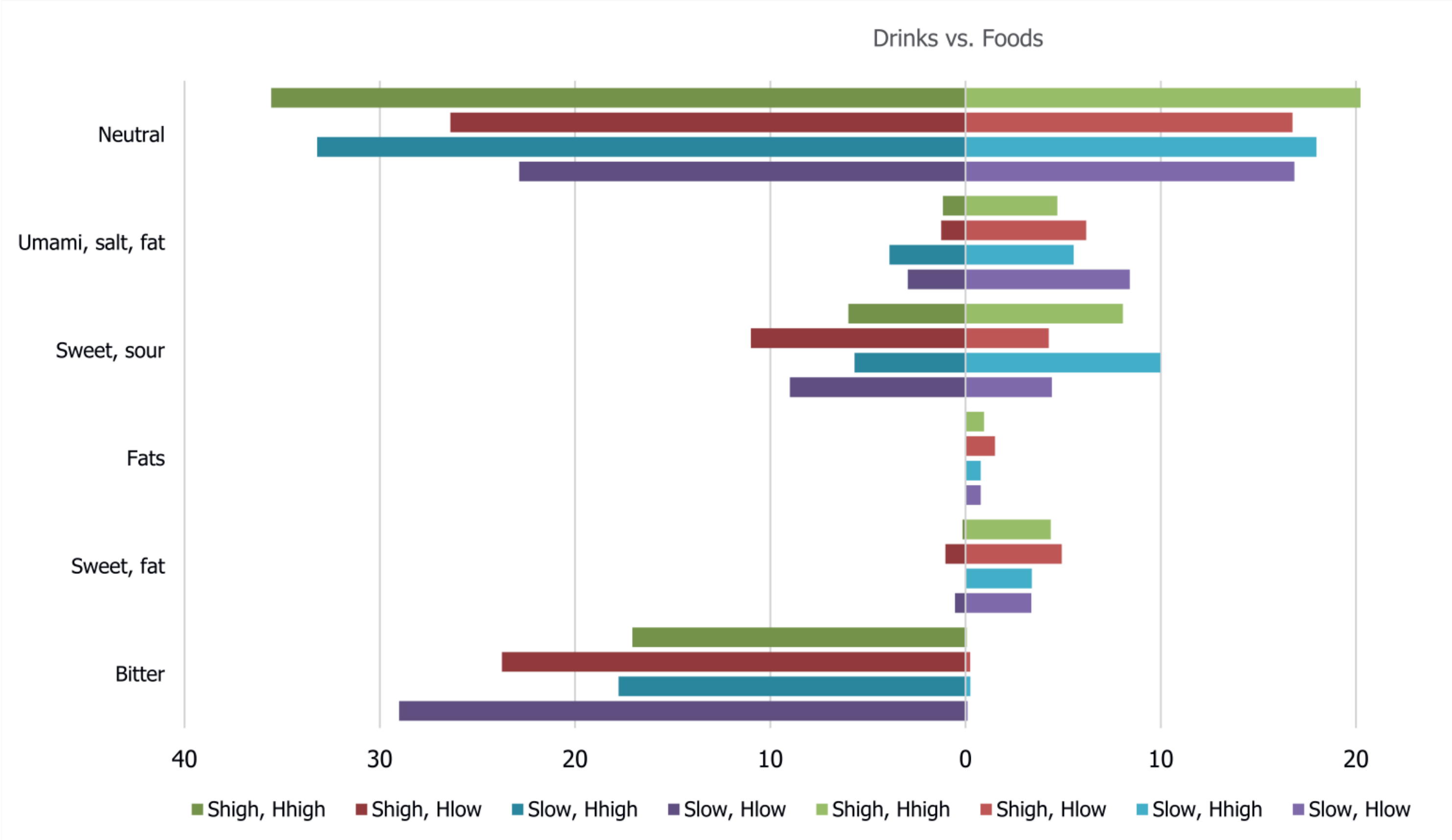

Figure 3 Contribution of taste clusters to the total amount consumed (in gram), expressed as a percentage, standardized to a 2000 kcal diet both drinks (left) and foods (right) using extremes of 4 subgroups, classified on the basis of the DHD-tertiles and pReCiPe tertiles from the NQplus study.

Drinks

The subgroups high on sustainability (S_{high}-H_{high} 35.6 gram%; S_{high}-H_{low} 33.2 gram%) consumed more drinks with a neutral taste than the subgroups low on sustainability (S_{low}-H_{high} 26.4 gram%; S_{low}-H_{low} 22.9 gram%) ($p<.001$). In addition, the S_{high}-H_{low} subgroup (11.0 gram%) and the S_{low}-H_{low} subgroup (9.0 gram%) consumed more drinks with a sweet, sour taste than the S_{low}-H_{high} subgroup (5.7 gram%) and S_{high}-H_{high} subgroup (6.0 gram%) ($p<.001$). Likewise, the subgroups low on health (S_{low}-H_{low} 29.0 gram%; S_{high}-H_{low} 23.7 gram%) consumed more bitter drinks than the subgroups high on health (S_{low}-H_{high} 17.8 gram%; S_{high}-H_{high} 17.1 gram%) ($p<.001$).

Discussion

The aim of this study was to compare the taste profiles of the current diet, of a less healthy and less sustainable diet and of a more healthy and more sustainable diet. Diets that scored high on health and sustainability did differ from diets that scored low on health and sustainability, in terms of taste. Consumers that have a healthier and more sustainable diet consumed less food products from the taste cluster 'umami, salt, fat' (16.1 en%) and 'bitter' (17.1 gram%) and more products from the taste cluster 'neutral' (41.9 en%) compared to consumers that have a less healthy and less sustainable diet (umami, salt, fat: 25.6 en%; bitter: 29.0 gram%; neutral: 33.0 en%).

This is expected as consumers with healthy and sustainable diets consumed lower amounts of meat, meat products and poultry (39g vs. 145g) and soups (28g vs. 87g) compared to other subgroups. These food groups are high contributors to GHGEs and land use in the taste cluster 'umami, salt, fat'. Moreover, these consumers also consumed low amounts of alcoholic beverages (7g/d) and coffee (373g/d) compared to consumers from other subgroups. These two food groups were main contributors in the taste cluster 'bitter'. In addition, consumers in the subgroup high on health and high on sustainability consumed more fruit (122g vs. 45g), vegetables (164g vs. 123g), whole grain cereal products (163g vs. 100g) and tea (550g vs. 187g) compared to the subgroup that was low on health and low on sustainability. All these food groups contributed to the taste cluster 'neutral', which was the largest taste cluster in the subgroup high on health and high on sustainability.

To our knowledge, this is the first study that investigates the relation of dietary taste patterns combining both a health indicator and an environmental sustainability indicator. Investigating food consumption from a sensory perspective is a relatively new area in nutrition epidemiology research. So far, taste has been studied in relation to the macronutrient content of foods, in which sweetness was correlated with the carbohydrate content of foods, and salt with protein content (Lease et al. 2016). In addition, a study found that taste can be related to macronutrients at different eating moments (van Langeveld et al. 2018). In the latter study, taste clusters were analysed based on a representative sample in the Netherlands. The authors found that taste patterns did not differ between the NQplus study and the Dutch National Food Consumption Survey. Hence, analysing dietary taste patterns using the taste clusters may therefore be generalized to healthy Dutch adults (van Langeveld et al. 2018).

In the present analysis, 24hRs were used as a measure of dietary intake. This method is subject to day-to-day variation in intake. Therefore, it is not possible to accurately estimate habitual dietary intake for episodically consumed foods, and subsequently habitual taste patterns at the individual level. Nevertheless, on the group level the within-person variation tends to be cancelled out if the population is large enough, and recalls are repeated within persons. In this study, the dietary taste patterns are compared at group level, which is appropriate given the sample size. Furthermore, in the present study we used only a subgroup of the study to describe the taste profiles. Only participants in the highest and lowest tertiles of the environmentally sustainability indicator and health indicators were used. These extremes demonstrated a clear distinction in the taste profiles between subgroups that were higher and lower on sustainability and health.

With regard to the healthiness of the diets, the DHD15-index was used as a measure of diet quality. Looman and co-workers assessed the DHD15-index in both 24hRs and Food Frequency Questionnaires (FFQ), in which both dietary assessments can be used as a valid measurement to score the healthiness of a diet (Looman et al. 2017). The DHD15-index is based on the Dutch Guidelines for a healthy diet 2015. In 2016, the Health Council in the Netherlands concluded that following the recommendations of a healthy diet would also have some ecological benefits, for instance the reduction of red meat (Kromhout et al. 2016). Biesbroek et al. (2018) confirmed that a 10-point difference in the DHD15-index (out of 140) was related to a 0.2 kg CO2-equivalents per day decrease of greenhouse gases (Biesbroek et al. 2018).

Environmental sustainability can be assessed in different ways. In this study, the pReCiPe score was used as an integrated indicator of environmental sustainability. The pReCiPe score takes into account greenhouse gas emissions, land use and fossil energy use (Tyszler et al. 2014). GHGE and LU are the most frequently used indicators of sustainability of the diet (van Dooren et al. 2017). Temme et al. (2015) assessed the environmental load of the Dutch diet by GHGEs, in which higher consumption of meat, dairy products, soft drinks and alcoholic beverages determined the largest differences between diets that were high on GHGEs and low on GHGEs (Temme et al. 2015). These results are in line with the results of the present study. Besides GHGEs, LU and FEU, water use and loss of biodiversity are also used as indicators for a sustainable diet (Jones et al. 2016), which might tackle other domains of sustainability. For instance, the production of fruits and vegetables require large amounts of water due to irrigation, and might be less sustainable as compared to measures of GHGE, LU and FEU (Tom et al. 2016). However, due to lack on available information on biodiversity loss and water use, these indicators could not be used in the present study. Therefore, we used an extensive database on GHGEs, LU and FEU, based on Dutch food consumption patterns to estimate the environmental sustainability of the Dutch diet (Blonk Consultants, dataset version 2013).

In this study we were able to cover a wide range of food products using the sensory database on taste clusters. Food products with similar food product characteristics (e.g., name or nutrient content) were linked to products to products in the taste-fat-texture database. Using extrapolation, 90% of the energy intake in the study population was covered. More sensory testing could be performed to cover a wider range of food items (e.g., soy products), although soy products, herbs and spices accounted for less than 1% of the energy intake of the population. Moreover, the taste clusters do not take into account the interaction of foods. Foods are rather consumed in combinations (e.g., bread with toppings) than separately. Furthermore, spices and herbs are used to enhance the taste of food products (Ghawi et al. 2014, Peters et al. 2014). These considerations might have an influence on the results, as the taste of foods can be altered or suppressed by food interactions. The food products in the taste cluster 'neutral' might be accompanied by foods from the taste cluster 'umami, salt, fat' to enhance the taste of neutral foods, which is common in a three component meal (e.g., potatoes, vegetables and meat) or lunch (e.g., sandwiches with toppings) in the Netherlands.

The taste clusters in the present study are based on an objective and analytical judgment of food products on the basic tastes (sweet, sour, salt, umami and bitter) and fat sensation of a trained panel (Teo et al. 2018a). These product evaluations do not represent the taste preferences of the average consumer, which are based on hedonic evaluations of food products. There might be a discrepancy between the taste of a food product and the hedonic evaluations by consumers. Consumers have an innate preference for sweetness, and an aversion of bitter tasting food products (Drewnowski 1997). Next to this, consumers also try to seek variety in the diet (McAlister and Pessemier 1982), as the preference for a food product might decrease in case of repeated exposure. Using the taste clusters in the present study, it is not possible to identify the actual taste preferences (liking) of consumers, only the actual taste distributions of the dietary pattern. Taste, in terms of liking, is an important determinant for food choices (Steptoe et al. 1995). Besides taste, there are some other well-known barriers and drivers for food choices, such as price, familiarity, convenience and habitual behaviour (Renner et al. 2012). Next to these, there are also social (e.g., contextual factors) and psychological (e.g., values and attitudes) factors that influence H&S food choices. Further research is needed to study the factors that specifically are related to sustainable (and healthy) food consumption choices. So far, studies have shown that health is one of the reasons for consumers to consume sustainable food products (Renner et al. 2012, Hoek et al. 2017).

In the present study the definition of the FAO was used to define sustainable diets (FAO 2010). As stated before, reducing the consumption of meat and other animal-based foods and increasing fruits and vegetable intake and other plant-based alternatives is beneficial for both the sustainability aspects of the diet and health of consumers. It is challenging to shift consumers towards a more H&S diet, as the definition of the concept of sustainability in relation to a diet is unclear to consumers (Siegrist et al. 2015, Geurts et al. 2017). Therefore, more research is needed to define a H&S diet that can be understood by consumers, to facilitate the shift towards a more H&S diet.

In conclusion, taste profiles of diets high on H&S contain less foods with umami, salt, fat and bitter tastes and more foods with neutral tastes as compared to diets low on H&S. This is related to lower intakes of meat products and coffee in diets high on H&S and higher intakes of fruits, vegetables, cereal products and tea as compared to diets low on H&S. The results suggest that taste profiles should be taken into account when proposing healthy and sustainable menus and meals.

Part 2

Consumer perceptions of food-related sustainability

Chapter 4

Consumer perceptions of food-related sustainability: a systematic review

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Abstract

Consumers play a crucial role in reducing the burden on the environment through their food choices. Currently, food choices are mainly determined by price, convenience, taste and health. To change eating patterns to more sustainable eating patterns, it is essential to understand how consumers interpret "sustainability" in relation to the food supply chain. The aim of this systematic review is to categorize and to describe consumer perceptions of food-related environmental sustainability in general. We conducted a systematic literature review of quantitative and qualitative studies published between January 2010 and June 2020. This resulted in 76 articles; 49 quantitative, 21 qualitative and 6 mixed-method studies. Open coding (grounded theory) was used, and codes were subsequently categorised into subcategories, categories and domains (domain analysis). In total, 834 codes were categorised into 118 subcategories. These subcategories were clustered into 30 categories describing seven different overarching domains: 1) production, 2) transportation, 3) product, 4) product group, 5) consumer, 6) waste and 7) contextual factors. The domains production (31%), transportation (19%) and product (14%) were the largest domains identified in quantitative studies, and in qualitative studies these were production (25%), consumer (20%) and product (20%). Environmental impact, (locally and organic) food choices and ethical production are the most frequent categories mentioned by consumers. However, this literature review also showed that consumers still lack key knowledge on some other specific food-related sustainability topics. In particular, consumers have difficulty defining the concept "sustainability" and to estimate the environmental impact of their food choices. Consumers believe that sustainability does not (yet) influence their food choices. Currently, consumers consider price, taste and individual health more influential than sustainability. It would be useful for policymakers to communicate sustainability knowledge in a transparent, evidence-based and controlled way and to guide consumers by designing a highly regulated and controlled sustainability label.

Keywords: consumer perceptions; sustainability; food chain; quantitative research; qualitative research; systematic review

Introduction

Food choices are mainly determined by price, convenience, taste and health (Allès et al. 2017). Currently, consumers rate environmental concerns as 'not important' (Lehikoinen and Salonen 2019). However, within the food system, consumers play a crucial role in reducing the burden on the environment through their food choices (FAO 2010). Consumers nowadays might even be more aware of environmental issues and the effect their food choices have on the environment, as sustainability receives more attention in the media.

The FAO defines sustainable diets 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" (FAO 2010). This definition is highly complex, and includes environmental, social and economic considerations. Consumers' food choices play a key role in the shift to more sustainable diets. It is therefore of great importance to understand how consumers interpret the concept "sustainability" in relation to their eating patterns.

Environmental sustainability indicators, including the use of natural resources such as water, land, energy, and emissions of greenhouse gases (GHGEs), are often used to assess environmental sustainability (Jones et al. 2016). These natural resources are used and greenhouse gases are produced throughout the supply chain, which comprises agricultural production, food processing and packaging, transportation and consumption (Bradbear and Friel 2011). The supply chain contributes about 25 percent of the total amount of GHGEs produced worldwide (Vermeulen et al. 2012), of which about 60 percent is produced by livestock (Gerber et al. 2013). In comparison, processing, packaging, transportation and waste disposal in total contribute around 5 to 12 percent of the total GHGEs (Vermeulen et al. 2012). Furthermore, social sustainability (e.g., social equity, human rights, decent working conditions and community resilience) and economic sustainability (e.g., long-term economic growth without compromising the environment or communities) are important indicators of sustainability, however these are considerably ignored compared to the environmental sustainability (Jones et al. 2016). Thus, the need to shift to more sustainable consumption patterns and production systems is evident, but challenging to achieve as cultural and economic factors should be taken into account (FAO n.d.).

As consumers have a key role in the transition to a more sustainable food system, it is essential to understand how consumers interpret "sustainability" in relation to the food supply chain. These insights are vital to improve quantitative consumer research on sustainability issues, while taking into account the consumer point of view. Furthermore, these insights can be used to guide policymakers in making informed guidelines and recommendations that align with the consumers' understanding of food sustainability.

Consumers' understanding of food-related sustainability has been reviewed in the context of local and organic foods (Schleenbecker and Hamm 2013, Feldmann and Hamm 2015, Hartmann and Siegrist 2017). However, consumer understanding of food-related sustainability in a general context has not been reviewed. Therefore, the aim of the present review is to categorize and describe consumer perceptions of food-related environmental sustainability in general. We define perceptions as 'ideas, beliefs or images consumers have as a result of how they understand or see food-related sustainability' (Oxford Dictionary 2021). The focus of this review is on adults in high income countries, the users of the formal markets in the urban food system. A systematic literature search was conducted, and extracted data were categorized and described using grounded theory and domain analysis (Corbin and Strauss 1990, Borgatti 1994).

Methods

Search strategy

A systematic search was conducted using the databases Web of Science, PsychInfo, CABabstracts and Scopus, which provide high quality, peer-reviewed journal articles in the social domain. The following search terms were defined on the presented research aim and research boundaries, and combined with the Boolean operators OR and AND: (("sustain*" OR "ecological perspective" OR "environment*" OR "footprint" OR "carbon" OR "green consumption" OR "environmental impact*" OR "climate change*" OR "greenhouse gas*" OR "gas emission*" OR "waste" OR "land use" OR "global warming" OR "energy" OR "biodiversity" OR "local" OR "organic" OR "ethic*" OR "environmentally-friendl*" OR ("perceived environmental impact" OR "perceived environmental activit*" OR "perceived environmental effect"))) AND ALL FIELDS: (("consumer perspective" OR "consumer opinion" OR "consumer view" OR "consumer behavi?r" OR "consumer*")) AND ALL FIELDS: (("food consumption" OR "sustainable consumption" OR "green consumption" OR "sustainable diet" OR "sustainable product*")) AND ALL FIELDS: ((defin* OR knowledge OR understand*)). Wildcards were used to broaden the terms. The asterisk (*) was applied after a word stem to retrieve articles that include words starting with this word stem. The question mark (?) was used to search for alternative spellings of a word. The search was restricted to title, abstract and keywords and limited to the last ten years, that is January 2010 to December 2018. We finished the search on the 12th of December 2018. An updated search was performed on the 3rd June 2020, extending the timespan to June 2020. A flowchart of the systematic search is presented in Figure 1. Articles had to be original scientific papers published in scientific journals, conference proceedings or governmental reports and written in English or Dutch. The first search in Web of Science (n=260), PsychInfo (n=88), CABabstracts (n=184) and Scopus (n=494) yielded 946 unique articles. The second search in Web of Science (n=1,107), PsychInfo (n=320), CABabstracts (n=1,010) and Scopus (n=1,786) yielded 3,569 unique articles. In total, we identified 4,515 articles.

After identification, 4,354 articles were excluded based on the following exclusion criteria: not related to consumers (e.g., the main focus on producers, retailers or policy, supply chain, plants or no consumer perceptions, n=1,516) or not related to food-related sustainability (e.g., electricity savings, smart savings or food safety, n=1,016) or both (e.g., other science fields, health, media, only about foods, non-food, n=777). Furthermore, we excluded studies conducted in low- and middle-income countries (World Bank 2019), because we assume that high income countries have a predominant urban food system with a formal market (n=640), and we excluded articles published before 2010 (n=353). In addition, articles that focused on children or teenagers (n=50), or were written in other languages than English or Dutch were excluded from analysis (n=2). This resulted in 161 articles, including 33 from the first search, and 128 from the second search. We included two articles in Dutch.

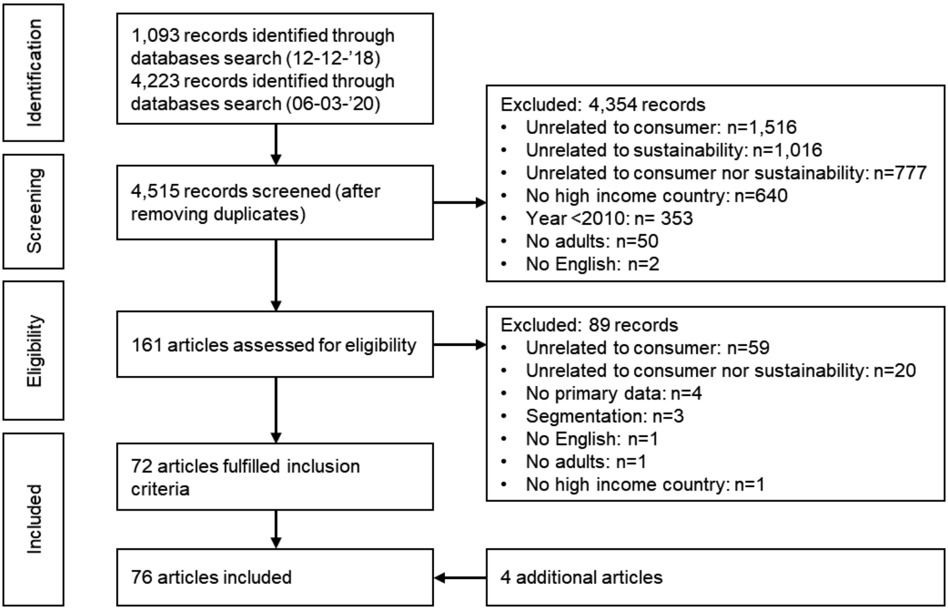

Figure 1 Flowchart of the systematic search.

The full text of these 161 articles was read in detail and again screened against the eligibility criteria. Articles that were not related to consumers (n=59) or were not related food-related sustainability and/or both (n=20) were excluded. In addition, articles from the same research group, in which identical data were repeated were excluded (n=4). In case of segmentation of the study population, we excluded articles that did not present the results from the total population (n=3). Additionally, articles that were written in a language other than English or Dutch (n=1), focused on children or teenagers (n=1) and were conducted in low- or middle-income countries (n=1) were excluded. Overall, our systematic search led to 72 eligible articles. Next, snowballing (forward and backward) was used to find articles that we had missed in our search (n=3). Last, an expert provided a governmental report that met the inclusion criteria. In total, we included 76 articles in this review. The included articles were read and the aim, the study approach (i.e., qualitative, quantitative or mixed-method), data collection method, operationalization, sample size, sex distribution, age range and country were extracted (Appendix A and Appendix B).

Coding and analysis of data

In the present review we used an iterative and an inductive process to code and to cluster codes using grounded theory and domain analysis. In the next section, we briefly explain how we applied grounded theory and domain analysis in the present review. Moreover, we describe how we processed papers with qualitative, quantitative and mixed-method designs.

Grounded theory & domain analysis

In the present review, we used both grounded theory and domain analysis to code and analyse the data. Grounded theory aims to develop and explain a phenomenon by identifying the key elements and explaining the relations of these elements to the context (Corbin and Strauss 1990). Domain analysis aims to understand how communities structure their world by searching for larger units of cultural knowledge, which are called domains (Borgatti 1994). We followed the four steps in domain analysis, as described by Coffey and Atkinson (1996).

The first step of domain analysis was to code the result sections of the selected papers (open coding strategy in grounded theory). We searched for statements and citations that described consumers' ideas, perceptions, actions or understandings about food sustainability. These statements or citations were then captured in a code that identified the underlying issue and phenomenon. For example, the statement "local foods are environmentally friendly" was coded as 'local' and 'environmentally friendly'. All (combinations of) codes were subsequently listed in the form of unstructured codes. In the second and third step of the process, we clustered the codes into subcategories based on proximity in meaning and refutation (axial coding strategy in grounded theory). The second and third step was an iterative process in which terms were introduced one by one and clustered by hand. This process involved two researchers (LvB, MM). For each code it was decided 1) to cluster it with other terms, based on proximity or 2) to create a new list of codes, based on refutations. These two steps were repeated with the subcategories to form cover terms (categories). The cover terms that described the same phenomenon were then grouped into domains, which described the same phenomenon. For instance, the domain waste included the categories food waste and recycling. Step four, the final step, was to identify semantic relationships between the subcategories and categories, and between the categories and the domains (selective coding in grounded theory). Codes that did not have clear relationships between the subcategories and the categories were discarded. A number of three different codes was used as a minimum for a subcategory.

Qualitative and quantitative coding

Slightly different coding approaches were used for coding the results of quantitative and qualitative studies. In quantitative studies, which included survey questions, three different outcome measures were extracted, namely frequencies, percentages and means of the Likert scale used. These results were only coded when the frequency was at least one, the percentage of the mentioned answers (among the responders) was ≥10% and the means were in the lowest or highest tertile of the total scale. Qualitative studies included results from interviews or focus groups in which results were coded whenever a participant mentioned a belief or perception of food-related sustainability. Mixed-method approaches were split into the qualitative and quantitative result section, and were separately coded as described above.

The results of the coding and clustering (domain, category, subcategory) were used to create two separate datasets, one for quantitative studies and one for qualitative studies. The frequency of each domain, category and subcategory was then calculated. The domains, categories and subcategories with their corresponding frequency are displayed in figures in the result section.

Overview of the selected studies

In total, 49 quantitative, 21 qualitative and 6 studies with mixed-methods were included in the present study. Only a small number of studies (n=12) was published before 2014. Most studies were conducted in the US (n=16), and European countries (n=93), most of these were conducted in Germany (n=12), Italy (n=12), and the UK (n=10). Other countries included Australia (n=3), New Zealand (n=1), Canada (n=1) and United Arab Emirates (n=1). Note that some studies are conducted in multiple countries (Appendix A and Appendix B).

Results

In this section, we briefly describe the results of the coding. Next, we describe the domains in more detail. The overview of the studies and their role in the domains and categories can be found in the Supplementary files.

Domains, categories and subcategories

In total, 986 citations and statements were coded using open coding (step 1). The codes were clustered into 118 subcategories. These subcategories were clustered into 30 categories describing 7 different overarching domains (axial coding, step 2 and 3). The seven domains that were identified were 1) production, 2) transportation, 3) product, 4) product group, 5) consumer, 6) waste and 7) contextual factors. A total of 152 codes had no clear relationships to the categories, and were therefore discarded (part of selective coding, step 4). Overall, we included in total 834 codes, 459 codes from quantitative studies and 375 from qualitative studies.

The formed domains, categories and subcategories are presented in figures separately for quantitative studies and qualitative studies (Figure 2-8). The domains production (31%), transportation (19%) and product (14%) were the largest domains derived from quantitative studies, and in qualitative studies these were production (25%), consumer (20%) and product (20%). For the quantitative studies, we found that the most frequent categories were "local", "organic food production" and "environment". For the qualitative studies, the largest categories are "ethical production", "organic food production" and "labelling in general".

Domain production

Consumers mainly referred to organic food production, the environment, ethical production, food production and seasonal production when talking about the domain "production" (Figure 2). In quantitative studies and qualitative studies, organic food production was described as environmentally friendly ($n_{quantitative}$=16, $n_{qualitative}$=7), without the use of pesticides ($n_{quantitative}$=12, $n_{qualitative}$=7) while protecting natural resources ($n_{quantitative}$=3, $n_{qualitative}$=7). In addition, in quantitative studies organic food production was described without genetically modified organisms (GMOs) ($n_{quantitative}$=6) and in qualitative studies in relation to humane treatment of animals ($n_{qualitative}$ =3).

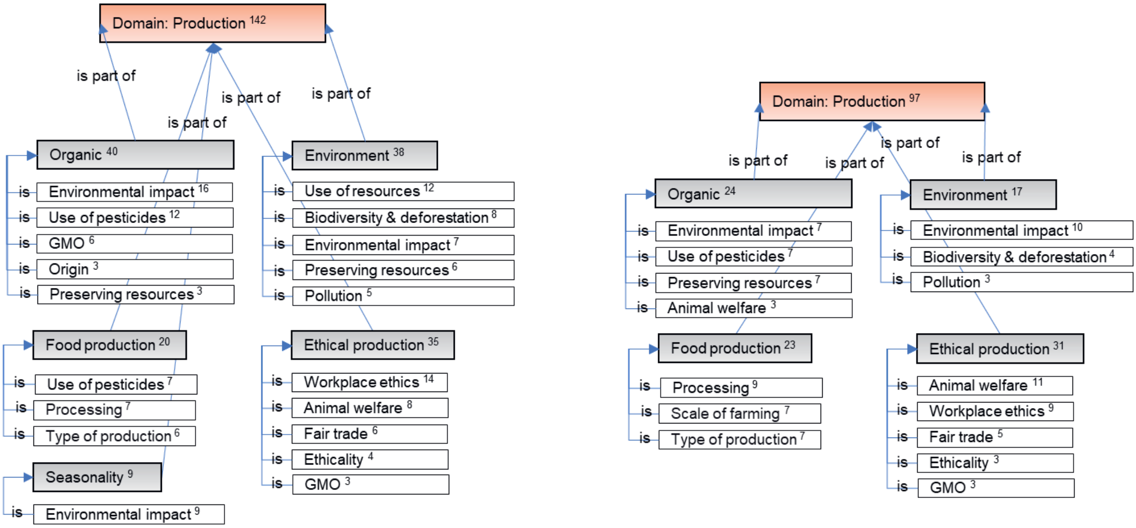

Figure 2 Domain production with subcategories (uncolored boxes), semantic relationships (labels on the arrows) and categories (filled boxed) for quantitative studies (left) and for qualitative studies (right). Number of codes in the subcategories, categories and domains are in superscript.

The category environment was, in both quantitative and qualitative studies, described in terms of greenhouse gas emissions (environmental impact) ($n_{quantitative}$=7, $n_{qualitative}$=10, pollution ($n_{quantitative}$=5, $n_{qualitative}$=3) and biodiversity degradation and deforestation ($n_{quantitative}$=8, $n_{qualitative}$=4). Furthermore, from quantitative studies, the use of land, water and energy ($n_{quantitative}$=12) and the protection of natural resources ($n_{quantitative}$=6) were also part of the category “environment”. Consumers referred to ethical production through the ethical dilemma of slaughtering animals ($n_{quantitative}$=8, $n_{qualitative}$=11), the working conditions and wages for food producers and the use of child labour ($n_{quantitative}$=14, $n_{qualitative}$=9), and fair trade, ecological production and the discussion whether GMO was morally right or wrong ($n_{quantitative}$=13, $n_{qualitative}$=11). For the category food production, consumers specified the use of pesticides in food production ($n_{quantitative}$=7), the degree of processing ($n_{quantitative}$=7, $n_{qualitative}$=9), whether foods should be grown in their own garden ($n_{quantitative}$=6, $n_{qualitative}$=7) and the scale of farming (shorter chains) ($n_{qualitative}$=7).

Domain transportation

When talking about "transportation", consumers referred to locally produced foods, the distance, the environment and transportation method (Figure 3). Locally produced foods were seen as environmentally friendly ($n_{quantitative}$=25, $n_{qualitative}$=4), sold directly from the farm and better for the local economy ($n_{quantitative}$=13, $n_{qualitative}$=6), and with shorter transportation distances ($n_{quantitative}$=6). The distance of foods was related to the origin of a product ($n_{quantitative}$=9, $n_{qualitative}$=5) and determined by the so-called food miles ($n_{quantitative}$=3, $n_{qualitative}$=8), i.e., the distance food travels. In addition, the environmental impact of transportation was mentioned ($n_{quantitative}$=6, $n_{qualitative}$=3). Moreover, the mode of transportation was mentioned in quantitative studies ($n_{quantitative}$=11). The mode of transportation discussed was transportation by plane, ship or truck, of which transportation by plane was associated with the greatest environmental impact.

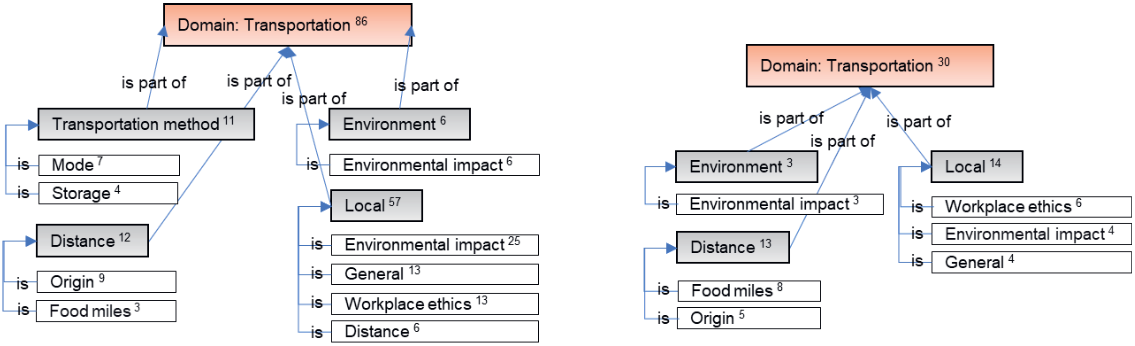

Figure 3 Domain transportation with subcategories (uncolored boxes), semantic relationships (labels on the arrows) and categories (filled boxed) for quantitative studies (left) and for qualitative studies (right). Number of codes in the subcategories, categories and domains are in superscript.

Domain product

Regarding the domain "product", consumers pointed out sustainability labels of food products ($n_{quantitative}$=33, $n_{qualitative}$=43) and packaging ($n_{quantitative}$=30, $n_{qualitative}$=30) (Figure 4). With regards to labelling, consumers referred to sustainability labels in general ($n_{quantitative}$=16, $n_{qualitative}$=24), and more specifically to eco-labels ($n_{quantitative}$=6, $n_{qualitative}$=10), organic labels ($n_{quantitative}$=11, $n_{qualitative}$=6) and fair-trade labels ($n_{qualitative}$=3). In quantitative studies, the function of labels (e.g., useful in food choices, or source of information), familiarity of the labels and lack of trust in labels were discussed. In qualitative studies, consumers seemed to be more sceptical of labelling. Terms that were mentioned in these studies included 'greenwashing', 'doubts about the criteria used to claim sustainability' and 'more transparency needed'. Moreover, it was mentioned that official certification was required to make the consumers trust the labels, and more knowledge was needed to understand the meaning of the labels. In contrast, consumers also pointed out that a label could assist to make more climate-friendly food choices, as it contains information about sustainability. Organic and fair-trade labels were mentioned as the most well-known labels ($n_{qualitative}$=6). Regarding packaging, we distinguished two categories, namely package material ($n_{quantitative}$=12, $n_{qualitative}$=11) and amount of packaging ($n_{quantitative}$=18, $n_{qualitative}$=19). Consumers referred to the use of different types of package material, including plastic and paper, of which plastic was seen as the least environmentally friendly alternative ($n_{quantitative}$=4, $n_{qualitative}$=3). Moreover, consumers stated that it was environmentally beneficial to have the minimum amount of packaging, but on the other hand they mentioned that to some extent packaging was necessary to protect the food products ($n_{quantitative}$=1).

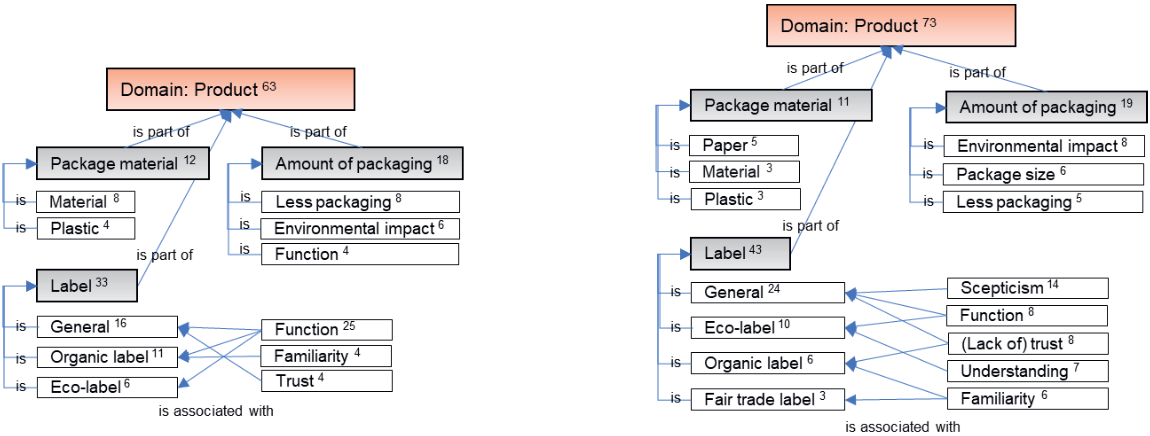

Figure 4 Domain product with subcategories (uncolored boxes), semantic relationships (labels on the arrows) and categories (filled boxed) for quantitative studies (left) and for qualitative studies (right). Number of codes in the subcategories, categories and domains are in superscript.

Domain product group

When consumers talked about food groups in the context of sustainability, they referred to meat ($n_{quantitative}$=10, $n_{qualitative}$=17), dairy ($n_{quantitative}$=10, $n_{qualitative}$=4), (free-range) eggs ($n_{qualitative}$=4) and (seasonal) fruits and vegetables ($n_{quantitative}$=3, $n_{qualitative}$=3) (Figure 5). The categories meat and meat reduction were associated. In the qualitative studies, consumers perceived meat to be savoury ($n_{qualitative}$=3), healthy ($n_{qualitative}$=3) and an essential component of the meal ($n_{qualitative}$=6). Consumers tend to underestimate the impact of meat, and consumers were not aware about the impact of meat consumption ($n_{quantitative}$=3, $n_{qualitative}$=5). On the contrary, some consumers were aware of the idea that reducing meat was environmentally beneficial ($n_{quantitative}$=8), healthier ($n_{quantitative}$=4, $n_{qualitative}$=4) and more animal friendly ($n_{qualitative}$=4), but consumers stated that they were reluctant to reduce their meat consumption (smaller portions or one meat-free day) ($n_{qualitative}$=4), or to become vegetarian ($n_{qualitative}$=4).

Domain consumer

Categories related to information ($n_{quantitative}=10$, $n_{qualitative}=11$), knowledge ($n_{quantitative}=3$, $n_{qualitative}=23$) and food choice ($n_{quantitative}=43$, $n_{qualitative}=41$) were captured in the domain "consumer" (Figure 6). The category 'food choice' contained perceptions about sustainable, locally and organic food choices. In quantitative studies, when consumers talked about their motives for or barriers to sustainable food choices, they referred to food safety, higher

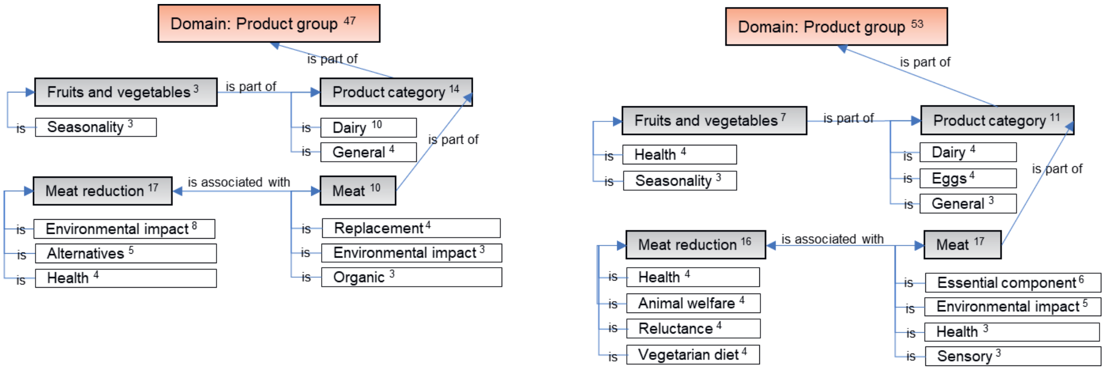

Figure 5 Domain product group with subcategories (uncolored boxes), semantic relationships (labels on the arrows) and categories (filled boxed) for quantitative studies (left) and for qualitative studies (right). Number of codes in the subcategories, categories and domains are in superscript.

prices, better taste and higher quality foods. Similar to sustainable food, locally produced products were also characterized by food safety, better taste and higher quality foods. In addition, consumers considered locally and organic foods to be healthy. In qualitative studies, motives for sustainable, locally produced and organic foods were more diverse. Consumers believed that sustainable foods were hard to find, inconvenient in use, more expensive and more reliable. However, sustainable foods were not much considered. Organic foods were chosen for their taste and higher quality, but the higher price was perceived as a barrier. Locally produced foods were perceived as fresher. Perceptions of price in locally produced foods were inconclusive, both cheaper and more expensive were mentioned.

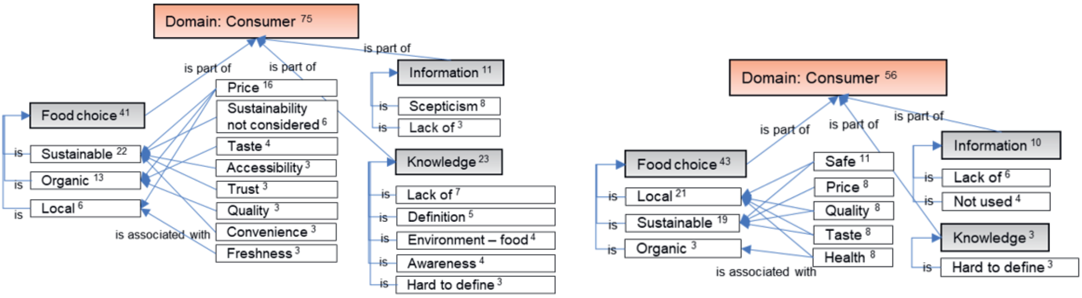

Figure 6 Domain consumer with subcategories (uncolored boxes), semantic relationships (labels on the arrows) and categories (filled boxed) for quantitative studies (left) and for qualitative studies (right). Number of codes in the subcategories, categories and domains are in superscript

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With regards to information on sustainability, consumers agreed that there was a lack of available information ($n_{quantitative}$=6, $n_{qualitative}$=3), however, if information was available, it was not used much ($n_{quantitative}$=4) and the information sources were distrusted ($n_{qualitative}$=8). Terms used were "questioning the existence of a problem", "nobody reads guidelines on climate-friendly choices" or "can we really trust it when one says it is environmentally friendly?". Moreover, consumers also agreed that sustainability was difficult to define ("difficult to identify climate-friendly foods", "lack of concrete idea what climate-friendly means" or "hard to explain sustainable consumption"). Adequate knowledge about the environmental impact of their food choices was lacking in most consumers. Some consumers mentioned that there was no connection between their food choices and environmental sustainability ($n_{qualitative}$=4).

Domain waste

When consumers talked about the domain "waste", they referred to food waste ($n_{quantitative}$=13, $n_{qualitative}$=19) and recycling ($n_{quantitative}$=29, $n_{qualitative}$=7) (Figure 7). In quantitative studies, reducing food waste and separating waste into different containers were considered to be sustainable by consumers. In qualitative studies, consumers mentioned that throwing food away was considered a waste of money. Moreover, consumers were not aware of the extent of the food waste problem, except for their own household. Consumers stated that reducing food waste was perceived as environmentally beneficial, however, consumers thought that throwing food scrapes away was sometimes unavoidable due to a shorter shelf life (e.g., fruits and vegetables).

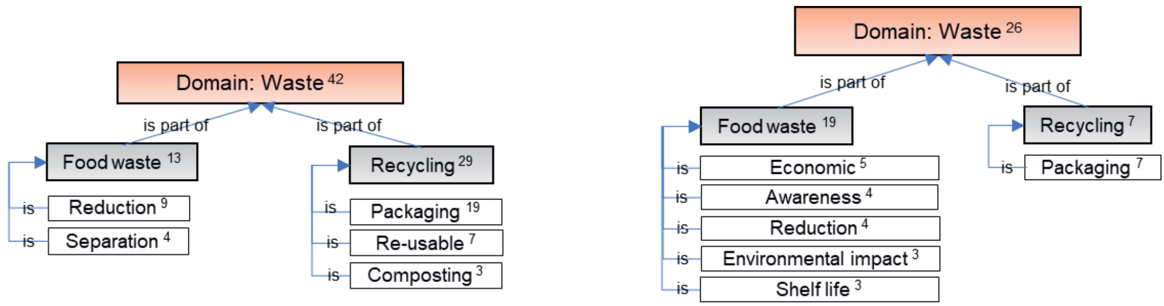

Figure 7 Domain waste with subcategories (uncolored boxes), semantic relationships (labels on the arrows) and categories (filled boxed) for quantitative studies (left) and for qualitative studies (right). Number of codes in the subcategories, categories and domains are in superscript.

Domain contextual factors

The domain "contextual factors" included factors outside the food production chain (Figure 8). Health was most often mentioned as the main reason why consumers followed a sustainable eating pattern ($n_{quantitative}$=11, $n_{qualitative}$=7). A term that has been mentioned is "Health affects oneself and sustainability is a bonus." Terms related to the categories future generation and responsibility included "sustainability is a future issue", "feel responsible for the future generations", "sustainability is a public concern", "society as a whole is responsible", "consumers alone cannot solve such a major issue" and "I feel powerless to change".

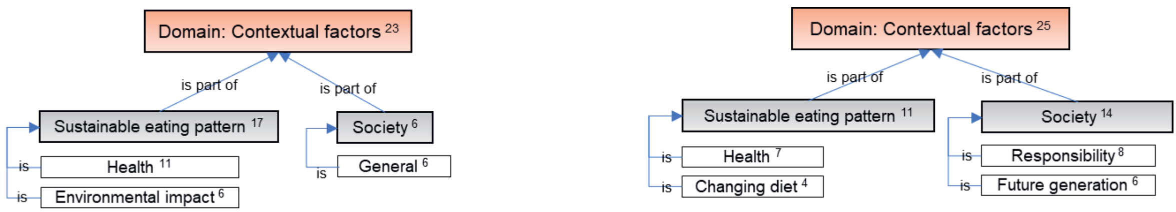

Figure 8 Domain contextual factors with subcategories (uncolored boxes), semantic relationships (labels on the arrows) and categories (filled boxed) for quantitative studies (left) and for qualitative studies (right). Number of codes in the subcategories, categories and domains are in superscript.

Discussion

The aim of this systematic review was to categorize and describe consumer perceptions of food-related environmental sustainability in general. This is the first review to provide an overview of the beliefs of consumers on food-related sustainability. We provided insights that are important to better target food related sustainability policies to the consumer. In the following sections we discuss the main results, the methodology used and opportunities for policy makers to steer consumers toward sustainable food consumption practices and, lastly, our conclusion.

Main results

We found that consumers referred most frequently to 'the environmental impact' when thinking about food-related sustainability. We noticed that the terms related to the environmental impact were 'environmentally friendly', 'environmental beneficial' and 'environmental impact'. The percentage of codes related to the 'environmental impact' was 17% and 11% in quantitative studies and qualitative studies, respectively. These results indicate that consumers recognize that using too much of the world's resources, such as land, water and energy, pollution, the carbon emissions, the loss of biodiversity and deforestation are a sustainability concern. Crippa et al. (2021) calculated that food production is responsible for 34% of total greenhouse gas emissions, with the largest contribution coming from agriculture and land use (71%). Food production, packaging, processing, transportation, retail, consumption and waste management accounted for the remaining 29% (Crippa et al. 2021).

However, based on this review, we can conclude that consumers are not aware of the actual impact of food production, and in particular livestock production. Some consumers recognize that there is some impact involved in food production, while others believe there is no connection between food production and the environment at all. Locally produced foods, organic food production, seasonal foods and reducing food packaging are all considered to be environmentally friendly. Interestingly, we know that organic food production is not necessarily more sustainable than conventional consumption, as organic food production requires more land (Redlichová et al. 2021). In addition, we observed that consumers are not fully aware of the environmental impact of meat production. Some consumers doubt that meat production negatively affects the environment. They need more evidence to be convinced that reduction of meat consumption is needed for the environment. Objective data show that animal production is a larger contributor to greenhouse gas emissions compared to plant-based food production (Poore and Nemecek 2018). Therefore, it is pivotal that policy makers provide information and knowledge to consumers in a straightforward, trustworthy, evidence-based way to communicate the environmental impact of food production, and in particular animal production.

Another main remark relates to the high contribution of codes related to locally produced ($\%_{total}$=12%) and organic foods ($\%_{total}$=10%). Our results showed that consumers believe that local and organic foods are part of a sustainable diet (e.g., low environmental impacts). Both locally produced and organic foods were rated as tastier ($n_{quantitative}$=5, $n_{qualitative}$=4) and healthier ($n_{quantitative}$=5, $n_{qualitative}$=3). Consumers stated intent to change towards a more (environmentally) sustainable diet for health reasons. Health reasons can be categorized as self-centred reasons, as it only benefits their own health. Environmental reasons can also be categorized as altruistic, as they benefit the well-being of future generations and the planet in the long term. Since individual health and taste are one of the main determinants of food choice (Steptoe et al. 1995), it is of interest for marketers to use individual health and taste as important aspects to promote more sustainable foods. However, it should be noted that sustainable food choices cannot be translated one to one with healthy food choices (Macdiarmid 2013). Consumers need nutritional guidance to choose healthy and sustainable foods, including better access to and availability of sustainable alternatives.

This review summarized barriers mentioned by consumers in relation in sustainable food consumption. Consumers perceived sustainable foods as inconvenient ($n_{quantitative}$=3) and expensive ($n_{quantitative}$=8, $n_{qualitative}$=16). Yet, beliefs about prices are not necessarily true. Donati et al. (2016) calculated that a healthy and sustainable diet is not necessarily more expensive than current Western diets. This may be useful for policy makers to remove price as a barrier in sustainable food consumption.

We found that sustainability is little or not considered when making food choices. One explanation might be the lack of knowledge and understanding of the concept of food sustainability. For consumers, the concept of food sustainability covers a wide range of terms. For example, terms that are frequently used are carbon footprint, climate change, climate-friendly, environmentally beneficial, environmental impact or environmentally friendly. These terms are used interchangeably, and consumers have difficulties to define sustainability in open-ended questions. We found a large range of terms that are related to food sustainability, considering the whole supply chain. Nonetheless, we can state that consumers lack knowledge about what is relevant for food-related sustainability. Therefore, it is highly important to use clear and consistent terms to communicate sustainability-related information to consumers.

It was also noted that consumers are sceptical about food sustainability, in particular with respect to information on labels and the existence of climate change. Sustainability is not yet perceived as a major concern; sustainable (food) consumption is considered to be a secondary effect of a (healthy) diet and consumers do not feel responsibility to change their eating patterns. However, consumers who want to change feel powerless to achieve environmental change (individual efforts vs. collective actions). Since consumers are aware of environmental labels, this can be a useful tool to increase people's awareness of the sustainability issue and the impact of food choices on the climate. On the other hand, some consumers show distrust towards sustainability labelling as a communication strategy. Lack of certification and control in food labelling, lack of transparency, and greenwashing have been briefly touched upon by consumers. It is therefore crucial for policy makers to address these consumer criticisms by communicating in an unambiguous and transparent way. This may be done by designing a universal sustainability label that is transparent, and regulated and controlled by the government.

Methodology

We used Grounded Theory and Domain Analysis to code and analyse the results. Domain analysis allowed us to answer questions about how consumers generally structure thoughts of food sustainability. Through open coding we efficiently identified statements and citations of consumers. Decisions on clustering of codes and subcategories, and semantic relations between subcategories and categories required subjective judgement. For example, we could have opted for the domain 'environmental impact', with subcategories related to the supply chain. The decisions made in this review are difficult to replicate, however, two researchers were involved in the categorization of subcategories and categories. Each code was discussed one by one to be clustered in other subcategories (based on proximity) or placed on a new list.

This systematic review included studies that used different methodologies (e.g., questionnaires, focus groups or interviews). Quantitative study approaches (e.g., web-based or face-to-face questionnaires) have the advantage of large sample sizes that which enhances target population representativeness, if sampled in a decent matter. However, the disadvantage of quantitative study approaches is that they are bounded to a limited number of items in the questionnaires. Research items are selected, structured and formulated by the researcher, and thus the selected questions are biased by the perspective of the researcher. In contrast, qualitative study approaches (e.g., focus groups or interviews) have the advantage to unravel the underlying perceptions of consumers, for example, the (lack of) knowledge on food-related sustainability or the sceptical notes, but they have only limited sample sizes. In the current review we used the advantages of both study methodologies; the large sample sizes of quantitative study approaches and the open-ended questions and discussions of qualitative study approaches.

One of the challenges in both quantitative and qualitative study approaches is obtaining the 'true' perceptions of consumers. Some perceptions are prone to social desirability, for instance participants may overreport engagement in sustainable behaviours and give higher rates of importance to ethical behaviours (e.g., use of child labour, working conditions, and animal welfare). Emotions such as guilt may play a role in these ethical dilemmas. Although consumers believe that ethical production and sustainable consumption are important, market shares of sustainable foods are relatively low. Social desirability might therefore result in overrepresentation of certain subcategories, and thus biased subcategories.

The quantitative studies included in this review had different study outcomes and presented the results in different ways (i.e., means, frequencies and percentages). We systematically coded the outcomes using predetermined cut-off points and therefore approached each study in the same way. Using these predetermined cut-off points we excluded three additional quantitative studies that met the inclusion criteria. However, none of the outcome measures in these three studies fell within the cut-off points (Liobikiene et al. 2016, Merle et al. 2016, Pohjolainen et al. 2016). Each study in this literature review was weighed equally, so we did not consider the number of participants when summarizing the results. In this review we aimed to give a complete overview of all perceptions regarding food-related sustainability, and therefore, weighing was not appropriate.

In this review we excluded articles that focused exclusively on a selected target groups (e.g., vegetarians) or on other segmented groups (e.g., sustainers vs. unsustainers). This makes it difficult to generalize our results. However, we were particularly interested in the 'general' consumer, to be able to advise policy on the largest consumer group. As a next step, it would be of great interest to study the perceptions of food-related sustainability in selected target groups and segmented groups. Moreover, locally produced and organic foods are highly represented in this review. We observed that some articles only focused on one aspect of sustainability, with organic foods (n=10) and locally produced (n=7) being the most extensively studied.

Moreover, we focused only on adults. When considering the demographics of the study populations, it became clear that age ranged from 16 to over 80 years old. Only two studies included participants younger than 18 years (Al-Taie et al. 2015, Bryła 2016). Older participants in studies might have different perceptions of sustainability, compared to the younger participants. However, as the results on perceptions in these papers were presented for the entire sample we could not stratify by age. Moreover, the majority of participants in the included studies were female (in at least 63% of all studies). Research suggests that women are more likely than men to engage in sustainable consumption, which may be explained by different lifestyle practices and social norms (Bloodhart and Swim 2020). In this review it was not possible to stratify by gender as results were only presented for the entire sample. We still believe that the perceptions of food-related sustainability are captured for both men and women, as most studies included both men and women.

In total, we included 76 articles conducted in 25 different high-income countries, which can be considered a good representation of the high-income countries. We assumed that high income countries have a predominant urban food system with a formal market. It would be interesting to examine the perceptions of consumers in low-income countries regarding food sustainability, as their food system is often more rural based. This could provide new insights on how consumers can shift to a more sustainable food system, with equal access to food.

Opportunities

This review points out several opportunities to facilitate consumers towards more sustainable behaviour. Consumers need to understand the importance of the environmental impact of food production on planetary degradation and other sustainability-related factors, such as packaging, waste and transportation. To this end, consumers need guidance to shift to sustainable food consumption. We believe that clear guidance and criteria should be used to label sustainable foods, as consumers believe that labelling can be beneficial to make more sustainable food choices (Laureati et al. 2013, Valor et al. 2014, Ekelund and Spendrup 2015, Klein and Menrad 2016).

More importantly, consumers must feel the urgency to shift to a sustainable diet. Currently, consumers do not consider food sustainability of high importance. Some concerns need to be addressed. First, consumers indicated that they feel powerless to combat climate change individually and they need governments to initiate collective actions. Second, sustainability is still seen as a future issue. However, we need to combat climate change now for future generations. It is therefore essential that governments take collective actions as soon as possible, and policymakers should communicate the urgency of environmental sustainability in a transparent, concise and evidence-based manner.

Beliefs of the next generations should also be considered, as its urgency increases for future generations to consume in a more sustainable way. As mentioned, little is known about food sustainability related perceptions of children or adolescents. A few studies introduced educational programs on sustainable consumption, aimed at raising awareness for ethical consumption (Schmid 2012) or making better decisions concerning sustainable consumption (Hadjichambis et al. 2015). Only Francis and Davis (2015) studied sustainability concerns and reasons for not consuming sustainably among adolescents, although they did not specifically focus on food-related sustainability. Therefore, it would be of great importance to monitor younger populations and examine their beliefs on environmental issues. Especially as climate change will greatly affect the next generation.

To reduce overall GHGEs from livestock production, it is key to reduce meat consumption. This review shows that consumers do believe that meat reduction is environmentally beneficial. We believe that producers can, for example, contribute by reducing the portion sizes of meat products, as a first step toward a more sustainable food system. Reynolds et al. (2019) showed that diets with reduced GHGEs are affordable in different income groups, and Goulding et al. (2020) showed that a healthy and sustainable diet cost less than a conventional Western diet. Policymakers can use price as a facilitator for a more sustainable diet. In addition, it would be useful for consumers to receive assistance in preparing and consuming more sustainable foods, as reducing meat consumption may involve new cooking techniques. One hurdle to overcome is that some consumers are sceptical about reducing their meat consumption. Consumers mentioned that meat is an essential component of a meal, that meat is part of a healthy diet, and that consumers like the sensory properties of meat (e.g., satiating value and taste). As such, these perceptions should be recognized, and healthy meat alternatives should be recommended.

It is also clear from this review that, in general, consumers do embrace certain collective initiatives to reduce the burden on the environment. Consumers find it important to minimize the amount of packaging, especially plastic packaging; or to manage their waste, such as recycling, reusing food packages, composting and separating waste. A review of Nemat et al. (2019) concluded that visual cues could motivate consumers to sort waste or to recycle food packaging. Furthermore, consumer initiatives, such as reducing plastic packaging by consumers and sorting waste show that consumers are capable of changing toward more sustainable behaviours, and these initiatives could be encouraged to take more steps toward a sustainable food system.

Conclusion

This review showed that consumers have a wide range of perceptions of food-related sustainability, covering the whole supply chain. Environmental impact, (locally and organic) food choices and ethical production are the most frequent categories mentioned by consumers. However, this literature review also showed that consumers still lack key knowledge on some other specific food-related sustainability topics. In particular, consumers have difficulty defining the concept "sustainability" and to estimate the environmental impact of their food choices. Overall, consumers believe that sustainability does not (yet) influence their food choices. Currently, consumers consider price, taste and individual health more influential than sustainability. It would be useful for policymakers to communicate sustainability knowledge in a transparent, evidence-based and controlled way to consumers.

Acknowledgements

The authors want to thank Peter Tamas (Wageningen University and Research) for his contribution in the methodology section in this review.

Appendix Table 1 Demographic characteristics of qualitative study approaches.

Author(s), year	Title	Sample size	Gender (% female)	Age range (mean)	Country	Method	Operationalization
Alevizou et al. (2015)	The well(s) of knowledge: the decoding of sustainability claims in the UK and in Greece	8x12	unk.	20-65	GR, GB	Focus groups	The perceptions of different claims and logos were investigated
Austgulen et al. (2018)	Consumer readiness to reduce meat consumption for the purpose of environmental sustainability: insights from Norway	4x6	50%	25-45	NO	Focus groups	Three themes are discussed: everyday food consumption (habits, food preferences, food procurement, cooking), group work (to come up with meat-free dinner recipes, climate labels), willingness to change to less or no meat
Campbell-Arvai (2015)	Food-related environmental beliefs and behaviors among university undergraduates. A mixed-methods study	40	58%	students	US	Focus groups	What factors are import for students when choosing meals, why these factors were important, the connections they made between their own food choices, food production practices and the health of the environment, actions to minimize potential negative environmental outcomes were discussed
de Carvalho et al. (2016)	Accessibility and trust: the two dimensions of consumers' perception on sustainability purchase intention	20	unk.	unk.	PT	Semi-structured interview	The question "What can be considered to be a sustainable product?" is answered
Eldesouky et al. (2020)	Perception of Spanish consumers towards environmentally friendly labelling in food	4x9	53%	18-55+	ES	Focus groups	Food purchase decisions, social and environmental labels, information on labels and reasons for purchase, willingness to pay and certified labels were discussed
Fernqvist et al. (2015a)	What's in it for me? Food packaging and consumer responses, a focus group study	3x6	unk.	20-40+	SE	Focus groups	Six different packaging options were presented, immediate responses were written down, then the discussion started on these packages
Fernqvist et al. (2015b)	Changing consumer intake of potato, a focus group study	6x4-8	68%	20-40+	SE	Focus groups	Main meal choices last three days, attitudes to fresh potato, knowledge and association to brands, buying behavior, potato packaging, sensory experiences, future scenarios of potato consumption

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Feucht and Zander (2018)	Consumers' preferences for carbon labels and the underlying reasoning. A mixed methods approach in 6 EU countries	32	FR: 70% GB: 82% DE: 64%	18-50+	FR, DE, IT, NO, ES, GB	Interview	Activities to combat climate change (yes-maybe-no), knowledge and information of climate change (e.g. global food trade, deforestation, livestock framing, reduction of meat, food waste, reduction of overproduction) are discussed
Gruber et al. (2014)	Inferential evaluations of sustainability attributes: Exploring how consumers imply product information	23	unk.	unk.	AT	Interview	In-depth understanding of the meanings ascribed by consumers to product attributes, evaluation of products, consumers' shopping behavior, decision-making criteria
Gutierrez and Thornton (2014)	Can consumers understand sustainability through seafood eco-labels? A U.S. and UK case study	28	71%	22-78	GB, US	Interview	The question “What does the word sustainable mean to you?” is answered
Hanss and Bohm (2012)	Sustainability seen from the perspective of consumers	123	±50%	18-82 (35±16)	NO	Face-to-face interview	What comes to your mind when you hear 'sustainability'?; 14 product attributes: the importance of these attributes for sustainable groceries (7-point scale); familiarity of 19 labels on a 7-point scale, indicative of sustainable products are rated
Hartikainen et al. (2014)	Finnish consumer perception of carbon footprints and carbon labelling of food products	33	unk.	24-65	FI	Focus groups	Own criteria for grocery shopping, how environmentally conscious participants are in general and related to food consumption, main environmental burdens of food, carbon footprint and carbon labelling of food products are discussed
Hoek et al. (2017)	Shrinking the food-print: a qualitative study into consumer perceptions, experiences and attitudes towards healthy and environmentally friendly food behaviors	29	62%	18-64	AU	Web-based interview	Associations, current behavior and the level of knowledge related to a healthy meal and an environmentally friendly meal. Hedonic response, associations, emotions and feelings, subjective knowledge and perceptions, current level of motivation, involvement and awareness of the four food-related behaviors. Perceived beneficial impact on health and environment are asked

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Klein and Menrad (2016)	Climate-friendly food choices regarding fruit and vegetables: how German consumers perceive their competency and what supporting measures they would prefer	12	75%	unk.	DE	Focus groups	Evaluation of the basic understanding of consumers' preferences for different information strategies on climate effect of food are discussed
Macdiarmid et al. (2016)	Eating like there's no tomorrow: public awareness of the environmental impact of food and the reluctance to eat less meat as part of a sustainable diet	87	54%	25-56+	GB	Focus groups Interview	Perceptions on climate change, awareness of the environmental impact of foods, participants' willingness to eat less meat for environmental benefits. Two statements: Some people think what we eat is contributing to climate change" and "Some people think that eating less meat would be good for the environment" (agree or disagree) are discussed
Mancini et al. (2017)	Which are the sustainable attributes affecting the real consumption behavior? Consumer understanding and choices	2x12	unk.	unk.	IT	Focus group	Discussing the degree of sensitivity of participants towards environmental impacts of food choices
Mann et al. (2018)	Australian consumers' view towards environmentally sustainable eating pattern	24	54%	19-69 (40)	AU	Telephone-based interview	Open questions on themes: participants' knowledge, attitudes and perceived effectiveness of participating in a sustainable eating pattern, current behavior, barriers and facilitators to engage in these behaviors and sources of information are questioned
Palmer et al. (2017)	Between global and local: exploring regional food systems from the perspective of four communities in U.S. Northeast	51	78%	25-93	US	Focus group	Perceptions on local and global food systems are discussed

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Risius et al. (2017)	Consumer preferences for sustainable aquaculture products: evidence from in-depth interviews, think aloud protocols and choice experiments	18	67%	unk.	DE	Interview	Explore consumers' perception of sustainable aquaculture and their understanding and acceptance of claims and labels for fish products from sustainable aquaculture
Sacchi (2018)	The ethics and politics of food purchasing choices in Italian consumers' collective action	6x(4-5) = 28	64%	20-65	IT	Focus groups	The values behind sustainable buying behavior were obtained using four topics: buying/non-buying (habit and frequency), value-based labels (awareness and motivation), participation in food cooperatives (participation and involvement) and consumption behavior and ethical products
Sattari et al. (2017)	Understanding consumers' perception of sustainable consumption: A ZMET approach	52	unk.	unk.	SE	Focus groups	Define the term 'sustainability' in general and express associations with the concept
Sijtsema et al. (2012)	Interplay of sustainability and health? Sustainable food from a consumer's perspective	3x6	50%	27-57 (39)	NL	Focus groups	Using pictures to give insights in an average meal, discuss which products are typically healthy and sustainable, perceptions to shift towards a more plant-based diet
Simpson and Radford (2012)	Consumer perceptions of sustainability: a free elicitation study	45	67%	25-65	CA	Free-elicitation	Understand whether consumers are aware of the three pillars of sustainability, and if they further associate sustainability with the notion of persistence
Sirieix et al. (2013)	Consumers' perception of individual and combined sustained food labels: a UK pilot investigation	16	unk.	20-60	GB	Focus groups	Participants' criteria for fruit and vegetable selection, their response to 13 labels/messages, their preferred/rejected combinational of labels/messages, and what participants thought about sustainable labels are discussed

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Valor et al. (2014)	The influence of knowledge and motivation on sustainable label use	289	66%	18-65+	ES	Interview (structured)	Recognition of 12 sustainable graphic labels, Knowledge on these recognized labels (product category, meaning and label use. Motivation: importance of labels on purchase decision, rank of three important attributes when buying food or beverages
Vega-Zamora et al. (2014)	Organic as a heuristic cue: what Spanish consumers mean by organic foods	4x8	53%	25-52	ES	Focus groups	Discussion topic on organic foods in general, and olive oil
Wakefield and Axon (2020)	"I'm a bit of a waster": Identifying the enablers of, and barriers to, sustainable food waste practices	10	70%	20-57	GB	Focus groups	Food waste: understandings, attitudes, relative importance of sustainable food waste management and current food waste practices are discussed

AT = Austria; AU = Australia; CA = Canada; DE = Germany; ES = Spain; FI = Finland; FR = France; GR = Greece; GB = United Kingdom; IT = Italy; NL = the Netherlands; NO = Norway; PT = Portugal; SE = Sweden; US = United States;

Appendix Table 2 Demographic characteristics of quantitative study approaches.

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Adams and Adams (2011)	De-placing local at the farmers' market: consumer perceptions of local foods	97	60%	18-65+	US	Survey	15 questions on attitudes towards local versus non-local food on a 5 point scale (mean)
Aertsens et al. (2011)	The influence of subjective and objective knowledge on attitude, motivations and consumption of organic food	529	53%	<25-65+	BE	Survey	17 possible motivations to buy organic foods on a 7-point Likert scale, 12 potential barriers to purchase organic vegetables (mean)
Al-Taie et al. (2015)	Exploring the consumption of organic foods in the United Arab Emirates	266	36%	16-65	AE	Survey	7 statements on consumers' perceptions on the impact of organic foods on the environment (agree or disagree); 8 statements on barriers of organic foods (agree or disagree) (percentages)
Annunziata and Scarpato (2014)	Factors affecting consumer attitudes towards food products with sustainability attributes	300	53%	18-65+	IT	Survey	Questions on food habits and lifestyle, attitudes and purchasing behavior with respect to sustainable food such as organic, fair trade and typical food on a 5-point scale (percentages)
Annunziata et al. (2019)	Effectiveness of sustainability labels in guiding food choices: Analysis of visibility and understanding among young adults	305	52%	(22±3)	IT	Survey	Personal values and food sustainability concerns, visibility and understanding of sustainability labels on a 5-point scale (means)
Aprile et al. (2016)	Consumers' preferences and attitudes towards local food products	200	63%	18-74	IT	Survey	11 statements about consumer perceptions and definitions on local foods on a 5-point scale (percentages)
Austgulen et al. (2018)	Consumer readiness to reduce meat consumption for the purpose of environmental sustainability: insights from Norway	1532	50%	18-89	NO	Survey	12 statements about climate change, hard to reduce meat consumption or have reduced meat consumption on a 5-point scale (percentages)

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Boesen et al. (2019)	Environmental sustainability of liquid food packaging: is there a gap between Danish consumers' perception and learnings from life cycle assessment?	197	62%	25-35	DK	Survey	Characteristics that are typical for a sustainable package, 12 statements (percentages)
Borrello et al. (2019)	Sustainability of palm oil: drivers of consumers' preferences	291	56%	(40.7)	IT	Survey	10 sustainability concerns on a 5-point scale (from Grunert et al. (2014)), environmental impacts of palm oil on a 5-point scale (means), frequency of reading information on a label
Bryła (2016)	Organic food consumption in Poland: Motives and barriers	1000	50%	15-65 (40)	PL	Survey	13 statements on organic food compared to conventional food on a 5-point scale (percentages)
Campbell-Arvai (2015)	Food-related environmental beliefs and behaviors among university undergraduates. A mixed -methods study	320	53%	students	US	Survey	12 statements describing food-related actions to capture participants' food-related environmental beliefs on a 5-point scale (percentages)
Chen et al. (2018)	Eco-labelling in fresh produce market: not all environmental labels are equally valued	2525	57%	18-80+	US	Survey	11 statements on the importance of extrinsic strawberry attributes on a 5-point scale (percentages)
de Boer et al. (2016)	Help the climate, change your diet: A cross-sectional study on how to involve consumers in a transition to a low-carbon society	NL: 527 US: 556	NL: 50% US: 50%	18-65	NL US	Survey	Frequency of meat eating, perceived relevance of mitigation; importance of the issue on climate change and perceived effectiveness ratings of different mitigation options on a 5-point scale (means)
de Carvalho et al. (2015)	Consumer sustainability consciousness: a five dimensional construct	992	61%	18-80	PT	Survey	20 statements on sense of retribution, access to information, labelling and peer pressure, health and crisis scenario on a 7-point Likert scale (means)

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Dzene and Eglite (2012)	Perspective of sustainable food consumption in Latvia	82	100%	19-35	LV	Survey	Attitudes and opinions on sustainable food consumption, to which extent consumers actively seek the more sustainable produced foods (percentages)
Ekelund and Spendrup (2015)	Climate labelling and the importance of increased vegetable consumption	184	unk.	unk.	SE	Survey	Ranking of different recommendations and views on GHE reduction actions (percentages)
Feucht and Zander (2018)	Consumers' preferences for carbon labels and the underlying reasoning. A mixed methods approach in 6 EU countries	6007	FR: 51% GB: 50% DE: 50% ES: 50% IT: 51% NO: 51%	18-70	FR DE IT NO ES GB	Choice experiment	Activities to combat climate change, knowledge and information of climate change (percentages)
Ghvanidze et al. (2016)	Consumers' environmental and ethical consciousness and the use of the related food products information: the role of perceived consumer effectiveness	821	GB: 53% DE: 51% US: 52%	18-64+	GB, DE, US	Survey	Perceived consumer effectiveness environmental conscious behavior, ethical concerns on a 5-point scale (means)
Goossens et al. (2017)	Qualitative assessment of eco-labels on fresh produce in Flanders (Belgium) highlights a potential intention - performance gap for the supply chain	553	68%	18-66+	BE	Survey	Extent of consuming sustainable, reasons for environmentally friendly purchasing, environmental information provision, eco-labels (percentages)
Grunert et al. (2014)	Sustainability labels on food products: consumer motivation, understanding and use	4408	GB: 51% FR: 51% DE: 55% ES: 48% PL: 51% SE: 51%	18-55+	GB FR DE ES SE PL	Survey	Sustainability concerns related to food of 14 items on a 7-point Likert scale (means)

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Halldorsdottir and Nicholas (2016)	Local food in Iceland: identifying behavioral barriers to increased production and consumption	120	56%	unk.	IS	Survey	Rate the importance of statements concerning local foods and product attributes (percentage)
Hartikainen et al. (2014)	Finnish consumer perception of carbon footprints and carbon labelling of food products	1010	50%	18-65	FI	Survey	List three factors that contribute most to the environmental load of food, their understandings and interest in carbon footprint labels, describe product carbon footprint in their own words, importance on food carbon footprints (open questions)
Herbes et al. (2018)	Consumer attitudes towards biobased packaging - a cross-cultural comparative study	FR: 443 DE: 948 US: 610	FR: 53% DE: 58% US: 50%	<30-59+	FR, DE, US	Survey	Consumer perceptions of the environmentally friendliness of food packaging on a 5-point scale (means)
Hiroki et al. (2016)	Consumer perceptions about local foods in New Zealand, and the role of life cycle-based environmental sustainability	240	67%	18-65+	NZ	Survey	11 key attributes associated with local foods (percentages)
Jerzyk (2015)	Sustainable packaging as a determinant of the process of making purchase decisions from the perspective of Polish and French young consumers	161	67%	17-30	PL, FR	Survey	18 expressions related to sustainable packaging, rated on a 5-point scale (means)
Kause et al. (2019)	Public perceptions of how to reduce carbon footprints of consumer food choices	627	59%	18-80	GB	Survey	Characteristics that are typical for produce/dairy/protein-rich products with a low carbon footprint (percentages)
Klein and Menrad (2016)	Climate-friendly food choices regarding fruit and vegetables: how German consumers perceive their competency and what supporting measures they would prefer	413	69%	16-50+	DE	Structured interviews	Perceived behavioral competency regarding different climate-friendly food choices on a 5-point scale (means)

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Lang et al. (2014)	Consumers' evolving definition and expectations for local foods	277	64%	unk.	US	Survey	Consumer definition of locally sourced and produced foods (10 items) on a 5-point scale (means)
Laureati et al. (2013)	Sustainability and organic production: How information influences consumer's expectation and preference for yogurt	157	64%	20-42	IT	Survey	Questions on which statements fits the respondents' experience on a 5 point scale and actual behavioral items (percentages)
Lazzarini et al. (2016)	Does environmental friendliness equal healthiness? Swiss consumers' perception of protein products	85	51%	20-64 (39±13)	CH	Ranking test	Perceived environmental friendliness & perceived healthiness of 30 food products, placing them on a 3m long line ranging from unhealthy - healthy and from not environmentally friendly - very environmentally friendly
Lehikoinen and Salonen (2019)	Food preferences in Finland: Sustainable diets and their differences between groups	2052	51%	<30-70+	FI	Survey	9 statements regarding sustainable food consumption on a 5-point scale (means)
Lindh et al. (2016)	Consumer perceptions of food packaging: contributing to or counteraction environmentally sustainable development?	157	46%	20-60+	SE	Survey	Consumer perceptions of packaging functions and material and consumer perception of what environmentally sustainable packaging is (open questions), consumer perceived importance of environmentally sustainable packaging (percentages)
Mäkiniemi and Vainio (2014)	Barriers to climate-friendly food choices among young adults in Finland	350	80%	(24±7)	FI	Survey	11 barriers to consume climate-friendly on a 5-point scale (means)
Mancini et al. (2017)	Which are the sustainable attributes affecting the real consumption behavior? Consumer understanding and choices	240	unk.	unk.	IT	Face-to-face interviews	Consumption habits, intrinsic and extrinsic attributes that affect food choice, understanding of labels (frequencies)

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Meyerding and Trajer (2019)	Consumer preferences for local origin: is closer better? The case of fresh tomatoes and ketchup in Germany	541	50%	18+	DE	Survey	Respondents' general purchase behavior and their perspective on locally grown produce, and food-related lifestyle statements on a 5-point scale (means)
Meyer-Hofer and Spiller (2014)	Characteristics and barriers of sustainable food consumption in Germany	300	52%	(45)	DE	Survey	How important it is to that the food you buy has been produced/traded according to the 4D (Environment, Climate protection, Fair trade, animal welfare) and Barriers on a 5-point scale (means)
Mohr and Schlich (2016)	Socio-demographic basic factors of German customers as predictors for sustainable consumerism regarding foodstuffs and meat products	1040	63%	18-66+	DE	Survey	Closed (means) and open questions (frequencies) on associations with sustainable food consumption, meat reduction and consciousness for sustainable purchase behavior
Nagyova et al. (2016)	Sustainable consumption of food: a case study of Slovak consumers	300	81%	15-50+	SK	Survey	Application of sustainable consumption (e.g. economical packages, ecological production, recycling of waste), factors leading to these purchases, including price and quality (percentages)
Panzone et al. (2016)	Socio-demographics, implicit attitudes, explicit attitudes, and sustainable consumption in supermarket shopping	895	55%	18-65+	US	Survey	Explicit attitudes on a 5-point scale to generate general attitudes towards sustainability (means)
Peano et al. (2019)	Sustainability for food consumers: Which perception?	804	55%	<21-60+	IT	Survey	Implementation of best-worst scaling methodology on consumers' perception about the concept of sustainability
Pearson (2011)	Consumer concerns: is organic food important in an environmentally responsible diet?	163	75%	11-55+	AU	Survey	The importance of different product features on a 5-point-scale (percentages)

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Petrescu et al. (2020)	Consumer understanding of food quality, healthiness, and environmental impact: a cross-national perspective	797	64%	(26)	BE, RO	Survey	Cues (n=59) that are often used for the evaluation of the food impact on the natural environment on a-7 point scale (means)
Rejman et al. (2019)	Do Europeans consider sustainability when making food choices? A survey of Polish city-dwellers	600	62%	21-70	PL	Survey	Factors influencing food choice measured on a 5-point scale (means)
Rood et al. (2014)	Nederlanders en duurzaam voedsel. Enquête over motieven voor verduurzaming van het voedselsysteem en consumptiegedrag	1105	unk.	18-70	NL	Survey	Motives that are contributing to a more sustainable food system (frequencies)
Schösler et al. (2014)	Fostering more sustainable food choices: can self-determination theory help?	1083	50%	18-75+	NL	Survey	Reasons for (not) frequently eating meat (max 3)
Shi et al. (2018)	Consumers' climate-impact estimations of different food products	226	unk.	unk.	CH	Survey	Rating the environmental impact of a product on a scale from 0-100, compare it with similar product with the smallest and highest environmental impact
Siegrist and Hartmann (2019)	Impact of sustainability perception on consumption of organic meat and meat substitutes	5586	52%	56±17	CH	Survey	Perceived environmental impact of various foods on a 7-point scale (means)
Siegrist et al. (2015)	Factors influencing changes in sustainability perception of various food behaviors: results of a longitudinal study	2600	54%	58±14	CH	Paper-and-pencil survey	Perceived environmental benefits of 6 ecological consumption patterns, willingness to reduce meat consumption and eating only seasonal fruits and vegetables, diet-related health consciousness on a 6-point scale (means)

Author(s), year	Title	Sample size	Gender (%female)	Age range (mean)	Country	Method	Operationalization
Tobler et al. (2011)	Organic tomatoes versus canned beans: how do consumers assess the environmental friendliness of vegetables?	79	70%	19-82 (49±16)	CH	Choice experiment Survey	Pairs of vegetable products were repeatedly shown and the participants were asked to choose the one that is more environmental friendly during the winter season. Environmental friendliness (19 statements) on a 7-point scale (means)
Van Loo et al. (2013)	Consumer attitudes, knowledge, and consumption of organic yogurt	774	62%	18-65+	BE	Survey	Perceived differences among organic and conventional yogurt were identified on a 7-point scale (means)
Vanhonacker et al. (2013)	Flemish consumer attitudes towards more sustainable food choices	221	64%	18-60+ (41±17)	BE	Survey	Personal concerns, perceived consumer effectiveness, ethical food choice motives on a 5-point scale (means and percentages)
Verain et al. (2015)	Sustainable food consumption. Product choice or curtailment?	942	50%	18-65 (42.3)	NL	Survey	Sustainable food behavior was measured with 9 items (means)
Wunderlich et al. (2018)	Consumer knowledge about food production systems and their purchasing behavior	123	83%	18-77	US	Survey	Participants selected a statement that best reflected their beliefs regarding how producing GMO, organic or conventionally grown food impacts the environment (percentages)
Zakowska-Biemans and Tekień (2017)	Free range, organic? Polish consumers preferences regarding information on farming systems and nutritional enhancement of eggs: a discrete choice based experiment	935	50%	<34-65+	PL	Survey	Items on subjective knowledge and perception of prices for organic and nutritionally enhanced food, food related lifestyle on a 7-point scale (means)
Zander et al. (2015)	EU organic logo and its perception by consumers	3000	67%	18-59+	EE, FR, DE, IT, PL, GB	Survey	Knowledge on the EU organic logo, other organic labels, organic farming principles, perception of organic food, relevance of origin (frequencies)

AE = United Arab Emirates; AU = Australia; BE = Belgium; CH = Switzerland; DE = Germany; DK = Denmark; EE = Estonia; ES = Spain; FI = Finland; FR = France; GB = United Kingdom; IS = Iceland; IT = Italy; LV = Latvia; NL = the Netherlands; NO = Norway; NZ = New Zealand; PL = Poland; PT = Portugal; RO = Romania; SE = Sweden; SK= Slovakia; US = United States

Supplementary files

These supplementary materials include an overview of the selected studies. The categories belonging to the seven main domains are indicated for each study. For example, Adams and Adams (2011) included codes that were categorized in the category 'local', belonging to the domain 'transportation', and included codes categorized in the category 'local' belonging to the domain 'consumer'.

Supplementary Table 1 Overview of the selected studies. The categories belonging to the seven main domains (production, transportation, product, product group, consumer, waste and contextual factors are indicated for each study.

Authors	Production	Transportation	Product	Product group	Consumer	Waste	Contextual factors
Adams and Adams (2011)		Local			Local		
Aertsens et al. (2011)	Organic				Organic food choice		
Alevizou et al. (2015)	Ethical production Organic		Eco-label Fair trade label Organic label		Organic food choice		
Al-Taie et al. (2015)	Organic						
Annunziata and Scarpato (2014)	Ethical production Organic				Food choice		
Annunziata et al. (2019)	Environment Food production Ethical production	Environment	Organic label			Food waste Recycling	
Aprile et al. (2016)		Distance Local			Food choice Local		
Austgulen et al. (2018)	Organic	Local		Fruits and vegetables Meat Meat reduction	Food choice Information Knowledge	Food waste	Dietary pattern Society
Boesen et al. (2019)			Amount of packaging Package material			Recycling	
Borrello et al. (2019)	Environment Food production Ethical production	Environment			Information	Food waste	Society
Bryła (2016)	Organic						

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Authors	Production	Transportation	Product	Product group	Consumer	Waste	Contextual factors
Campbell-Arvai (2015)	Environment Ethical production Food production Organic	Distance Local	Amount of packaging Package material	Meat Meat reduction	Food choice Knowledge Local	Food waste Recycling	
Chen et al. (2018)[a]							
de Carvalho et al. (2015)	Environment Ethical production	Local	General label			Recycling	Dietary pattern
de Carvalho et al. (2016)		Local	General label		Food choice		
de Boer et al. (2016)	Seasonality	Local					
Dzene and Eglite (2012)	Environment Ethical production Seasonality	Local Transportation method			Food choice Information	Recycling	Dietary pattern
Ekelund and Spendrup (2015)	Organic	Local	Amount of packaging General label	Fruits and vegetables Meat reduction		Food waste	
Eldesouky et al. (2020)			Fair trade label General label		Knowledge		
Fernqvist et al. (2015a)	Ethical production	Local	Package material		Organic food choice	Food waste	
Fernqvist et al. (2015b)			Amount of packaging General label Organic label Package material		Organic food choice		

Authors	Production	Transportation	Product	Product group	Consumer	Waste	Contextual factors
Feucht and Zander (2018)	Environment Ethical production Food production Organic	Local	General label	Fruits and vegetables Product category	Food choice Information Knowledge	Food waste	Dietary pattern Society
Ghvanidze et al. (2016)	Environment		Amount of packaging		Information	Food waste Recycling	Dietary pattern
Goossens et al. (2017)			Eco-label		Food choice Information		Dietary pattern
Gruber et al. (2014)	Ethical production Organic	Distance		Product category	Organic food choice		
Grunert et al. (2014)	Environment Food production Ethical production					Food waste	Society
Gutierrez and Thornton (2014)	Ethical production Food production				Food choice Knowledge		Dietary pattern Society
Halldorsdottir and Nicholas (2016)		Local			Local		
Hanss and Bohm (2012)	Environment Ethical production	Environment	Package material			Recycling	
Hartikainen et al. (2014)	Food production	Environment	Amount of packaging Eco-label General label Package material	Meat	Information Knowledge		Dietary pattern

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Authors	Production	Transportation	Product	Product group	Consumer	Waste	Contextual factors
Herbes et al. (2018)			Amount of packaging Package material			Recycling	
Hiroki et al. (2016)		Local			Local		
Hoek et al. (2017)	Ethical production Food production Organic	Local	Amount of packaging	Fruits and vegetables Meat Meat reduction Product category	Food choice Information	Food waste Recycling	Dietary pattern
Jerzyk (2015)			Amount of packaging Package material			Recycling	
Klein and Menrad (2016)			General label		Information	Food waste	
Lang et al. (2014)		Local					
Laureati et al. (2013)	Environment Food production Ethical production Organic Seasonality	Distance Local	General label			Food waste Recycling	
Lazzarini et al. (2016)	Ethical production Food production Organic	Distance Transportation method		Meat Product category			Dietary pattern
Lehikoinen and Salonen (2019)		Distance Local					
Lindh et al. (2016)		Environment	Amount of packaging Package material			Food waste Recycling	

Authors	Production	Transportation	Product	Product group	Consumer	Waste	Contextual factors
Macdiarmid et al. (2016)	Environment Ethical production	Distance Environment	Amount of packaging Package material	Meat Meat reduction	Information Knowledge	Food waste Recycling	Dietary pattern Society
Mäkiniemi and Vainio (2014)					Food choice		
Mancini et al. (2017)	Ethical production Food production	Distance Local	Amount of packaging Eco-label General label	Fruits and vegetables	Information Knowledge	Food waste Recycling	Dietary pattern
Meyerding and Trajer (2019)		Local			Local		
Meyer-Hofer and Spiller (2014)			General label		Food choice Knowledge		
Mohr and Schlich (2016)	Ethical production Food production Seasonality	Distance		Meat reduction	Food choice		Dietary pattern Society
Nagyova et al. (2016)	Ethical production		Amount of packaging		Knowledge	Food waste Recycling	
Palmer et al. (2017)		Local			Local		
Panzone et al. (2016)			Amount of packaging				
Peano et al. (2019)	Environment Ethical production	Local			Food choice		Dietary pattern Society
Pearson (2011)	Ethical production Organic Seasonality	Local	Amount of packaging				
Petrescu et al. (2020)	Environment Food production Ethical production Seasonality	Distance Environment Local Transportation method	Amount of packaging General label Organic label Package material	Product category	Food choice	Recycling	Dietary pattern

Authors	Production	Transportation	Product	Product group	Consumer	Waste	Contextual factors
Risius et al. (2017)	Environment Ethical production Food production Organic	Distance Local	General label Organic label	Product category			
Rood et al. (2014)		Local	General label	Fruits and vegetables Meat reduction	Local	Food waste	
Sacchi (2018)	Ethical production Food production Organic	Distance	General label Organic label		Food choice		
Sattari et al. (2017)	Environment Ethical production	Local		Meat Product category	Food choice	Food waste	Dietary pattern Society
Schösler et al. (2014)							Meat reduction
Shi et al. (2018)		Seasonality	Distance Transportation method				Meat
Siegrist and Hartmann (2019)			Transportation method				Fruits and vegetables Meat
Siegrist et al. (2015)			Local Transportation method			Amount of packaging	Fruits and vegetables
Sijtsema et al. (2012)	Ethical production Food production Organic	Distance Local	Amount of packaging Package material	Fruits and vegetables Meat reduction Product category	Food choice Knowledge Local Organic food choice	Recycling	Society
Simpson and Radford (2012)	Environment Ethical production		Amount of packaging		Food choice Information Knowledge	Food waste Recycling	Society

Authors	Production	Transportation	Product	Product group	Consumer	Waste	Contextual factors
Sirieix et al. (2013)			Eco-label Fair trade label General label Organic label				
Tobler et al. (2011)	Environment Food production Ethical production Organic Seasonality	Distance Transportation method	Amount of packaging Package material				Dietary pattern
Valor et al. (2014)			General label				
Van Loo et al. (2013)				Product category			
Vanhonacker et al. (2013), Vega-Zamora et al. (2014)	Environment	Environment Local		Meat Meat reduction		Food waste Recycling	Society
Verain et al. (2015)				Meat Meat reduction Product category			
Wakefield and Axon (2020)			Amount of packaging			Food waste	
Wunderlich et al. (2018)	Ethical production Food production Organic						
Zakowska-Biemans and Tekień (2017)[a]							
Zander et al. (2015)	Organic		Organic label		Organic food choice		

[a] The codes in these articles are discarded in the final stage of the domain analysis (selective coding). These codes did not have clear relations to the

Chapter 5

Perceptions and intentions to consume sustainable foods: Exploring associations with beliefs about food attributes, environmental responsibility and education though the Theory of Planned Behaviour

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Abstract

Consumers have a wide range of perceptions related to food sustainability. These perceptions cover the supply chain (e.g., food production, processing, and transport), product characteristics (e.g., local, organic), and specific food groups. This study examined Dutch consumers' current perceptions of food sustainability, and their intention to consume sustainable foods and attitudes by exploring the associations with beliefs about food attributes, environmental responsibility, and education through the lens of the Theory of Planned Behaviour. A cross-sectional study was conducted among a Dutch representative sample (N=988). Data were analysed using structural equation modelling (SEM). The Dutch consumers have a wide range of perceptions related to food sustainability, including organic and ethical food production, locality, healthiness and price of sustainable foods, and fruits and vegetables. Their intention to consume sustainable foods was positively associated with attitudes toward perceived food sustainability ($\beta=0.09$, $p=.005$), subjective norms ($\beta=0.12$, $p=.002$), perceived behavioural control (PBC) ($\beta=0.27$, $p<.001$), and environmental responsibility ($\beta=0.53$, $p<.001$). Moreover, beliefs about palatability ($\beta=.32$, $p<.001$), perceived healthiness ($\beta=0.65$, $p<.001$), food sustainability knowledge ($\beta=0.10$, $p<.001$), and high education level ($\beta=0.05$, $p<.001$) were positively associated with attitudes toward perceived food sustainability. Beliefs about perceived inconvenience ($\beta=-0.30$, $p<.001$) and price ($\beta=-0.08$, $p=.02$) were negatively associated with PBC. In conclusion, Dutch consumers' perception were mainly related to organic and ethical food production, locality, healthiness and price of sustainable foods, and fruits and vegetables. Their intention to consume these foods was influenced by environmental responsibility, and their attitudes were influenced by the food attributes palatability and perceived healthiness, food sustainability knowledge, and education level. The price and perceived inconvenience of sustainable foods should be addressed as barriers to sustainable food consumption.

Keywords: Theory of Planned Behaviour, consumer perceptions, food sustainability, Structural Equation Modelling, behavioural intention, attitudes

Introduction

A shift of consumers towards a more sustainable diet is critical to mitigate the adverse effects of food consumption on the environment, i.e. increasing plant-based foods and reducing animal-based foods (Hallström et al. 2015, Aleksandrowicz et al. 2016). However, this shift is impossible when consumers struggle to define food sustainability (Meyer-Hofer and Spiller 2014, Feucht and Zander 2018). Generally, consumers have shown to have a wide range of perceptions related to food sustainability. These perceptions cover the whole supply chain (*e.g., food production, processing, and transport*), certain product characteristics (*e.g., local, organic*), and specific foods (*e.g., seasonal fruits and vegetables*) (van Bussel et al. 2022). In the current study, we label these perceptions as "perceived food sustainability". In order to shift toward a more sustainable diet, we need to explore how these consumer perceptions could be better aligned with the public communication of recommendations for sustainable diets, for example the message to increase the intake of plant-based foods and to reduce animal-based foods.

Many consumers believe that organic and locally produced foods – no or at most one supply chain party between farmer and consumer (van der Schans and van Wonderen 2019) - are part of a sustainable diet (Schleenbecker and Hamm 2013, Feldmann 2015, Hartmann 2017). Therefore, one would expect that consumers who want to eat more sustainable are more likely to buy these foods. Yet, the market shares of organic foods and locally produced foods are still very low in the Netherlands; both have a market share below 5% (van der Schans and van Wonderen 2019, IRi 2020). Despite this discrepancy between beliefs and market shares, not much is known about the potential facilitators and barriers influencing the intention to consume sustainable foods (for a review of environmentally sustainable products, see Joshi and Rahman (2015)).

Thus far, research using the Theory of Planned Behaviour (TPB) solely focused on sustainable food characteristics and specific food groups when examining food sustainability. Attitudes, subjective norms, and perceived behavioural control predicted the intention to consume organic foods (Arvola et al. 2008, Scalco et al. 2017, Fleșeriu et al. 2020), local foods (Shin et al. 2016, Kumar and Smith 2018), and fruits and vegetables (Middleton and Smith 2011). The current study adds insights into the potential facilitators and barriers to sustainable food consumption, as it also includes consumer perceptions of food sustainability. Particularly, this study focuses on attitudes toward perceived food sustainability, beliefs about attributes of sustainable foods (*i.e. palatability, perceived healthiness, perceived inconvenience, and price*) (Drewnowski and Monsivais 2020), perceived environmental responsibility (Davis et al. 2020), and knowledge on food-related sustainability (Hartmann et al. 2021). Hence, this study contributes to broaden our understanding of consumer perceptions on food sustainability and provides valuable insights to key stakeholders to promote the consumption of sustainable foods.

It has been argued that education level plays a role in food choices (Worsley et al. 2004). Higher educated, compared to lower educated, have better access to nutrition information, take innovation sooner, and are likely to have a higher income level later in life (*i.e. higher on the social class hierarchy*) (Worsley et al. 2004). Effects of education level may provide valuable insights into attitudinal and knowledge differences in food sustainability, therefore, this study considers education level as a potential facilitator or barrier to sustainable food consumption.

To summarize, this is the first study that examines Dutch consumers' current perceptions of food sustainability, and their intention to consume sustainable foods and attitudes by exploring the associations with beliefs about food attributes, environmental responsibility, and education through the lens of the Theory of Planned Behaviour. In the present study, we conducted a cross-sectional survey among a representative sample of the Dutch population in terms of gender, age, and education level. We analysed the data using a structural equation model (SEM).

Conceptual framework

The TPB has been widely used to explain and predict behavioural intention and planned behaviour (Ajzen 1991, 2020). In the TPB, behavioural intention is the readiness of a person to perform a certain behaviour and is considered to be the immediate antecedent of behaviour (Ajzen 2019). The TPB attempts to explain behavioural intention based on three factors: 1) attitudes, which refer to "the degree to which a person has a favourable or unfavourable evaluation of appraisal of certain behaviour" (Ajzen 1991), 2) subjective norms, which indicate the perceived social pressure of peers or family to perform or not to perform a certain behaviour, and 3) perceived behavioural control, which includes the perceived ability of a person to perform a certain behaviour (Ajzen 1991). In the context of sustainable food consumption, we found only little research in the literature using the TPB solely focusing on perceived food sustainability. Previous findings will be described in the following sections.

Behavioural intention – Most previous studies only focused on the role of attitudes as a determining factor for the purchase of, for instance, organic foods, locally produced foods, and explicitly labelled sustainable foods, i.e. dairy products with organic or local labels (Thompson et al. 1994, Honkanen et al. 2006, Vermeir and Verbeke 2008, Scalco et al. 2017, Kumar and Smith 2018). In general, the TPB posits that when positive attitudes exist, this will lead to behavioural intention and eventually performance of the behaviour. Other studies also investigated the role of subjective norms and perceived behavioural control, which were found to be significant predictors of consumption of, for instance, organic foods and locally produced foods (Donahue 2017, Kumar and Smith 2018). As far as we know, research into whether attitudes, subjective norms, and perceived behavioural control predict the intention to consume sustainable foods is lacking. Following the TPB, we expect that (Figure 1):

H1: Attitudes toward perceived food sustainability are positively associated with the intention to consume sustainable foods

H2: Subjective norms are positively associated with the intention to consume sustainable foods

H3: Perceived behavioural control is positively associated with the intention to consume sustainable foods

Beliefs about attributes of sustainable foods – Food choices are mainly determined by palatability, perceived healthiness, convenience, and price (Drewnowski and Monsivais 2020). It is, therefore, likely that beliefs about these food attributes are associated with attitudes toward perceived food sustainability. Beliefs about palatability and perceived healthiness are expected to have a positive associations with attitudes, as sustainable foods are considered palatable and healthy (Dzene and Eglite 2012, Sijtsema et al. 2012, Alevizou et al. 2015, Mann et al. 2018). On the contrary, beliefs about inconvenience and price are expected to have a negative association with attitudes, as sustainable foods are considered inconvenient and expensive (Mäkiniemi and Vainio 2014, Meyer-Hofer and Spiller 2014), although the beliefs about price depend on the interpretation of food sustainability consumers have in mind (*e.g., local foods are considered relatively cheap* (Rood et al. 2014, Palmer et al. 2017)). In addition, it has been proposed that beliefs about inconvenience and price have a negative association with perceived behavioural control (Birch and Lawley 2010, Churuangsuk et al. 2020, Ruangkanjanases et al. 2020). Consumers who believe that sustainable foods are inconvenient or expensive perceive themselves as less or not capable of consuming sustainable foods. Therefore, we expect that:

H4: The beliefs about palatability (a) and perceived healthiness (b) are positively associated and perceived inconvenience (c) and perceived price (d) are negatively associated with attitudes toward perceived food sustainability

H5: The beliefs about perceived inconvenience (a) and price (b) are negatively associated with perceived behavioural control

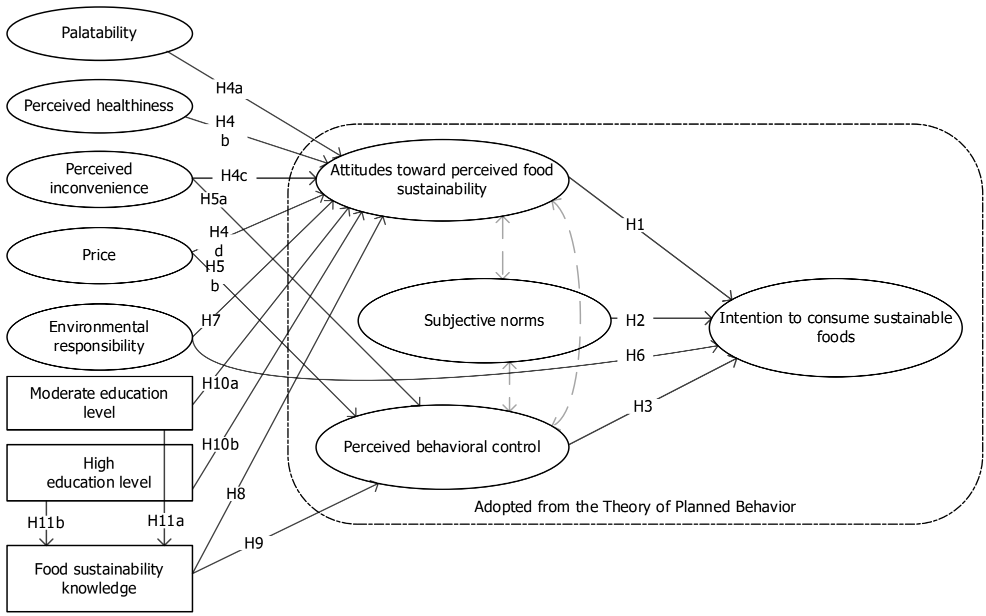


Figure 1 Proposed conceptual model including hypotheses H1-H11. Observed variables are displayed in rectangular boxes and latent variables in oval boxes. Attitudes, subjective norms, perceived behavioral control, and the intention to consume sustainable foods are adopted from the Theory of Planned Behavior.

Environmental responsibility – Environmental responsibility is related to a general concern or awareness for the environment. We assume that environmental responsibility and environmental concern are associated and can be used interchangeably (Grasso et al. 2015, Syropoulos and Markowitz 2021). A few studies showed that environmental awareness is related to a more positive environmental attitude (Hải and Mai 2013, Ribeiro and Fernandes 2020). Therefore, we expect that environmental responsibility has a positive association with attitudes. Moreover, it has been speculated that environmental awareness is a component of an attitudinal construct (Verachtert 2022). Consequently, we expect that environmental responsibility has a positive association with the intention to consume sustainable foods.

H6: Environmental responsibility is positively associated with the intention to consume sustainable foods

H7: Environmental responsibility is positively associated with attitudes toward perceived food sustainability

Food sustainability knowledge – Knowledge has been added as a background factor in the Theory of Reasoned Action model (Ajzen and Fishbein 1980), which is the precursor of the TPB. Knowledge could influence behavioural, normative, and control beliefs (Ajzen

2019). In the current conceptual model, knowledge is hypothesized to influence attitudes and perceived behavioural control (Ajzen 2002). Previously, having knowledge of food sustainability has been positively associated with attitudes (Aertsens et al. 2011, Torabian-Riasati et al. 2017). Moreover, we reason that consumers with higher knowledge levels better understand the concepts of food sustainability, and therefore perceive themselves to be more capable of consuming sustainable foods. Thus, we hypothesize that:
H8: Food sustainability knowledge is positively associated with attitudes toward perceived food sustainability
H9: Food sustainability knowledge is positively associated with perceived behavioural control

Education level – From the literature, it is evident that education level explains some of the differences in sustainable food consumption. Particularly, it has been argued that higher education levels are related to increased knowledge about environmental issues (Blankenberg and Alhusen 2019). Moreover, higher education levels seem to affect pro-environmental attitudes, pro-environmental behaviour, and environmental concerns (Klineberg et al. 1998, Panzone et al. 2016). We, therefore, hypothesize that:
H10: Compared to a low education level, a moderate education level (a) and high education level (b) are positively associated with attitudes toward perceived food sustainability
H11: Compared to a low education level, a moderate education level (a) and high education level (b) are positively associated with food sustainability knowledge

Methods

Data collection

A sample of 988 participants were recruited via an online consumer panel (Unravelresearch, Utrecht, the Netherlands) in July-August 2021. The sample was representative of the Dutch population in terms of gender, age, and education level. Respondents were 18 years and older and had to be able to read, understand and write Dutch. The participants filled out an online survey via Qualtrics (version July-August 2021, Provo, UT, USA). The survey started by asking for their informed consent; participants were informed that participation was voluntary and that they had the right to withdraw at any point in time. Participation was anonymous and data were not distributed to other third parties. The median time to complete the online session was 16 minutes (interquartile range of 12-24 minutes).

Before data analyses, we removed unreliable responses from the dataset. First of all, 24 participants completed the questionnaire within 5 minutes, which was considered too fast for a serious response. Next, another 24 participants were removed because they made multiple attempts to complete the survey. And last, yet another 24 participants were removed who completed all questions in the middle or the outer points of the scale, in combination with a non-informative answer to the open question, for example: "I do not know what sustainable food means" (2.5% of the sample). As there was some overlap in groups, in total 58 participants were removed from the dataset, and a total of 930 participants were included in the current data analysis.

Outline survey

The online survey consisted of five parts. In the first part, participants answered an open question about what they understood by "sustainable food". We included this question to give participants the opportunity to formulate their own perceptions of sustainable foods. In the second part, socio-demographic characteristics were questioned, including gender, education level, age, and whether participants identified themselves as omnivorous, flexitarian, pescatarian, vegetarian, or vegan (i.e. self-reported dietary preference). The latter question was asked to get an insight into how focused people were on food sustainability. The third part consisted of an implicit association test (between food sustainability and palatability) (*results described elsewhere*). The fourth part consisted of 42 items (see Table 2) aiming to measure the constructs of the conceptual model (Figure 1), which will be described in more detail in the next section. The fifth part of the survey included a food sustainability knowledge questionnaire, consisting of 16 questions.

Measures

Subjective norm (*3 items*), perceived behavioural control (*4 items*), behavioural intention (*3 items*), and environmental responsibility (*6 items*) were assessed using 7-point Likert-type response scales, going from 1 (strongly disagree) to 7 (strongly agree). We used Francis et al. (2004) as guidance to construct the items of the TPB. Four items on environmental responsibility were adopted from Davis et al. (2020) and one item from Panzone et al. (2016). We used 7-point bipolar adjectival response scales to assess the attitudes toward perceived food sustainability (*8 items*) and beliefs about food attributes of sustainable foods, including palatability (*4 items*), perceived healthiness (*3 items*), perceived inconvenience (*4 items*), and price (*4 items*). All items were tested for understandability in a pilot study (*N=77 participants)*. We changed the statement (PBC3) from "In general, I am not capable of eating sustainably" to "In general, I am capable of eating sustainably". In addition, we changed the statement (Res3) from "I pay attention to environmental protection in daily life and consumption" to "I pay attention to environmental protection in consumption". The Likert-type response scales items were presented in a randomized (per-participant) order. The same was done for the bipolar adjectival response scales. Food sustainability knowledge was measured using the Food Sustainability Knowledge Questionnaire (*16 questions*) from Hartmann et al. (2021), which was translated into Dutch. The questions were in a fixed order. Education level was divided into three categories: low (primary school, lower vocational education, lower secondary education), moderate (intermediate vocational education, higher secondary education), and high (higher vocational education, university).

Consumer perceptions of food sustainability

The open question about what participants understood by "sustainable food", hereafter called the consumer perceptions, created the opportunity to formulate their own perceptions of sustainable foods (N=988). In order to place these perceptions in context, we manually coded the consumer perceptions using open coding. In total, 3026 perceptions were coded into 3360 codes and categorized into 151 subcategories. After that, a second, independent researcher (L.D.) categorized all the codes into the pre-defined subcategories to estimate the Inter-Rater-Reliability (IRR) among the two researchers. In these 151 subcategories, the IRR coefficient was 0.83 (Cohen's Kappa) (Geisler and Swarts 2019). The two researchers discussed the codes that were placed in different subcategories and chose one of the subcategories as the final subcategory. One subcategory included 381 codes that were not related to food sustainability and were therefore discarded. Moreover, small subcategories that contained only one or two codes were discarded, resulting in 2979 codes and 122 subcategories. These subcategories were then clustered into 33 larger categories with 8 overarching themes.

Data analyses

First, the negatively stated items were recoded, then the normality of the items was checked using the skewness coefficients and excess kurtosis coefficients. The skewness coefficients and kurtosis coefficients were within the -2 and +2, indicating acceptable deviations from normality *(George and Mallery 2021)*. Therefore, all items were included in the present analysis.

We used a two-stage approach to test the hypothesized model (Anderson and Gerbing 1988). First, we checked the measurement part of the model, for which we used confirmatory factor analysis (CFA). The aim was to confirm the factor structure of attitudes toward perceived food sustainability, subjective norm, perceived behavioural control, intention to consume sustainable foods, environmental responsibility, and the beliefs about food attributes of sustainable foods, including palatability, perceived healthiness, perceived inconvenience, and price. To later compare the fit of the CFA model with that of the structural model, we included dummy variables for moderate education level and high education level, and food sustainability knowledge (*number of correct knowledge items*) (*Kuder Richardson (KR-20) reliability = 0.80*) as one-item factors in the CFA model. We evaluated the model in terms of the properness of the estimates, fit indices (*Tucker-Lewis*

Index (TLI), Comparative Fit Index (CFI), Relative Noncentrality Index (RNI), Standardized Root Mean Square Residual (SRMR), and Root Mean Square Error of Approximation (RMSEA)), item reliabilities, R^2's, composite reliabilities (*CR's*), convergent validities (AVE's), and discriminant validity (*square root of AVE's*) with the inter-factor correlations. If the square root of AVE for a factor was lower than its inter-factor correlation, we checked whether a one-factor CFA model for the two constructs gave an equivalent or a worse fit than a two-factor CFA model (Fornell and Larcker 1981).

Second, we estimated and tested the structural part of the model using structural equation modelling (SEM). The same criteria were used as in the CFA. Modification indices were checked for model improvement and were considered to be added when paths could be justified in the context of theory. CFA and SEM were conducted in R (*package Lavaan version 0.6-12*) using a maximum likelihood estimation with robust standard errors (*MLR*). We have made assumptions about the coefficient signs in our hypotheses, and therefore we used one-tailed tests (Kock 2015).

Results

Descriptive characteristics

Sample characteristics

Half of the participants were female (*50%*), and the age of the sample ranged between 18 and 69 years old, with a mean age of 46 years (see Table 1). In total, 17% of the sample had a low education level, 45% had a moderate education level and 38% had a high education level. The mean age of low-educated participants was somewhat higher (*M=49 years*) than moderate and high-educated participants (M=*45 years (p=.009) and M=46 years (p=.07), respectively*). More than half of the sample identified themselves as omnivores (*57%*), and about one-third of the participants as flexitarian (*eating consciously without meat at least once per week*) (*36%*). Only a small number of participants were vegetarian (*4%*) or vegan (*2%*). Compared to low and moderate-educated participants, high-educated participants identified themselves less frequently as omnivorous (*49%*) and more frequently as flexitarian (*42%*) or as vegetarian (*6%*) compared to lower or moderate-educated participants (χ^2 *(10, N=930) = 20.8, p=0.02*) (Table 1).

Table 1 Characteristics of the study sample by education level (n=930).

Variable	Category	Low educated (n=158)	Moderate educated (n=415)	High educated (n=357)	Total
		n (%)	n (%)	n (%)	n (%)
Gendera	Male	81 (51)	213 (51)	170 (48)	464 (50)
	Female	77 (49)	201 (48)	187 (52)	465 (50)
Meat preference	Omnivore	96 (61)	258 (62)	174 (49)	528 (57)
	Flexitarian	52 (33)	138 (33)	149 (42)	339 (36)
	Vegetarian	6 (4)	12 (3)	23 (6)	41 (4)
	Vegan	2 (1)	6 (1)	6 (2)	14 (2)
	Other	1 (1)	1 (0)	2 (1)	4 (0)
	Pescatarian	1 (1)	0 (0)	3 (1)	4 (0)
		Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Age	(in years)	49 (1.3)[d]	45 (0.8)[d]	46 (0.7)	46 (0.5)
Food sustainability knowledge b		8.3 (0.3)[e]	9.0 (0.2)[c]	9.8 (0.2)[c,e]	9.2 (0.1)

[a] One participant mentioned "prefer not to say"

[b] Score (0-16), a higher score indicates higher food sustainability knowledge

[c] $p<.05$; [d] $p<.01$; [e] $p<.001$

Consumer perceptions of food sustainability

In response to the open question consumers indicated a wide range of different perceptions related to food sustainability. These perceptions were mainly related to the production of foods, the environment, locality, consumers' food choices, and specific food groups. The production of foods contained subcategories of organic, ethical, natural, and seasonal produce. The category "organic" was largest; *10.8% of the perceptions were related to this*. Next, consumers mentioned ethical production, including 'animal welfare' (*5.7%*) and 'ethicality' (*6.0%*). Natural production, e.g., 'production without pesticides' (*2.7%*) or 'without fertilizers' (*1.5%*), and seasonal production (*1.9%*) were less often mentioned. Consumers referred to the environment in terms of 'general terms' (*e.g., "nature", "climate"*) (*3.4%*), 'environmental impact' (*2.2%*), 'environmentally friendliness' (*5.0%*), the 'use of resources' (*1,7%*) and terms related to 'soil and nature' (*2.7%*). The second largest category included perceptions related to 'local, regional and import' (*8.1%*), including for instance 'local foods' (*6.8%*), 'local farms' (*0.5%*), and 'home-grown foods' (*0.4%*). Furthermore, consumers perceived sustainable foods to be 'healthy' (*6.2%*), 'expensive' (*2.4%*), and of 'high quality' (*1.1%*). In addition, they were perceived to be 'natural' (*1.6%*), 'without additives' (*1.3%*), and 'nutritious' (*0.8%*). Moreover, 'fruits and vegetables' were perceived to be sustainable foods (*5.2%*). Being 'vegetarian' or 'vegan' was mentioned in 3.8% of all codes. For a full overview of the food sustainability perceptions that were mentioned by the consumers, see Appendix A.

Measures

The measures from the survey covered the whole range of 1 to 7, and the means varied from 3.14 (*Con1*) to 5.78 (*ATT7*) (Table 2).

Confirmatory Factor Analysis

Initial CFA model

First, confirmatory factor analysis (CFA) with 12 factors was conducted on all 42 items. The initial CFA model indicated a poor fit (Satorra-Bentler corrected $\chi^2(756) = 2447, p<.001, TLI = .899, CFI = .902, RNI = .902, SRMR = .075, RMSEA = .059$) (Table 5). Then, one by one, we removed the items PBC4, Pri4, Res2, PBC2, Con2, ATT4, and Res1 due to poor item reliabilities (R^2*'s <.43*). Content validity, on closer examination of the items, explained why these items scored lower in the CFA models.

Final CFA model

After removing six items (PBC4, Pri4, Res2, PBC2, Con2, ATT4, and Res1), the final CFA model was conducted with 12 factors on the remaining 36 items, including the three one-item factors (Table 3). The final CFA model indicated a good fit, see Table 5. Most of the items were reliable (R2's>0.5), however, smaller R2's were observed for perceived inconvenience (Con4 =.42, Con1 =.46), perceived behavioural control (PBC1 =.45), attitude (ATT8 =.48), and subjective norms (SN2 =.48). The items Con1 and Con4 were kept in the model to obtain composite reliability and the item PBC1 was kept as part of the two-item construct.

The composite reliability did not fall below the cut-off values in all factors (Table 3). The AVE for perceived inconvenience fell slightly below .5, however, this is considered acceptable as the CR is above .6 (Fornell and Larcker 1981). We therefore concluded that convergent validity was acceptable. Based on the correlations in Table 4, discriminant validity might have been an issue in six pairs of constructs, including attitude-palatability, attitude-perceived healthiness, attitude-perceived inconvenience, palatability-perceived inconvenience, palatability-perceived healthiness, and environmental responsibility-behavioural intention (Table 4). To further investigate this, we compared the one-factor model with the two-factor model for each of these pairs. The results of all pairs indicated that the two-factor model had a better fit than the one-factor models (see supplementary files for fit indices and test statistics). It was therefore assumed that discriminant validity was not at stake.

Table 2 Items with descriptions, mean score (SE).

Construct Item	Item descriptions/statements	Mean	SE
Intention (strongly disagree – strongly agree)			
INT1	I expect to eat sustainable foods next week	4.36	0.05
INT2	I intend to eat sustainable foods next week	4.42	0.05
INT3	I will eat sustainable foods next week	4.52	0.05
Attitude "for me, sustainable foods are.."			
ATT1	Bad – Good	5.49	0.04
ATT2	Unpleasant – Pleasant	4.90	0.05
ATT3	Negative – Positive	5.42	0.05
ATT4	*Dull – Exciting*	*4.28*	*0.04*
ATT5	Uneasy – Comfortable	5.07	0.05
ATT6	Wrong to do – Right to do	5.43	0.05
ATT7	Bad for the environment – Good for the environment	5.78	0.04
ATT8	Unethical – Ethical	5.19	0.05
Subjective norm (strongly disagree – strongly agree)			
SN1	People that are important to me think that I should eat sustainable foods	3.71	0.05
SN2	It is expected from me that I eat sustainable foods	3.58	0.05
SN3	I feel pressured to eat sustainable foods	4.04	0.05
Perceived behavioral control (strongly disagree – strongly agree)			
PBC1	I'm confident I can eat sustainable foods if I want to	5.10	0.04
PBC2[a]	*For me eating sustainable foods is difficult*	*4.02*	*0.05*
PBC3	In general, I am capable of eating sustainably	4.92	0.04
PBC4	*I decide solely whether I eat sustainable foods*	*5.62*	*0.04*
Palatability "for me, sustainable foods are.."			
Pal1	Not tasty – Tasty	5.03	0.05
Pal2	Disgusting – Delicious	4.94	0.05
Pal3	Unappetizing – Appetizing	5.08	0.05
Pal4	Disgusting – Delightful	4.96	0.04
Perceived healthiness "for me, sustainable foods are.."			
Hea1	Bad for me – Good for me	5.26	0.04
Hea2	Bad for my health – Good for my health	5.45	0.04
Hea3	Unhealthy – Healthy	5.35	0.05
Perceived inconvenience "for me, sustainable foods are.."			
Con1	Easy to prepare –Difficult to prepare	3.14	0.04
Con2	*Easy to find –Difficult to find*	*3.83*	*0.05*
Con3	Convenient – Inconvenient	3.62	0.05
Con4	Simple – Difficult	3.77	0.05
Price "for me, sustainable foods are.."			
Pri1	Affordable – Unaffordable	4.37	0.05
Pri2	Worth less –Worth more	5.36	0.04
Pri3	Cheap – Expensive	5.25	0.05
Pri4	*Basic need – Luxury*	*4.20*	*0.05*
Environmental responsibility (strongly disagree – strongly agree)			
Res1	*I am concerned about what I can personally do to help to protect the environment*	*4.33*	*0.05*
Res2[a]	*It is not my responsibility to change my diet for environmental reasons*	*4.39*	*0.05*
Res3	I pay attention to environmental protection in consumption	4.61	0.05
Res4	I make personal sacrifices to reduce pollution	4.56	0.05
Res5	I do not buy products that potentially harm the environment	4.28	0.05
Res6	I have stopped buying certain products for environmental reasons	4.08	0.06

Items that are removed in the final CFA model (in italic)

a Items are recoded, scores representing the recoded mean and SE.

5

Table 3 Latent variables, range of completely standardized factor loadings, composite reliability (CR), and Average Variance Extracted (AVE) of the final CFA model.

Latent variable	No. of items	Range factor loadings a	CR[b]	AVE[c]
Behavioral intention	3	.89-.93	.94	.83
Attitude	7	.70-.87	.93	.65
Subjective norms	3	.69-.84	.80	.57
Perceived behavioral control	2	.67-.87	.75	.60
Palatability	4	.83-.90	.92	.75
Perceived healthiness	3	.77-.84	.85	.65
Perceived inconvenience	3	.65-.76	.74	.48
Price	3	.76-.85	.83	.63
Environmental responsibility	5	.70-.84	.84	.57
Food sustainability knowledge	1			
Moderate education level	1			
High education level	1			

[a] completely standardized; [b] Cut-off value CR >.7; [c] AVE >.5

Structural equation model

Initial model

After the confirmatory factor analyses, we performed a structural equation model to estimate and test the structural part of the model. The fit indices of the SEM model to test the conceptual model of Figure 1 were inferior to those for the CFA model (Table 5). Similar to the final CFA model, R^2's ranged between .39-.86. Smaller, more unreliable R^2's were found in perceived inconvenience (Con4= .39, Con1= .45), perceived behavioural control (PBC1= .46), attitude (ATT8= .47), and subjective norms (SN2= .48). The unreliable items were the same as in the CFA model.

Improved SEM model

The modification indices suggested to include an association between knowledge and perceived healthiness (MI = 139), attitude (MI = 136), or palatability (MI = 112). However, there is no theoretical support to include such an association, and therefore these associations were not added to the model. Another modification index (MI = 123) suggested an association of perceived behavioural control on environmental responsibility. It seems logical that consumers who are more environmentally concerned and have engaged in more sustainable behaviour in the past would consider themselves better capable of consuming sustainable foods (Kumar et al. 2022, Si et al. 2022). Adding the association to the model decreased the χ^2 ($\chi^2(1) = 94.2, p<.001$), and we obtained a reasonable to good fit *(Table 5).* The composite reliabilities were acceptable and comparable with the CFA model (ranging from .74-.93) (Table 6).

Table 4 Correlations between latent variables, with the square root of AVE on the diagonal (in italic).

	INT	SN	PBC	ATT	Pri	Pal	Con	Hea	Soc	Kno	edu_M	Edu_H
INT	*0.91*											
SN	0.61	*0.76*										
PBC	0.76	0.45	*0.78*									
ATT	0.56	0.24	0.56	*0.81*								
Pri	-0.39	-0.38	-0.40	-0.09	*0.79*							
Pal	0.58	0.25	0.58	0.90	-0.20	*0.86*						
Con	-0.61	-0.29	-0.67	-0.72	0.49	-0.81	*0.70*					
Hea	0.48	0.20	0.51	0.95	-0.02	0.84	-0.67	*0.81*				
Res	0.86	0.67	0.75	0.55	-0.37	0.57	-0.62	0.49	*0.75*			
Kno	0.28	0.11	0.31	0.44	0.04	0.36	-0.17	0.41	0.25	*1*		
edu_M	-0.06	-0.04	-0.06	-0.04	0.03	-0.04	0.05	-0.04	-0.07	-0.04	*1*	
edu_H	0.08	0.02	0.10	0.08	0.00	0.07	-0.02	0.05	0.04	0.12	-0.71	*1*

INT: intention to consume sustainable foods, SN: subjective norms, PBC: perceived behavioral control, ATT: attitude, Pal: palatability, Hea: perceived healthiness, Con: perceived inconvenience, Pri: price, Res: environmental responsibility, Kno: Food sustainability knowledge, edu_M: moderate education level, edu_H: high education level

Table 5 Summary of fit indices of the CFA models and SEM models.

Fit index	Cut-off value[a] (Hair et al. 2019)	Initial CFA model	Final CFA model	Initial SEM model	Final SEM model
Satorra-Bentler corrected χ^2		2447 (756) p<.001	1401 (497) p<.001	1634 (515) p<.001	1650 (548) p<.001
TLI	>.92	.889	.928	.914	.920
CFI	>.92	.902	.940	.925	.930
RNI	>.92	.902	.940	.925	.930
SRMR	<.08	.075	.056	.080	.076
RMSEA	<.07	.059	.055	.059	.057

TLI: Tucker-Lewis Index, CFI: Comparative Fit Index, RNI: Relative Noncentrality Index, SRMR: Standardized Root Mean Square Residual, RMSEA: Root Mean Square Error of Approximation

Table 6 Latent variables, range of completely standardized factor loadings, composite reliability (CR), and Average Variance Extracted (AVE) in the final SEM model.

Latent variable	No. of items	Range factor loadings[a]	CR	AVE
Behavioral intention	3	.89-.93	.93	.83
Attitude	7	.68-.86	.92	.63
Subjective norms	3	.69-.84	.80	.57
Perceived behavioral control	2	.66-.85	.74	.59
Palatability	4	.83-.90	.92	.75
Perceived healthiness	3	.77-.84	.85	.65
Perceived inconvenience	3	.65-.76	.74	.49
Price	3	.76-.85	.83	.63
Environmental responsibility	5	.70-.83	.84	.57
Food sustainability knowledge	1			
Moderate education level	1			
High education level	1			

[a] *completely standardized*

Interpretation structural part of the final SEM model

Figure 2 displays the completely standardized regression coefficients and the coefficient of determination for the structural part of the SEM model. As expected, attitudes toward perceived food sustainability (β=.09, p=.005), subjective norms (β=.12, p=.002), perceived behavioural control (β=.27, p<.001), and perceived environmental responsibility (β=.53, p<.001) were positively associated with the intention to consume sustainable foods. In addition, as hypothesized palatability (β=.32, p<.001), perceived healthiness (β=.65, p<.001), and food sustainability knowledge (β=.10, p<.001) were positively associated with attitude toward perceived food sustainability. There was no support for associations between perceived inconvenience (β=.00 p=.49), price (β=-.00, p=.46), and environmental responsibility (β=.04, p=.07) and attitudes toward perceived food sustainability. However, we found support for a negative association between perceived inconvenience (β=-.30, p<.001) and price (β=-.08, p=.02), and perceived behavioural control. Furthermore, we found that food sustainability knowledge (β=.14, p<.001) and, as expected, environmental responsibility (β=.52, p<.001) were positively associated with perceived behavioural control. The coefficient of determination (R^2) of our model was large (Cohen 1988) for perceived behavioural control (R^2=.64), intention to consume sustainable foods (R^2= .78), and attitudes toward perceived food sustainability (R^2=.94) (Figure 2).

Total, direct, and indirect effects of education level on attitude

We found that (high) education level had a positive direct effect on attitude (*moderate vs. low*: β=.04, p=.06, *high vs. low:* β=.05, p<.001) (Figure 2). Moreover, education level also had a positive effect on food sustainability knowledge (*moderate vs. low*: β=.10, p=.01, *high vs. low:* β=.20, p<.001). In addition, food sustainability knowledge also had a positive effect on attitudes (β=.10, p<.001), indicating that there might be an indirect effect of education level on attitude via food sustainability knowledge. We found a positive indirect effect of education level on the attitude toward perceived food sustainability via food sustainability knowledge (*moderate vs. low: β=.01, p=.03, high vs. low: β=.02, p=.001).* Moreover, we also found a positive total effect of education level on attitude (*moderate vs. low: β=.05, p=.02, high vs. low: β=.06, p=.005)*.

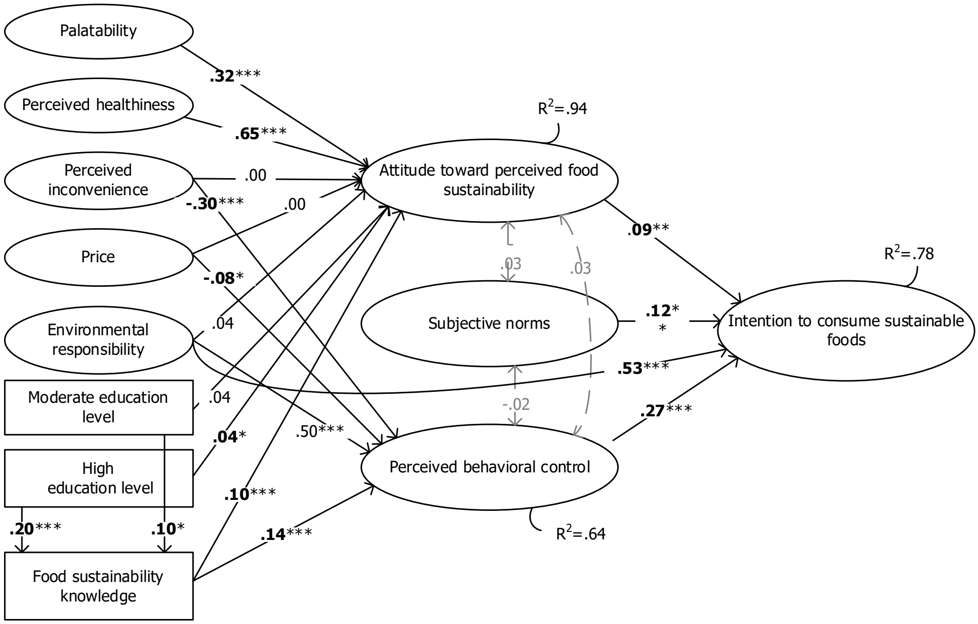


Figure 2 Results structural equation model with completely standardized regression coefficients (p<.05, ** p<.01, *** p<.001). The dotted lines represent covariances between attitude-subjective norms, attitude-perceived behavioral control, and subjective norm – perceived behavioral control. Hypothesis testing supported in bold. R²: Coefficient of determination*

Discussion

This is the first study that examined Dutch consumers' current perceptions of food sustainability, and their intention to consume sustainable foods and attitudes by exploring the associations with beliefs about food attributes, environmental responsibility, and education through the lens of the Theory of Planned Behaviour. Perceived healthiness and palatability had the largest associations with attitude toward food sustainability and environmental responsibility had the largest association with perceived behavioural control and behavioural intention. In the next sections, we discuss our main findings regarding the TPB, beliefs about food attributes, environmental responsibility, food sustainability knowledge, and differences in education level in more detail.

Theory of Planned Behavior

As expected, all three main components of the TPB were relevant predictors of the intention to consume sustainable foods. Attitudes, subjective norms, and perceived behavioural control were positively associated with the intention to consume sustainable foods (Table 4). This is in line with previous studies focusing on organic foods, local foods, and fruits and vegetables (Arvola et al. 2008, Vermeir and Verbeke 2008, Middleton and Smith 2011, Donahue 2017, Scalco et al. 2017, Fleșeriu et al. 2020). Behavioural intention is assumed to capture the motivational factors that influence a certain behaviour, but with the assumption that one is fully in control to decide whether or not to perform the specific behaviour (Ajzen 1991). Behavioural intention is considered to be influenced by contextual factors, such as availability, accessibility, resources, and skills (Ajzen 1985). In this study, we found that the intention to consume sustainable foods was influenced by multiple factors, including beliefs about food attributes, environmental responsibility, and food sustainability knowledge levels.

Beliefs about food attributes of sustainable foods

As hypothesized, we found that more positive beliefs about perceived healthiness and palatability had a positive association with attitudes toward perceived food sustainability, which means that consumers who perceived sustainable foods to be palatable and healthy held more positive attitudes toward perceived food sustainability. In addition, Dutch consumers perceived sustainable foods to be healthy, natural, and of high quality. The results imply that, in order to shift toward more sustainable food consumption patterns, taste preferences and the perceived healthiness of sustainable diets could be used to steer consumers toward more sustainable food choices. These beliefs affect the intention to consume sustainable foods through attitudes. Furthermore, in line with our hypotheses, we found that beliefs about perceived inconvenience and price were negatively associated with perceived behavioural control. Likewise, Dutch consumers perceived sustainable foods as expensive. This may suggest that price and perceived inconvenience issues concerning sustainable food consumption should be addressed.

Environmental responsibility

Feeling responsible for the environment was the strongest predictor of behavioural intention and perceived behavioural control. This may indicate that, in studying sustainable food consumption, environmental responsibility should be considered as a determining factor in the Theory of Planned Behaviour. Still, the definition of environmental responsibility is broad, and considers aspects of environmental awareness, environmental concern, and environmentally responsible behaviour. In follow-up research, a unified scale should be further developed and validated to better capture these aspects of environmental responsibility. Previously, perceived environmental responsibility was associated with environmental concern (Syropoulos and Markowitz 2021) and the latter was associated with perceived behavioural control (Kumar et al. 2022, Si et al. 2022). Therefore, we assumed that environmental responsibility may be associated with perceived behavioural control. Our data shows that consumers who felt responsible for the environment were more capable of consuming sustainable foods. This suggests that it is important to strengthen the sense of environmental responsibility to shift toward sustainable eating patterns.

Food sustainability knowledge

As hypothesized, we found that enhanced food sustainability knowledge was positively associated with positive attitudes and perceived behavioural control. Research into the associations between environmental knowledge and attitudes find inconsistent results; some find no association between knowledge and attitudes (Aertsens et al. 2011, Paço and Lavrador 2017, Torabian-Riasati et al. 2017, Sun et al. 2018), whereas others do find an association (Debora Indriani et al. 2019, Liu et al. 2020). The found association with perceived behavioural control was in line with findings from Ruangkanjanases et al. (2020). The latter found that enhanced environmental literacy was positively associated with perceived behavioural control (Ruangkanjanases et al. 2020). Our findings imply that consumers with enhanced sustainability knowledge believed that they were better capable of consuming sustainable foods, probably because they are better able to identify sustainable foods. Nevertheless, the Food Sustainability Knowledge questionnaire was not validated in the Dutch food context (i.e. questionnaire was translated to Dutch), however, the questions were tested for understandability in a pilot study (n=77). Thus, enhancing sustainability knowledge resulted in an increased intention to consume sustainable foods through attitudes and perceived behavioural control. Food sustainability knowledge might be enhanced through education.

Socio-demographic characteristics

We found that moderate- and higher-educated consumers had more knowledge of food sustainability compared to lower-educated consumers. A high education level, compared to low education level, had a positive effect on attitude, with an indirect effect via food sustainability knowledge. In addition, the higher-educated defined themselves more often as being flexitarian, vegetarian, and vegan compared to the lower-educated. This may imply that higher educated consumers already focus more on sustainability or are more environmentally conscious. There is, therefore, a strong need to enhance knowledge in the lower education groups in order to provide them with more knowledge and skills to choose sustainable foods.

Methodological considerations

In the present study, the CFA model was used to check the measurement part of the model. We evaluated the model in terms of the properness of the estimates, fit indices, item reliabilities, composite reliabilities, convergent, and discriminant validity. At first glance, discriminant validity was at stake in six pairs of constructs. However, in general, highly correlated constructs are not problematic if they are not predictors of the same construct. Therefore, performing one-factor and two-factor CFA models in the pairs attitude-palatability, attitude-health, attitude-convenience, and environmental responsibility-intention was not necessary. The pairs palatability-convenience and palatability-health were of main concern regarding discriminant validity due to multicollinearity. Nevertheless, the one-factor CFA model showed a worse fit than the two-factor CFA model, and we concluded that discriminant validity was not an issue.

The survey was conducted online and anonymized, which increases the risk of recruiting careless responders that are only interested in receiving the incentive as fast as possible (Brühlmann et al. 2020). We noticed that 24 participants completed the survey within 5 minutes, which was not plausible. Moreover, we also noticed that participants scored all items in the middle of the scale, or that participants had multiple attempts in filling out the questionnaire. As a result, we removed these participants from the analysis. These participants were most likely to be moderate-educated males, aged 18-35 years (n=18). Still, we obtained a sample of Dutch adults that was representative of education level and gender (CBS 2021). In addition, in our data we found that about 36 percent of the sample identified themselves as flexitarian, 4 percent as vegetarian, and 2 percent as vegan. Statistics Netherlands reported that about 5 percent of the Dutch do not consume meat, and higher-educated are more likely to be flexitarian, pescatarian, vegetarian, or vegan (Kloosterman et al. 2021). In our sample, we found a similar trend. We therefore have no reason to believe that our sample is not representative of the Dutch population.

Although the demographics and self-reported dietary preference are representative for a Dutch population, the consumer panel might have not been fully representative in terms of opinions, views, or perceptions of food sustainability of the Dutch population. We left the interpretation of what sustainable food or food sustainability entails up to the respondents themselves. We did not provide the respondents with a definition, as one's own perceptions are most closely related to their sustainable behaviours. This could make it difficult to interpret the results. The perceptions we observed were in line with the perceptions of food-related sustainability from other studies in high-income countries (van Bussel et al, 2022). The perceptions were mainly related to the food supply chain (*e.g., production, transportation, waste management*), certain product characteristics (*e.g., food labelling, organic and local*), and specific food groups (*e.g., fruits and vegetables, meat and meat* *alternatives*). Therefore, there is no concern that the sustainability perceptions of our consumer panel are different from other high-income countries.

The current study used the TPB as a theoretical framework to study the potential facilitators and barriers to sustainable food consumption. The limitation is that we measured intention and not actual behaviour, such as food choices or shopping behaviour. We found that the food attributes perceived healthiness and palatability, food sustainability knowledge, and environmental responsibility are potential facilitators of sustainable consumption, and that the food attributes price and perceived inconvenience are potential barriers to sustainable consumption. However, it is still unknown if these potential facilitators and barriers influence actual behaviour, like shopping behaviour, as this is mostly guided by heuristics or habitual consumption practices. Therefore, we cannot conclude whether consumers value the facilitators and barriers we found as important when purchasing sustainable foods. This needs to be verified in follow-up studies.

Recommendations

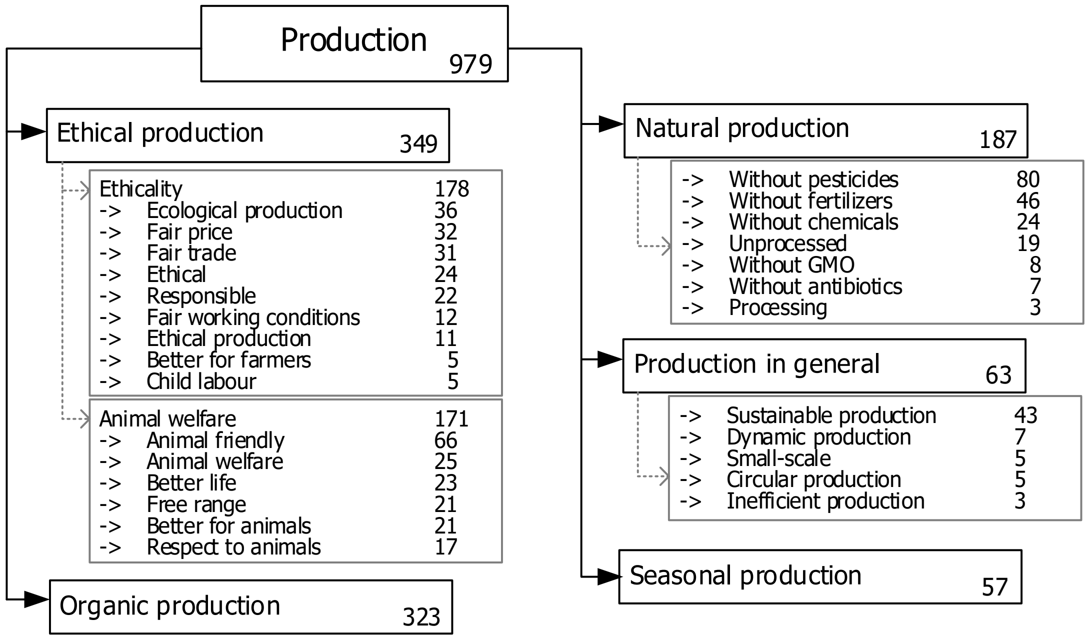
The expenditures on organic and local foods are still low, while the expenditures of foods with sustainability labels are increasing (Logatcheva 2021). This suggests that consumers are becoming more aware of sustainability issues. Our results suggest that in order to steer consumers towards sustainable purchases, stakeholders can attempt to raise feelings of environmental responsibility or emphasize the healthiness and taste of sustainable foods. Moreover, consumers who believe that sustainable foods are inconvenient and expensive may believe that they are not able to consume sustainable foods. This implies that consumers think that they for instance lack cooking skills or the ability to identify sustainable foods. Enhancing food sustainability knowledge could provide consumers the knowledge and skills they need to choose sustainable foods.

In order to steer consumers further toward more sustainable food consumption it is important to consider consumer perceptions. These perceptions influence the attitudes and the intention to consume sustainable foods, and eventually sustainable food consumption. As a previous review suggests, focusing on sustainability issues that are not aligned with the consumer perceptions of sustainability might raise scepticism among consumers (*e.g., sustainability claims could be considered as greenwashing, sustainability issues do not exist, no connection between food and the environment*) (van Bussel et al. 2022). Therefore, key stakeholders should consider the consumer perceptions and address the barriers of sustainable food consumption, e.g., the perceived price of sustainable foods.

Conclusion

This study showed that consumer perceptions of food sustainability are mainly related to organic and ethical food production, locality, healthiness and price of sustainable foods, and fruits and vegetables. Moreover, this study showed that the intention to consume these sustainable foods was influenced by attitudes, subjective norms, PBC, and especially environmental responsibility. Though, the environmental responsibility scale should be further developed and validated to better capture the different aspects of environmental responsibility. In addition, we found that attitudes toward perceived food sustainability were influenced by the food attributes palatability and perceived healthiness, food sustainability knowledge, and education level. The food attributes price and perceived inconvenience negatively influenced PBC. Therefore, key stakeholders should focus on taste preferences and the perceived healthiness of sustainable foods to steer consumers to more sustainable food choices, and price and perceived inconvenience should be addressed.

Appendix A: Consumer perceptions of food-related sustainability (N=930)



Appendix Figure 1 Consumer perceptions of food sustainability related to 'production' (32.9%) (N=2979)

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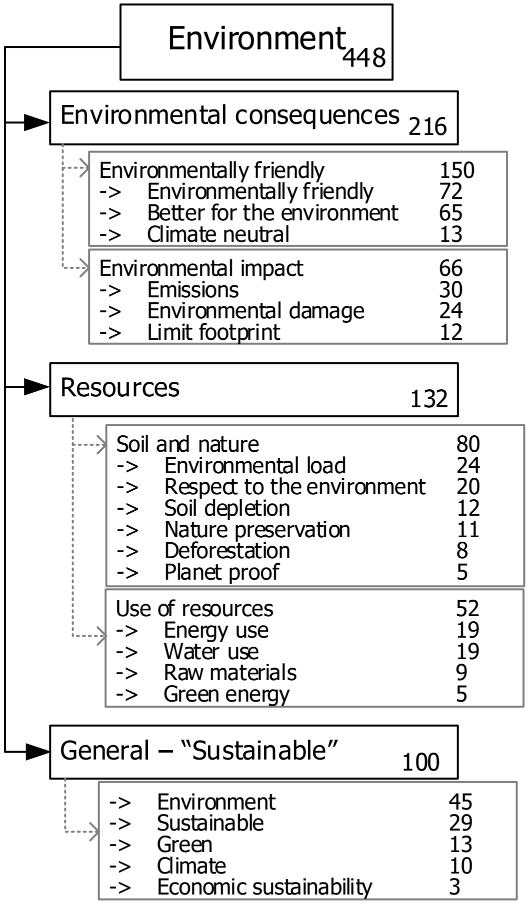
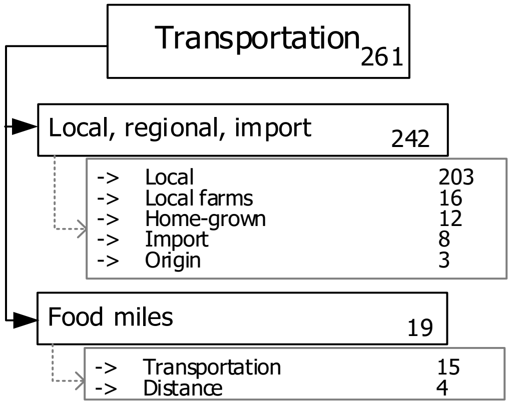
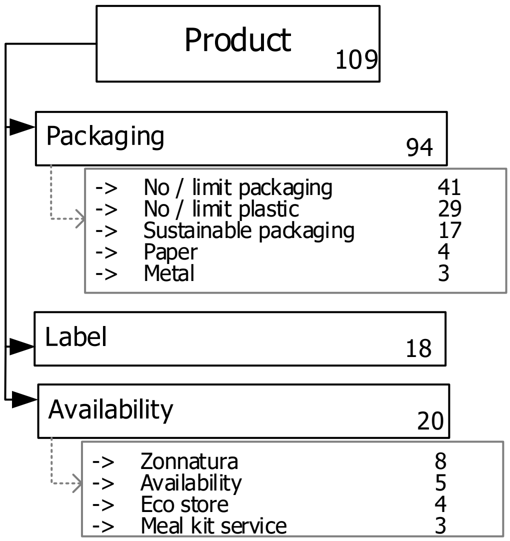


Appendix Figure 2 Consumer perceptions of food sustainability related to the 'environment' (15.0%) (N=2979)



Appendix Figure 3 Consumer perceptions of food sustainability related to 'transportation' (8.8%) (N=2979)



Appendix Figure 4 Consumer perceptions of food sustainability related to the 'product' level (4.4%) (N=2979)

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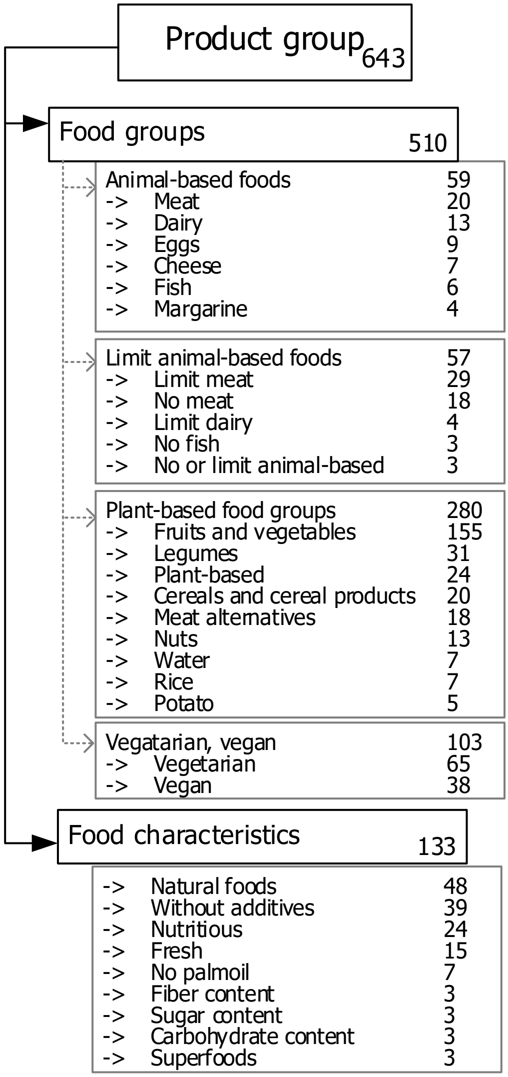
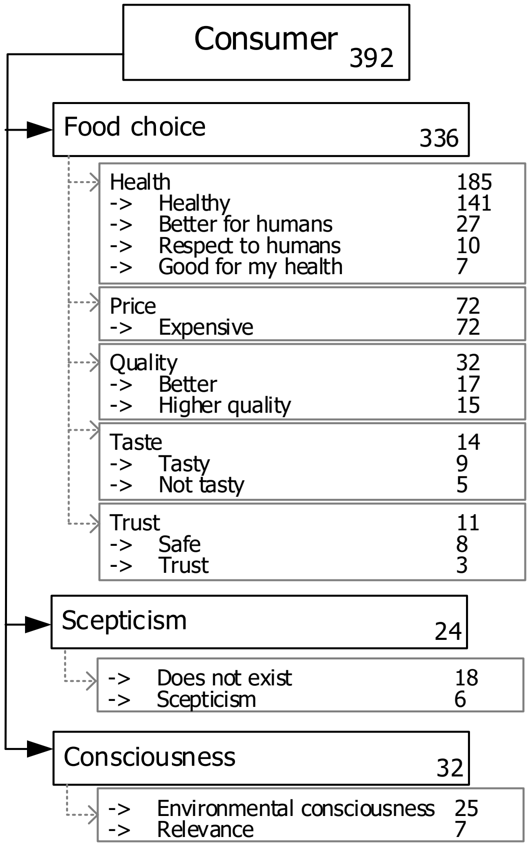
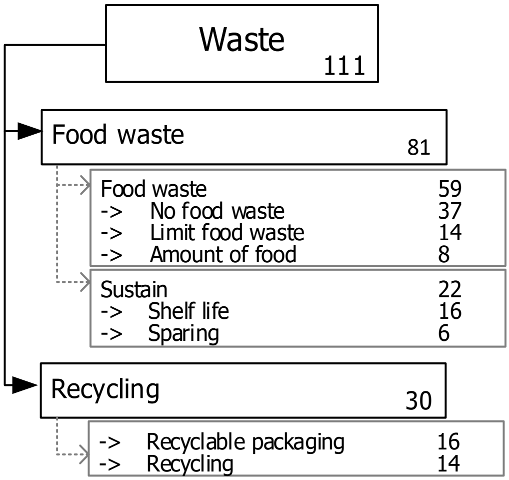


Appendix Figure 5 Consumer perceptions of food sustainability related to the food groups and food characteristics (21.6%) (N=2979)



Appendix Figure 6 Consumer perceptions of food sustainability related to the 'consumer' (13.2%) (N=2979)



Appendix Figure 7 Consumer perceptions of food sustainability related to waste (3.7%) (N=2979)

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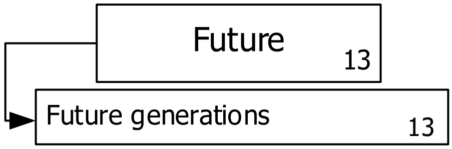

Appendix Figure 8 Consumer perceptions of food sustainability relate to 'future generations' (0.4%) (N=2979)

Supplementary files

Supplementary Table 1 One-factor and two-factor confirmatory factor analysis (CFA)

	Satorra-Bentler corrected χ^2	df	p-value	TLI	CFI	RNI	SRMR	RMSEA	χ^2 difference	p-value
Attitude & Palatability										
1-factor CFA model	407.6	44	<.001	.878	.903	.903	.055	.146	218.2	<.001
2-factor CFA model	274.8	43	<.001	.920	.937	.937	.048	.118		
Attitude & Perceived healthiness										
1-factor CFA model	189.3	35	<.001	.932	.947	.947	.035	.108	36.5	<.001
2-factor CFA model	169.8	34	<.001	.938	.953	.953	.034	.104		
Attitude & Convenience										
1-factor CFA model	379.4	35	<.001	.855	.887	.887	.073	.144	21.0	<.001
2-factor CFA model	252.4	34	<.001	.902	.926	.926	.054	.118		
Palatability & Convenience										
1-factor CFA model	96.1	14	<.001	.939	.959	.959	.052	.111	110.4	<.001
2-factor CFA model	31.0	13	.003	.985	.991	.991	.024	.055		
Palatability & Perceived healthiness										
1-factor CFA model	129.9	14	<.001	.907	.938	.938	.051	.151	190.3	<.001
2-factor CFA model	27.7	13	.01	.987	.992	.992	.022	.057		
Environmental responsibility & Behavioral intention										
1-factor CFA model	180.0	14	<.001	.912	.942	.942	.055	.145	62.5	<.001
2-factor CFA model	32.7	13	.002	.990	.994	.994	.018	.049		

Chapter 6

Implicit and explicit associations between sustainability aspects of foods and palatability. Exploring the differences in food attributes and socio-demographic characteristics.

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Manuscript in preparation

Abstract

Consumers play a key role in reducing environmental impact through their food choices. These choices are largely determined by the food attributes palatability, perceived healthiness, convenience, price and may nowadays also include sustainability. However, consumers do not fully consciously weigh these attributes when making food choices. The current study investigated the implicit and explicit associations between sustainability aspects of foods and palatability and whether these associations, food attributes, and socio-demographic characteristics predict the intention to consume sustainable foods. Observational data were collected from an online panel, representative for the Dutch population (N=988, 18-69 y, 51% male). The survey included implicit (implicit association test) and explicit measures on the association between sustainability aspects of foods and palatability, food attributes and behavioural intention. Sustainable aspects of foods were more strongly associated with being "palatable" than with being "unpalatable", both implicitly (D-score .79±.35; $p<.001$) and explicitly. However, these effects were small and did not predict the intention to consume sustainable foods. This was predicted by perceived healthiness ($\beta=.63$, $p<.001$), high education level ($\beta=.16$, $p=.03$), and price ($\beta=-.43$, $p<.001$). Key stakeholders should focus on food culture (e.g., education level) and explicit food attributes (i.e. perceived healthiness), while price barriers should be taken away.

Keywords: implicit association test, food sustainability, palatability, perceived healthiness, price, education level

Introduction

There is an urgent need to shift to a sustainable food system that delivers food security and nutrition for all, in such a way that the economic, social, and environmental bases to generate food security and nutrition for future generations are not compromised (FAO 2018, United Nations 2018). Currently, food production and consumption are responsible for about 24% of total greenhouse gas emissions (World Bank 2020). Consumers play a key role within the food system through their dietary food choices. However, the current Western eating patterns are not very sustainable. Therefore, a better understanding of consumer motives and barriers is critical to steer them towards more sustainable food choices.

Food choices are largely determined by the food's palatability, perceived healthiness, convenience, and price (Steptoe et al. 1995, Allès et al. 2017). Recently, we showed that consumers believe that the main contributors to a sustainable diet are locally produced and organic foods (van Bussel et al. 2022). In addition, several studies have shown that consumers perceive local and organic foods to be more palatable than conventional foods (Sijtsema et al. 2012, Rood et al. 2014, Aprile et al. 2016). It is, therefore, likely that one of the reasons for choosing sustainable foods (i.e. locally produced and organic foods) is their palatability. Furthermore, several studies showed that locally produced and organic foods are perceived as healthier compared to conventional foods (Adams and Adams 2011, Sijtsema et al. 2012, Vega-Zamora et al. 2014). However, it is still unknown whether palatability and perceived health are important motives for sustainable food choices.

On the other hand, barriers to consume more sustainable foods might include inconvenience and a high price. Depending on the sustainability aspects consumers have in mind (e.g., organic food, local food), sustainable foods are often perceived as inconvenient or expensive (Stubbs et al. 2018). It is believed that it takes time, effort, and knowledge to prepare sustainable meals and they limit freedom of choice (e.g., plant-based meals) (Schenk et al. 2018, Figueira et al. 2019). In addition, organic foods are perceived to be more expensive (Alevizou et al. 2015, Bryła 2016, Mann et al. 2018). Therefore, perceived inconvenience and a high price should be considered as barriers in sustainable food consumption. In the current study, we hypothesize that inconvenience and price negatively predict the intention to consume sustainable foods, while palatability and perceived healthiness positively predict the intention to consume sustainable foods (Figure 1).

It has been argued that consumers do not fully consciously weigh all relevant food choice motives (e.g., palatability, perceived healthiness, perceived inconvenience, price) when making a food choice (Dijksterhuis et al. 2005). Particularly, consumers may rely on heuristics or contextual cues to make food choices, using minimum cognitive effort (Cohen and Babey 2012). The dual processing theory posits that cognitive processes are either quick and automatic (system 1) or slow and deliberate (system 2) (Kahneman 2011). Food choices tend to be automatic responses, unconscious (implicit), or based on habits rather than a deliberate, slow, or conscious (explicit) process. Hence, implicit and explicit measures should be treated as two distinct constructs (Karpinski and Hilton 2001), and both constructs are expected to explain different parts of consumer behavior. Combining implicit and explicit measures, therefore, provides insights into the similarities and discrepancies between the measures and combined could better explain consumer behaviour.

To our best knowledge, research into the implicit and explicit associations between sustainability aspects of foods and palatability has not been reported. Results on whether healthy or unhealthy foods are perceived as palatable are inconclusive. On the one hand, Werle et al. (2013) found in French undergraduate students that healthy foods (e.g., broccoli, apple, salad, salmon) are perceived as palatable. On the other hand, Raghunathan et al. (2006) found that in undergraduate students, healthy foods (same stimuli as Werle et al. (2013)) are associated with unpalatable, and unhealthy foods (e.g., pizza, hamburger, fried fries) with palatable. The latter found that this unhealthy = tasty intuition is present at both conscious and unconscious levels (Raghunathan et al. 2006). It is unknown whether such an association is also present in sustainable versus unsustainable foods. Moreover, it is unknown whether the implicit associations between sustainability aspects of foods and palatability predict behavioural intention. Furthermore, it is unclear if there is a correlation between the explicit and implicit measures.

This is the first study that aims to investigate the implicit and explicit associations between sustainability aspects of foods and palatability among Dutch adults. Moreover, this study aims to examine whether these implicit and explicit associations predict the intention to consume sustainable foods. In addition, it examines whether food attributes and socio-demographic characteristics predict the intention to consume sustainable foods. We studied the implicit and the explicit associations in a representative Dutch sample of adult consumers (N=988) using an online survey with an implicit association test (IAT) and explicit questions. As a result, this allowed us to assess the implicit and explicit associations between sustainability aspects of foods and palatability and relate these associations to the intention to consume sustainable foods.

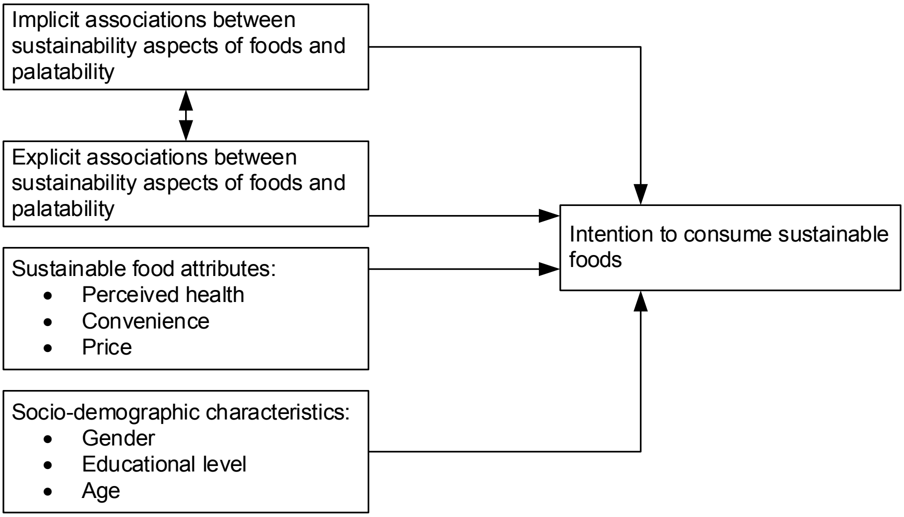

Figure 1 Conceptual model. Dependent variable: intention to consume sustainable foods. Factors that might be associated with the behavioral intention to consume sustainable foods: implicit and explicit associations between sustainability aspects of foods and palatability, perceived healthiness, perceived inconvenience and price, and socio-demographic characteristics.

Methods

Sample

Between July and August 2021, 988 participants were recruited from a commercial online consumer panel (UnravelResearch, Utrecht, the Netherlands). In total, 1801 participants started the survey, of which 813 participants only completed the first or first two parts. Therefore, these participants were excluded from the analysis. The sample was representative of the Dutch population in terms of gender, educational level, and age. Participants were joining voluntarily and could stop the study at any time. Anonymity was guaranteed and data were not distributed to third parties. Participants gave digital informed consent and received an online monetary voucher after participation. Positive advice was obtained from the Social Ethics Committee of Wageningen University, the Netherlands.

Survey

The online survey consisted of five parts. First, participants were asked to write down (open question) what "sustainable food" meant to them. Second, participants reported their socio-demographic characteristics, including age, gender, education level and whether they followed an omnivorous, flexitarian (I sometimes consciously don't eat meat) or vegetarian diet. The third part of the survey consisted of an IAT. The fourth part included questions related to the explicit associations between sustainability aspects of foods and palatability, behavioural intention, and food attributes. Other survey items that were questioned in the fourth part (i.e. environmental responsibility, subjective norms, perceived behavioural control, and attitudes) and the fifth part of the survey (sustainability knowledge questionnaire) are not used for the current analyses and will be described elsewhere. Data were collected via Qualtrics (version July-August 2021, Provo, Utah, USA). The median time needed for participants to complete the total survey was 16 minutes (interquartile range 12-24 minutes).

Education level was divided into three categories: low (primary school, lower vocational education, lower secondary education), middle (intermediate vocational education, higher secondary education), and high (higher vocational education, university).

Implicit measures

To measure the implicit associations between sustainability aspects of foods and palatability, participants completed an IAT, which is a well-established method to assess implicit attitudes (Greenwald et al. 1998, Greenwald et al. 2009). The IAT is a categorization task that relies on latencies. This is the time (in milliseconds) that it takes for participants to sort stimuli ("sustainable" and "unsustainable" words) and attributes ("palatable" and "unpalatable" words) into the correct categories, as fast and accurate as possible, by pressing the left or right response key on the keyboard. The response keys correspond to different combinations of stimuli and attributes categories (e.g., "sustainable" words paired with "palatable" words, or "sustainable" words paired with "unpalatable" words) (Table 2) (Figure 2). The latency is considered to reflect the relative strength of an association between stimuli and attribute concepts. If participants responded faster in one combination of stimuli and attribute categories than in the other, it is assumed that the implicit association between those concepts is stronger than the implicit association between the concepts in which participants responded slower. During the IAT, the words were presented in the centre of the screen (Figure 2).

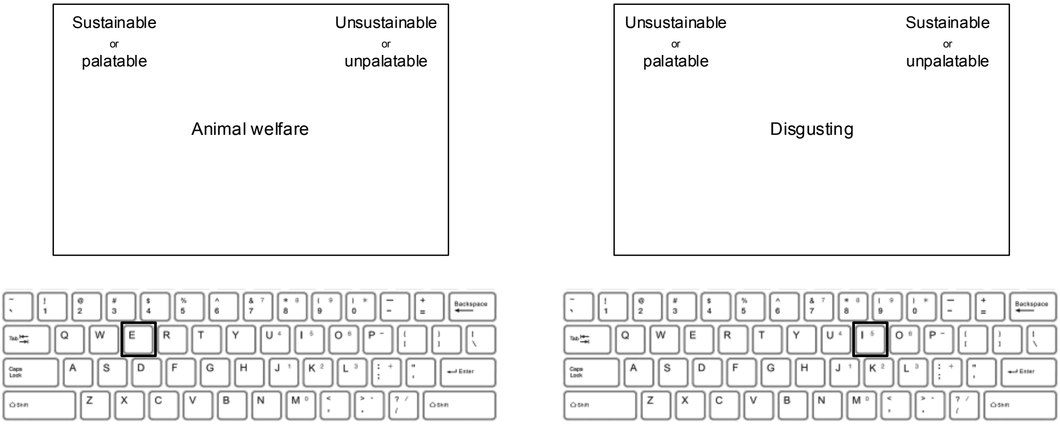

Figure 2 Two example screenshots of IAT. The left screenshot shows a stimulus in a compatible block. Animal welfare belonged to the left response key, and therefore the participants had to press "e" as fast as possible. The right screenshot shows an attribute from an incompatible block. Disgusting belonged to the right response key, and therefore participants had to press "i" as fast as possible.

Selection of stimuli and attributes

Potential stimuli (e.g., sustainability aspects) were selected based on previous studies (van Bussel et al. 2022). Potential attributes were selected based on synonyms and antonyms of the word 'palatable'. Next, a pilot study was conducted with 77 participants to determine if these potential stimuli and attributes were suitable and understandable. For this, participants were asked to score the 28 potential stimuli for their explicit association with sustainability on a 100-point scale (ranging from not sustainable at all – very sustainable). The seven words that scored on average the highest on "sustainable", and the seven words that scored highest on "unsustainable", with the lowest variability, were chosen as stimuli. The words highest associated with the stimulus category "sustainable" were: 'nature conservation' (70±27), 'apples from the region' (79±17), 'recycling' (79±18), 'local' (76±19), 'seasonal product' (81±15), 'animal welfare' (69±25), and 'unpacked' (70±23). The words most associated with the stimulus category "unsustainable were: 'food waste' (15±16), 'greenhouse gases' (23±24), 'child labor' (18±22), 'plastic' (24±22), 'pesticides' (33±29), 'import' (35±22), and 'waste incineration' (34±25). In addition, participants in the pilot test were asked to categorize 26 potential attributes into "palatable", "unpalatable" and "other". The eight words most often categorized as "palatable" and the eight words most often categorized as "unpalatable" were chosen as attributes (Table 1). See the supplementary files for a full overview of the results of the stimuli and attributes tested in the pilot.

Table 1 Overview of the stimuli and attributes selected for the IAT.

Stimuli		**Attributes**	
Sustainable	Unsustainable	Palatable	Unpalatable
Nature conservation	Food waste	Delicious	Disgusting
Apples from the region	Greenhouse gases	Appetizing	Unappetizing
Recycling	Child labor	Lovely	Despicable
Local	Plastic	Delightful	Sordid
Seasonal product	Pesticides	Divine	Bah
Animal welfare	Import	Yummy	Gross
Unpacked	Waste incineration	Gorgeous	Squicky
		Scrumptious	Unpleasant

Note: the stimuli and attributes are translated from Dutch. See supplementary files for Dutch stimuli and attributes

Presentation scheme of stimuli and attributes

The attributes and stimuli were presented according to the design of Greenwald et al. (2003). In total, the IAT consisted of seven blocks (Table 2). The first two blocks aimed to get participants familiar with the stimuli and attribute categories used in the IAT. Blocks 1, 3 and 4 were in the reversed order compared to blocks 5, 6, and 7. Participants were randomly assigned to one of two permutations to avoid order effects, that is participants started either with sustainable and palatable words on the left response key or with unsustainable and palatable words on the left response key.

D-score

The implicit association score, the so-called D-score, was calculated for each participant by the procedure described by Greenwald et al. (2003). The D-score is a relative measure (ratio) of the difference between the mean latency and the standard deviation of a congruent block and an incongruent block (ranging from -2 to +2). To calculate the D-score, the trials from blocks 3, 4, 6 and 7 were used. First, trials were eliminated if the latency exceeded 10.000 ms (132 trials). Participants were eliminated if more than 10% of all trials had latencies less than 300 ms (133 participants). An inclusive standard deviation was calculated for all remaining trials in blocks 3 and 6, and in blocks 4 and 7. Next, the average latency of the correct trials was calculated for blocks 3, 4, 6 and 7. Trials that were not correct were replaced by the mean latency of the corresponding block with an additional penalty of 600 ms (see D_4 from Greenwald et al. (2003) or D_{600} from Glashouwer et al. (2013)). Next, the average latencies of the resulting values for each of the four blocks were calculated, and differences between blocks 6 and 3 and between blocks 7 and 4 were computed. These differences were divided by their inclusive standard deviations, and the last step was to average the two quotations. Higher and positive D-scores reflect stronger implicit associations, with sustainable being associated with palatable, and unsustainable with unpalatable. In contrast, lower and more negative D-scores represent a stronger association between unsustainable and palatable, and between sustainable and unpalatable.

Next to the D-score, the mean latency in the four blocks, the stimuli trials (sustainable and unsustainable words), and attribute trials (palatable and unpalatable words) were calculated. Moreover, we calculated the average error rates in the four blocks, the stimuli trials, and attribute trials. Finally, we ranged participants based on the mean latency and number of errors and we described the socio-demographic characteristics of the quickest and slowest participants, and participants with the least and most mistakes.

Table 2 Design of the IAT, including target stimuli (sustainable-unsustainable words) and attributes (palatable - unpalatable words).

Block	N trials	Function	Items assigned to the left key	Items assigned to the right key
1	20	Practice	Sustainable words	Unsustainable words
2	20	Practice	Palatable words	Unpalatable words
3	20	Practice	Sustainable + palatable words	Unsustainable + unpalatable words
4	40	Test	Sustainable + palatable words	Unsustainable + unpalatable words
5	20	Practice	Unsustainable words	Sustainable words
6	20	Practice	Unsustainable words + palatable words	Sustainable + unpalatable words
7	40	Test	Unsustainable words + palatable words	Sustainable + unpalatable words

Note: Participants were randomly assigned to one of two permutations. Blocks 1, 3, and 4 are the reversed of blocks 5, 6, and 7. Participants started either with sustainable and palatable words on the left response key or with unsustainable and palatable words on the left response key. Block 2 was a practice block to introduce the palatable and unpalatable words.

Explicit measures

In the fourth part of the survey, we measured the explicit association between sustainability aspects of foods and palatability. Participants scored 3 statements on 7-point Likert response scales ranging from 1 (strongly disagree) to 7 (strongly agree). The statements were adapted and translated from Raghunathan et al. (2006). The following statements were scored: "there is no way to make food more sustainable without sacrificing the taste", "things that are sustainable rarely taste good" and "sustainable foods taste good". Next to statements on sustainability aspects of foods and palatability, three statements on the intention to consume sustainable foods were scored: "I intend to eat sustainable foods next week", "I expect to eat sustainable foods next week" and "I will eat sustainable foods next week".

In addition, explicit attitudes toward food attributes, including perceived healthiness (3 items), perceived inconvenience (4 items), and price (4 items) were assessed with 7-point bipolar adjective response scales. Table 4 provides an overview of the Likert scale items and the bipolar adjectives items. The 17 items that were used for the current study were presented in random order. Skewness and kurtosis of all scale items were between -1 and 1, therefore all items were used in the exploratory factor analysis.

Exploratory factor analysis

We conducted an exploratory factor analysis (with Oblimin rotation) to determine the internal consistency of the multi-item scales, including behavioural intention, explicit associations between sustainability aspects of foods and palatability, and the beliefs about food attributes (i.e. perceived healthiness, perceived inconvenience, and price). For the explicit measures, the reversed statements were recoded. Items that were loaded on more than one factor were rejected. Factors with internal consistency (Cronbach's alpha) above .7 were considered acceptable and were considered when theoretically relevant. Accepted items were used to compute latent variables based on standardized factor scores.

Statistical analysis

Correlations between the latent variables were calculated and interpreted in terms of significance and importance (Taylor 1990). Next, single and multiple regression models were used to investigate whether implicit associations between sustainability aspects of foods and palatability (model A), explicit associations (model B), or food attributes (model C) predicted the intention to consume sustainable foods. Furthermore, model A, B and C were combined in model D, and last, we added socio-demographic characteristics to the model (model E) to investigate whether explicit and implicit associations, food attributes, and socio-demographic characteristics predicted the intention to consume sustainable foods. Age was added as a continuous variable, gender as a dummy variable (reference was female), and education level included two dummy variables (reference was low education level).

Hypotheses were specified before data collection and the data analysis plan was pre-specified. Data were analyzed in RStudio (version 2022.01.1 Rstudio 2009-2022, PBC, Boston) and SAS (version 9.4 Cary, NC: SAS Institute Inc.).

Results

Sample

Participants of the panel were aged 18 to 69 years (45.5±14.9 years), and 49% of them was female (Table 3). Approximately, 17% had a low level of education, 45% had a middle level of education and 37% had a high level of education. Most participants identified themselves as omnivores (57%) or flexitarian (36%). More women reported to be vegetarian (7%) or vegan (3%) compared to males (2% and <1%, respectively).

Table 3 Socio-demographic characteristics of the total sample (N=988) and stratified by gender.

Variable		Total N=988	Males n=501 (51%)	Females n=485 (49%)
		Mean (se)	Mean (se)	Mean (se)
Age (in years)		45.5 (.47)	45.0 (.70)	46.2 (.64)
		%	%	%
Educational level	Low	17	17	18
	Middle	45	47	43
	High	37	36	39
Dietary lifestyle	Omnivore	56	64	49
	Flexitarian	36	33	40
	Vegetarian	5	2	7
	Vegan	2	0	3
	Pescatarian	0	0	0
	Other/missing	1	0	1

Implicit associations between sustainability aspects of foods and palatability

We found a positive D-score, indicating a positive association between sustainability aspects of foods and palatability (0.79±.35; p<.001; range -0.90–1.64) (Table 4). This indicates that sustainable words were stronger associated with being palatable than with being unpalatable. Likewise, unsustainable words were stronger associated with being unpalatable than with being palatable. Latency was on average shorter when sustainable words were paired with palatable words and unsustainable words with unpalatable words (congruent blocks) (954 ms±514) than when unsustainable words were paired with palatable words and sustainable words were paired with unpalatable words (incongruent blocks) (1417 ms±779) (Figure 3).

Practice blocks had higher latencies than the test blocks (congruent: 1013 ms±588 vs. 925 ms±470; incongruent: 1546 ms±863 vs. 1353 ms±724). Moreover, we found that latencies were higher for categorizing sustainable and unsustainable words (1326 ms±767 and 1329 ms±747, respectively) than for categorizing palatable and unpalatable words (1051 ms±605 and 1069 ms±628, respectively) (Figure 3).

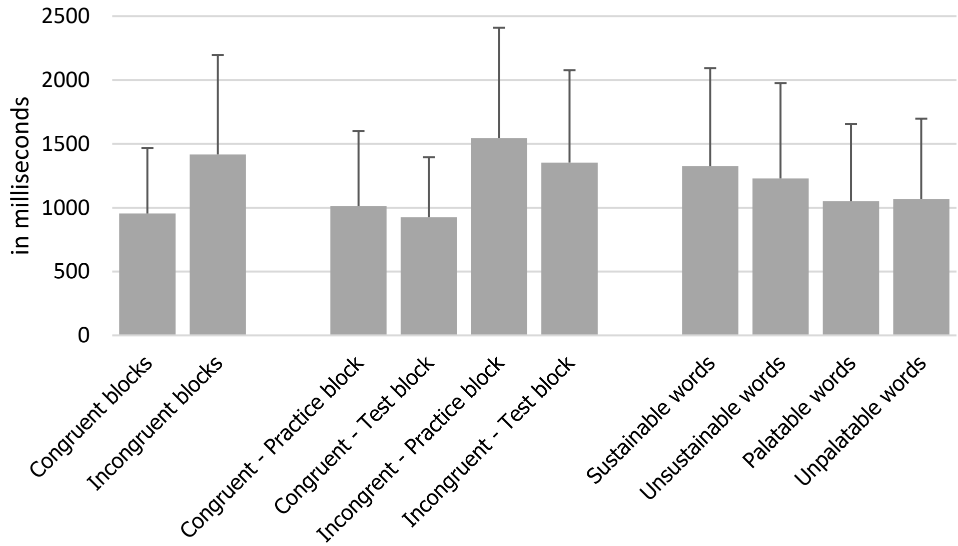

Figure 3 Mean latencies (in milliseconds) of congruent and incongruent blocks, the practice and test blocks, and the stimuli (sustainable and unsustainable words) and attributes (palatable and unpalatable words) (n=856)

The average error rate in the IAT was 11% (range 0%-75%) in all trials (practice and test blocks). As expected, errors were more common in the incongruent blocks (17%) than in the congruent blocks (5%). Moreover, the average error rates were higher for categorizing sustainable and unsustainable words (16% and 15%, respectively) than for categorizing palatable and unpalatable words (7% and 7%, respectively). The crude mean of latencies and number of errors in IAT were moderately negatively correlated ($r=-0.22$, $p<.001$).

In order to see whether latency and errors were more prominent in certain consumer groups, we ranked consumers based on their mean crude latency and the number of errors (both based on the median). Four subgroups were formed based on their latencies (fastest responses vs. slowest responses) and the number of mistakes (least mistakes vs. most mistakes). Males, older-aged (58-69 years), and lower-educated were most likely to have the longest latencies and most mistakes. Opposite to that, females, younger-aged (18-40 years), and higher-educated were most likely to have the fastest latencies and least mistakes (see Supplementary files).

Table 4 Descriptive results of implicit associations between sustainability aspects of foods and palatability, items on behavioral intention, explicit associations between sustainability aspects of foods and palatability, and attitudes toward food attributes, presented for the total sample and stratified by gender [(mean (se)].

		Total N=988	**Males N= 501**	**Females N=485**	**p-value**
	Implicit measure				
D-score (n=856)		.79 (.01)	.79 (.02)	.80 (.02)	ns
Item	Item description explicit measures				
Int1	I expect to eat sustainable foods next week	4.4 (.05)	4.3 (.07)	4.4 (.07)	ns
Int2	I intend to eat sustainable foods next week	4.4 (.05)	4.4 (.07)	4.5 (.07)	ns
Int3	I will eat sustainable foods next week	4.5 (.05)	4.4 (.07)	4.6 (.07)	.03
Pal1[a]	there is no way to make food more sustainable without sacrificing the taste	3.5 (.05)	3.8 (.08)	3.3 (.07)	<.001
Pal2[a]	things that are sustainable rarely taste good	3.3 (.05)	3.6 (.07)	3.0 (.07)	<.001
Pal3	sustainable foods taste good	5.1 (.04)	5.0 (.06)	5.2 (.05)	.003
Hea1[a]	good for me – bad for me	2.8 (.04)	3.0 (.06)	2.6 (.06)	<.001
Hea2	bad for my health – good for my health	5.4 (.04)	5.3 (.06)	5.5 (.06)	.002
Hea3[a]	healthy – unhealthy	2.8 (.05)	3.0 (.07)	2.5 (.06)	<.001
Con1[a]	difficult to prepare – easy to prepare	4.8 (.04)	4.8 (.06)	4.9 (.06)	ns
Con2	easy to find – difficult to find	3.9 (.05)	3.9 (.06)	3.9 (.07)	ns
Con3[a]	inconvenient – convenient	4.4 (.04)	4.4 (.06)	4.4 (.06)	ns
Con4	easy – difficult	3.8 (.05)	3.8 (.06)	3.9 (.07)	ns
Pri1[a]	unaffordable – affordable	3.7 (.05)	3.8 (.07)	3.5 (.07)	<.001
Pri2	economical – pricey	5.3 (.04)	5.1 (.06)	5.5 (.06)	<.001
Pri3[a]	expensive – cheap	2.9 (.05)	3.0 (.07)	2.7 (.06)	<.001
Pri4	basic need - luxury	4.2 (.05)	4.2 (.06)	4.2 (.07)	ns

Items were scored on 7-point Likert scale (1: strongly disagree; 7: strongly agree) and 7-point bipolar adjective response scales (representing the adjectives on 1 and 7).

Student's t-test was used to test for differences between males and females.

ns: non-significant

Explicit measures

Table 4 describes the crude results of the items of the explicit measures, including behavioural intention, explicit associations between sustainability aspects of foods and palatability, and the attitudes towards food attributes. These results suggest that the participants had a high intention to consume sustainable foods next week; they scored on average higher than 4. Moreover, the items related to the sustainability aspects of foods and palatability indicated a positive association, with reversed scores lower than 4 and the positively stated item higher than 4. The mean scores on items related to perceived healthiness, perceived inconvenience and price suggested that sustainable foods were perceived as healthy, convenient and expensive.

Latent factors and their reliabilities

The exploratory factor analysis resulted in five factors, which together explained 67% of the variance (Table 5). One-by-one, the items "basic need – luxury" (Pri4), "difficult to prepare – easy to prepare" (Con1) and "sustainable foods taste good" (Pal3) were removed from the exploratory factor analysis model as they loaded on multiple factors. In the final model, the item "inconvenient – convenient" (Con3) was included, even though the factor loading was relatively low (.30). We decided to include this item because of its theoretical relevance and to increase the internal consistency of the scale, otherwise the Cronbach's alpha of items representing perceived inconvenience was below 0.7. All five Cronbach's alphas were above 0.7 and were therefore considered acceptable. The items within the five factors were combined into standardized factor scores and these were labelled as 'intention to consume sustainable foods', 'explicit associations between sustainability aspects of foods and palatability', 'attitude toward perceived healthiness', 'attitude toward perceived inconvenience', and 'attitude toward price'.

Associations between latent factors

Table 6 shows the correlation matrix of the implicit association (D-score) and the 5 latent variables from the explicit measures. The intention to consume sustainable foods was weakly correlated with the extent to which participants associated sustainable foods to be palatable as measured explicitly ($r=.18$; $p<.001$; Adjusted $R^2=.03$) but was not associated with the implicit measure ($r=.04$; $p=.30$; Adjusted $R^2<.001$). These explicit and implicit measures were weakly positively correlated ($r=.22$; $p<.001$; Adjusted $R^2=.05$). Moreover, the intention to consume sustainable foods was positively correlated with the attitudes toward perceived healthiness ($r=.48$; $p<.001$; Adjusted $R^2=.23$), and negatively correlated with the attitudes toward perceived inconvenience ($r=-.37$; $p<.001$; Adjusted $R^2=.14$) and price ($r=-.42$; $p<.001$; Adjusted $R^2=.18$).

Table 5 Results of the exploratory factor analysis and internal consistency analysis.

Item[a]	Factor					Dimension	Cronbach's alpha
	1	2	3	4	5		
Int1	.91					Intention to consume sustainable foods	.93
Int2	.93						
Int3	.88						
Pal1		.87				Explicit associations between sustainability aspects of foods and palatability	.82
Pal2		.79					
Hea1			.80			Attitude toward perceived healthiness	.84
Hea2			.82				
Hea3			.65				
Con2				.67		Attitude toward perceived inconvenience	.71
Con3				.30			
Con4				.76			
Pri1					.75	Attitude toward price	.82
Pri2					.68		
Pri3					.89		

Extraction Method: Principal Axis Factoring. Rotation Method: Oblimin with Kaiser Normalization.
[a] See Table 4 for item descriptions

Table 6 Correlations between latent variables (Pearson's correlation coefficients).

	1	2	3	4	5	6
1. Intention to consume sustainable foods	1	.04	.18	.48	-.37	-.42
2. Implicit associations between sustainability aspects of foods and palatability (D-score)		1	.22	.15	-.05	.13
3. Explicit associations between sustainability aspects of foods and palatability			1	.62	-.36	.15
4. Health				1	-.57	.05
5. Convenience					1	.31
6. Price						1

Implicit associations between sustainability aspects of foods and palatability (n=856)

Prediction of the intention to consume sustainable foods

Table 7 presents the results of single and multiple regression models. First, we ran models A, B, and C, including the implicit associations, the explicit associations, and food attributes, respectively. In model A, we found that the implicit associations did not predict the intention to consume sustainable foods ($F(1,853)=1.08$, $p=.30$, Adjusted $R^2<.00$). However, explicit associations ($\beta=.19$, $t=5.6$, $p<.001$) positively predicted the intention to consume sustainable foods ($F(1,986)=31.8$, $p<.001$, Adjusted $R^2=.03$). In model C we included perceived healthiness, perceived inconvenience, and price ($F(3,984)=255.1$, $p<.001$, Adjusted $R^2=.44$) (Table 7). Perceived healthiness ($\beta=.59$, $t=18.5$, $p<.001$) and convenience ($\beta=.10$, $t=3.0$, $p<.01$) positively predicted while price ($\beta=-.50$, $t=-18.2$, $p<.001$) negatively predicted the intention to consume sustainable foods.

Adding both the implicit and explicit associations to model C (model D) suppressed the explicit associations between sustainability aspects of foods and palatability and perceived inconvenience ($F(5,849)=143.6$, $p<.001$, Adjusted $R^2=.45$). Still, perceived healthiness ($\beta=.64$, $t=16.2$, $p<.001$) and price ($\beta=-.42$, $t=-13.4$, $p<.001$) were associated with the intention to consume sustainable foods. In model E, we also included socio-demographic

Table 7 Prediction of the intention to consume sustainable foods by the implicit and explicit associations between sustainability aspects of foods and palatability, perceived healthiness, convenience, price, education level, age and gender.

Regression coefficients (SE) and significance for five models					
Model	A β (SE)	B β (SE)	C β (SE)	D β (SE)	E β (SE)
Constant	-.07	0	0	-.04	-.14
Implicit associations	.10 (.09)			.02 (.07)	.03 (.07)
Explicit associations		.19 (.03) ***		-.06 (.04)	-.07 (.04)
Perceived healthiness			.59 (.02) ***	.64 (.04) ***	.63 (.04) ***
Convenience			.10 (.04) **	.03 (.04)	.03 (.04)
Price			-.50 (.03) ***	-.42 (.03) ***	-.43 (.03) ***
Middle education					.08 (.07)
High education					.16 (.07) *
Age (in years)					-.00 (.00)
Male vs. females					-.07 (.05)
F-test (df1, df2)	1.1 (1, 853)	31.8 (1, 986)	255.1 (3, 984)	143.6 (5, 849)	81.0 (9, 843)
Sig. (p-value)	.30	<.001	<.001	<.001	<.001
Adjusted R^2	.00	.03	.44	.45	.46

** $p<.05$, ** $p<.01$, *** $p<.001$*

Low education level was used as a reference category characteristics, where a high level of education (β=.16, t=2.2, p=.03) predicted behavioural intention ($F(9,845)=81.0$, $p<.001$, Adjusted $R^2=.46$).

Discussion

This study investigated the implicit and explicit associations between sustainability aspects of foods and perceived palatability among Dutch adults. Results show that consumers associated sustainability aspects of foods more with being palatable than unpalatable, both explicitly and implicitly. Only the explicit associations predicted the intention to consume sustainable foods. In addition, this study examined whether food attributes and socio-demographic characteristics predicted the intention to consume sustainable foods. It appeared that perceived healthiness and being highly educated positively predicted, and price negatively predicted the intention to consume sustainable foods. Our results did not support the hypothesis that convenience negatively predicted the intention to consume sustainable foods.

Main results

Explicit and implicit associations

This was the first study that aimed to investigate the implicit and explicit associations between sustainability aspects of foods and palatability. We found that sustainability aspects of foods and palatability were positively associated, both explicitly and implicitly. This indicates that sustainable foods were more strongly associated with being palatable than with being unpalatable. In line with our findings, previous studies have reported that sustainable foods (e.g., environmentally friendly, local, organic), on the explicit level, were generally perceived as being more palatable than conventional foods (Adams and Adams 2011, Aertsens et al. 2011, Sijtsema et al. 2012, Gruber et al. 2014, Rood et al. 2014, Vega-Zamora et al. 2014, Alevizou et al. 2015, Zander et al. 2015, Aprile et al. 2016, Hiroki et al. 2016, Meyerding and Trajer 2019). In our study, we also found that the explicit associations between sustainability aspects of foods and palatability predicted the intention to consume sustainable foods (model B). However, the adjusted R-squared suggested that the explicit associations did not explain much variation to the model (3%). Palatability has not been studied extensively in relation to the intention to consume sustainable foods. Only Rah et al. (2004) showed that palatability of soy products had a negative effect on the intention to consume soy products (Rah et al. 2004), which might be due to a taste stigma of soy products (Wansink 2003).

As mentioned, we found that implicit associations between sustainability aspects of foods and palatability were positive, i.e. the mean D-score was significantly exceeded 0. Although consumers stronger associated sustainable words with "palatable" and unsustainable words with "unpalatable", this did not predict the intention to consume sustainable foods. Implicit attitudes may be more closely related to the intention to consume sustainable foods under time pressure. If participants are not able to reflect too much on the cognitive processes then choosing foods becomes more automatic (McGuire and Beattie 2019). Our study neither included time pressure nor a real-life setting in which participants could choose sustainable foods. Adding a time pressure component and an actual food choice would provide additional insights into the relation between the implicit measure, the intention to consume sustainable foods, and actual food choices.

In our study there is a weak positive correlation between the implicit and explicit measures. Both measures reveal the same evaluative tendencies (Karpinski and Hilton 2001), i.e. sustainable foods were more strongly associated with being palatable than with being unpalatable in both the IAT and in the explicit measures. Correlations are lower when two measures lack conceptual correspondence (Gawronski et al. 2007). For example, we studied the association between sustainability aspects of foods and palatability in self-report and indirect measures, resulting in higher conceptual correspondence. However, it was unknown how "sustainability aspects of foods" were perceived by the participants. At the beginning of the survey, participants were asked to write down what "sustainable food" meant to them. These perceptions could not be used in the IAT as potential stimuli. For the IAT stimuli, we used the results of a pilot study (n=77) to determine words that were mostly associated with sustainable and unsustainable. So far, we do not know whether these consumer perceptions of sustainability aspects of foods given by the participants match the pre-set categories of sustainable and unsustainable foods, which might result in a lower conceptual correspondence. The found correlation between implicit and explicit measures (.22) lies within the range previously found in meta-analyses (Hofmann et al. 2005, Cameron et al. 2012), strengthening the reliability of our result that conceptual correspondence was adequate.

Food attributes

We hypothesized that the perceived healthiness of sustainable foods would positively predict behavioural intention and that inconvenience and price would negatively predict the intention to consume sustainable foods. Indeed, we found that perceived healthiness positively predicted behavioural intention and price was negatively associated (models C-E), but for convenience we found only a negative association with behavioural intention in the correlation matrix and a positive association with behavioural intention in the regression models. Previously, health consciousness and perceived healthiness were found to have positive effects on behavioural intention (of sustainably sourced foods and local foods) (Dowd and Burke 2013, Kumar and Smith 2018) and the price was found to be negatively associated with behavioural intention (Liobikienė et al. 2016). Hence, our results were in line with these previous findings.

Socio-demographic characteristics

Regarding sociodemographic characteristics, our results suggested that higher-educated adults had a higher intention to consume sustainable foods than lower-educated adults. Previous research also indicated that a higher education level is a predictor of sustainable behaviour (Meyer 2015, Mohr and Schlich 2016, Ajibade and Boateng 2021), which might be moderated by environmental literacy or environmental concern. Moreover, research suggested that women are more engaged in sustainable consumption compared to men (Zelezny et al. 2000), however, our results did not show gender differences (when controlling for implicit and explicit associations between sustainability aspects of foods and palatability, food attributes, education level, and age). In addition, in line with Wiernik et al. (2013), age had no effect on the intention to consume sustainable foods.

Implicit association test

For the current study we developed a novel web-based implicit association test in Qualtrics. Carpenter et al. (2019) found that latencies in Qualtrics were higher than the latencies measured of an IAT programmed in a different web-based tool, i.e. Inquisit, however, the authors concluded that these differences were not significantly higher (i.e. median 120-150 ms higher) (Carpenter et al. 2019). It would be useful to measure the implicit associations between sustainability aspects of foods and palatability in third-party reaction-time software (e.g., Inquisit or E-prime) to confirm whether there are no differences between web-based survey tools and reaction-time software.

It was difficult to compare our IAT results with other IATs in the field due to a lack of transparency in data. For instance, only Panzone et al. (2016) reported latencies to check any order effects, in which the latencies were in the range of 1156-1173 ms. In addition, the stimuli and attributes used by Beattie and Sale (2009) could not be found (except for high and low carbon footprint products, and good/bad words), and McGuire and Beattie (2019) only mentioned some of the stimuli (e.g., bicycle, local apples, energy saving lightbulbs, luxury car, standard lightbulb, and bottled water). Our D-score of .79 (±.35) was comparable to the D-scores of sustainability IATs focusing on sustainability and valence (.72±.29 (Panzone et al. 2016); .59±.32 (Steiner et al. 2018); .99 (McGuire and Beattie 2019)). All studies indicated that sustainability was more strongly associated with a positive valence. To make it easier to compare IAT results, it is necessary to report all the stimuli and attributes, the procedure and scoring algorithm, the software used as well as an overall D-score, the mean latencies, and error rates.

We followed Greenwald et al. (2003) in calculating the D-score, in which trials that exceeds 10.000 ms are discarded and participants are removed who have more than 10% of their trial latencies less than 300 ms. Low and high latencies provide some additional information about the attributes and stimuli used in the IAT. For example, we found that the categorization of the stimuli had systematically higher latencies compared to the categorization of the attributes used in the IAT. This might indicate that stimuli were not easy to categorize into the sustainable or unsustainable categories or that participants were not familiar with the words (Greenwald et al. 2021). Nonetheless, it appeared that the D-score is relatively insensitive to the treatment of extreme latencies (Nosek et al. 2014). We, therefore, followed Greenwald et al. (2003) by removing participants who have more than 10% of their latencies less than 300 ms and trials above 10.000 ms.

Beside latencies, errors could also provide information about the stimuli and attributes used in the IAT. We found an average error rate of 11% in all trials. We did not discard the incorrect trials because it has shown to worsen the reliability and validity of the IAT (Richetin et al. 2015). In addition, removing participants with high error rates would result in a loss of an excessive amount of data (Greenwald et al. 2003). More importantly, higher error rates, especially in the categorization of the stimuli, might indicate that the words used in the IAT representing sustainable and unsustainable were not perceived as either sustainable or unsustainable. However, in our study the attributes and stimuli were chosen based on a review of the consumer perceptions towards food sustainability (van Bussel et al. 2022) and a pilot study with 77 participants, in which we pretested a series of attributes and stimuli on their appropriateness. This resulted in a selection of stimuli and attributes that were mostly associated with either sustainable or unsustainable and palatable or unpalatable. Therefore, we believe that the words representing sustainable and unsustainable were familiar to the participants. Nevertheless, the sustainable and unsustainable words, compared to palatable and unpalatable words, may have taken longer to cognitively process due to the length of the words and potential ambiguous terms.

Women, younger-aged (18-40 years) and higher-educated were more prominent in having the fastest latencies and the least mistakes. This suggests that the tested sustainability aspects of foods were most familiar to women, younger-aged, and higher-educated and/or that these participants were the most accurate in the IAT. In addition, men, older-aged and lower-educated were most likely to have the highest latencies and most mistakes. It has been shown that reaction times will increase with age (Gottsdanker 1982, Hummert et al. 2002). It is unknown why men and lower-educated were more likely to have the highest latencies and most mistakes, but this might indicate that men and lower-educated were less familiar with the sustainability concepts or that they lack computer skills to complete an IAT. Moreover, the crude mean latencies were negatively associated with the number of errors. This indicates that there is a trade-off between responding fast and making mistakes.

Further research

In our study, it was not possible to examine actual behaviour or self-reported behaviour related to sustainability aspects of foods due to a lack of understanding of the sustainability concept in our sample. The intention to consume sustainable foods does not necessarily imply that actual (sustainable) behaviour is also influenced by health and price aspects. It would be useful to get insights into shopping behaviour as a mean of real-time food purchases or to include self-reported behaviour items in the survey, even though self-reported measures only weakly correlates with actual behaviour (Kormos and Gifford 2014).

It could be seen from the results of the pilot study that it is difficult to select words that represent sustainable and unsustainable. Many words related to food sustainability have ambiguous meanings to consumers (e.g., land use, fair trade, organic), and consumers have a wide range of perceptions related to food sustainability (van Bussel et al. 2022). As a consequence, the overall latencies to categorize the stimuli were larger than the latencies to categorize the attributes in the IAT. Latencies might decrease with increased knowledge on sustainability aspects of foods or with shorter terms representing sustainable and unsustainable. It would be useful to think of a better design to measure implicit associations between sustainability aspects of foods and palatability. A personalized IAT could be an option, although it is not possible to implement in large consumer surveys.

Conclusion

To conclude, perceived healthiness, high education level and price are key predictors of behavioural intention to consume sustainable foods. We show that sustainability aspects of foods are stronger associated with being palatable than with being unpalatable, both in an implicit association test and when explicitly asked for. Only explicit measures of education level, perceived healthiness and price predicted behavioural intention to consume sustainable foods. Although implicit measures revealed that sustainable foods are stronger associated with being palatable, this did not predict intentions. Instead of advocating palatability of sustainable foods, key stakeholders, such as governments and food industry, should focus on food culture (e.g., education level) and explicit food attributes (i.e. perceived healthiness), while price barriers should be taken away.

Acknowledgement

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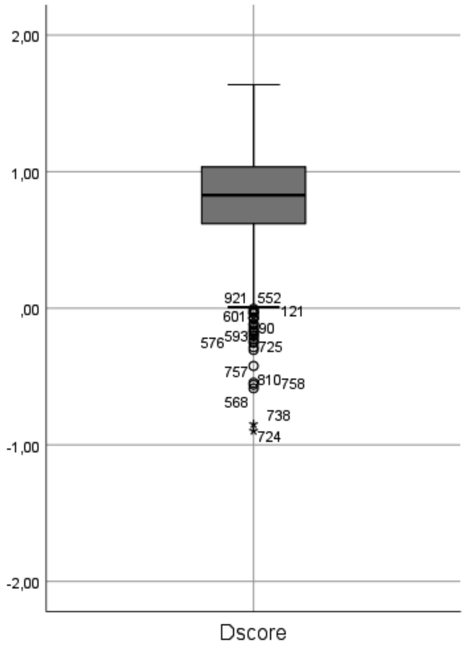
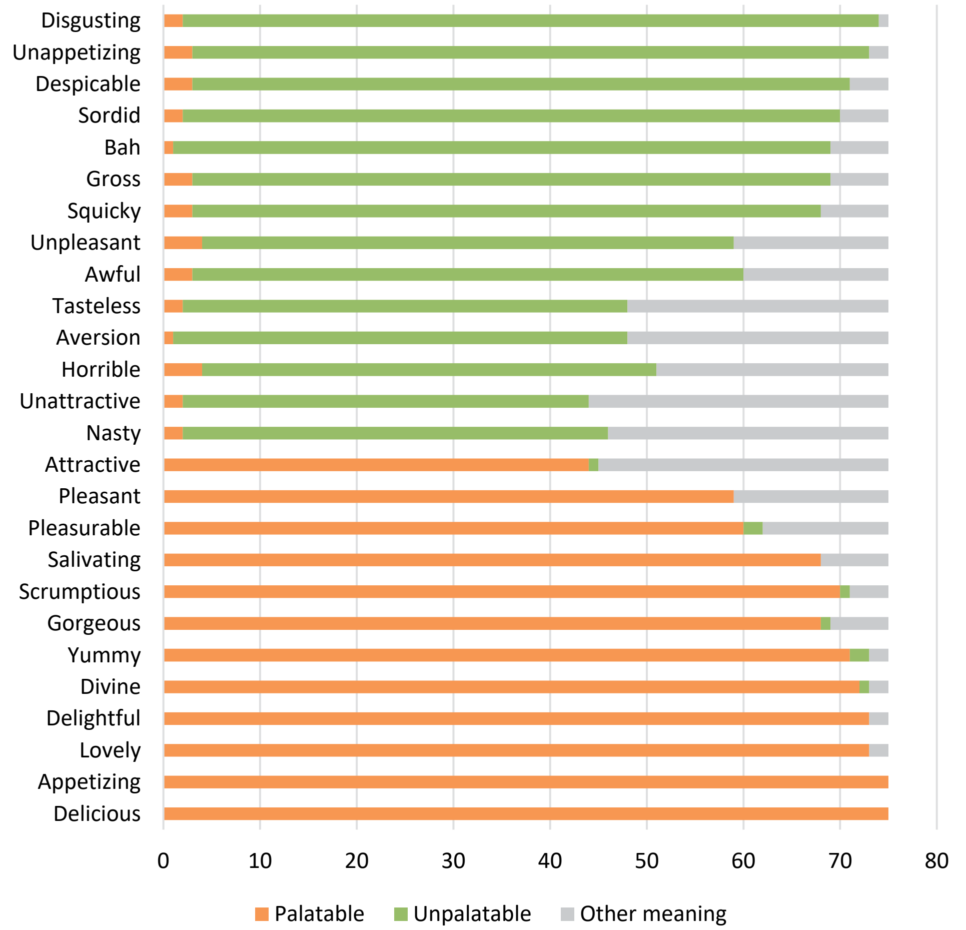
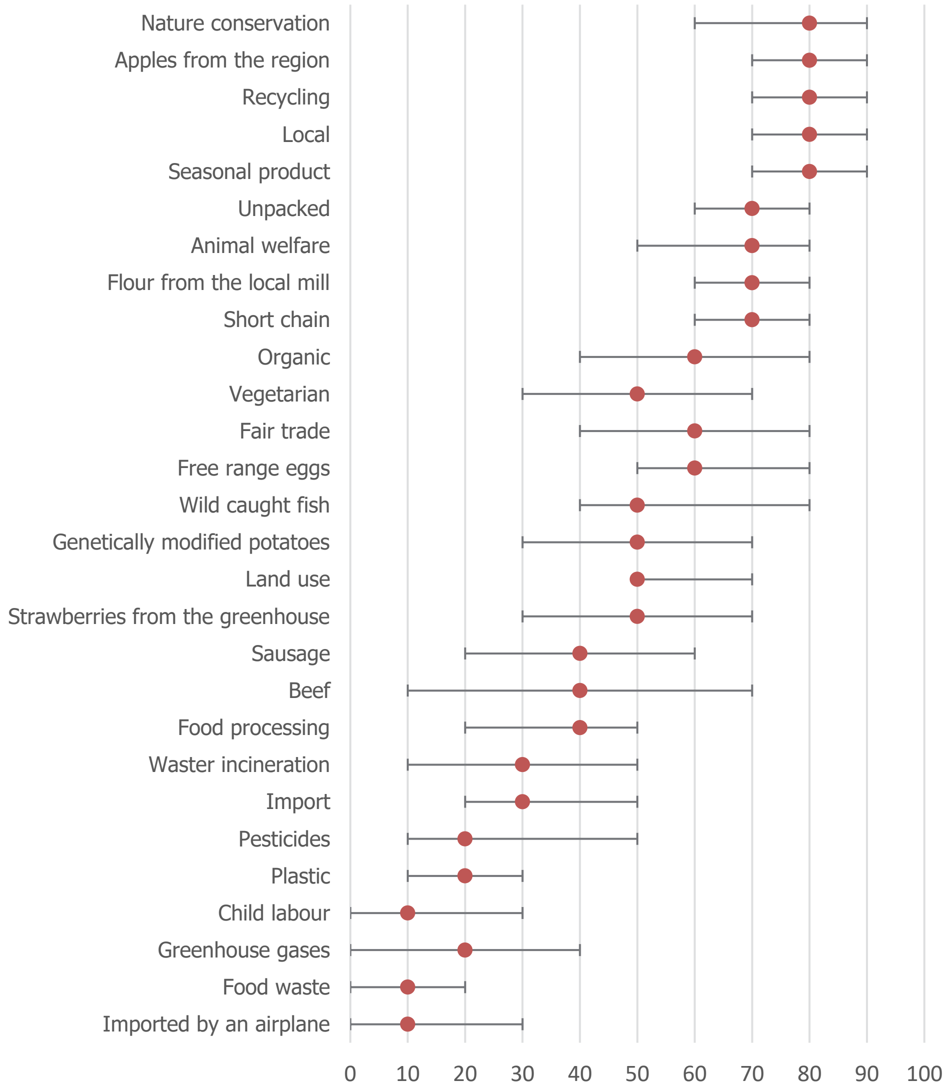
Supplementary files



Supplementary Figure 1 Boxplot of the D-score



Supplementary Figure 2 Results of categorizing palatable and unpalatable words (pilot test, n=75)



Supplementary Figure 3 Results from pilot study. Median and interquartile range of 28 words on its perceived sustainability. Imported by airplane has not been chosen as stimulus in the IAT because of its length (in Dutch) (n=77)

Supplementary Table 1 Attributes and stimuli used in IAT (in Dutch)

Stimuli		**Attributes**	
Sustainable	Unsustainable	Palatable	Unpalatable
Natuurbehoud	Voedselverspilling	Heerlijk	Ranzig
Appels uit de regio	Broeikasgassen	Smakelijk	Onsmakelijk
Recycling	Kinderarbeid	Verrukkelijk	Smerig
Lokaal	Plastic	Overheerlijk	Goor
Seizoensproduct	Bestrijdingsmiddelen	Zalig	Bah
Dierenwelzijn	Import	Yummie	Walgelijk
Onverpakt	Afvalverbranding	Hemels	Jakkes
		Appetijtelijk	Onaangenaam

Supplementary Table 2 Segmentation of sample, based on mean latency (in milliseconds) and errors

	Fastest latencies, least errors (n=187)		**Fastest latencies, most errors (n=240)**		**Slowest latencies, least errors (n=244)**		**Slowest latencies, most errors (n=183)**	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Latency (in milliseconds)	967	7	916	8	1306	14	1319	15
Errors (number)	5	0	23	1	5	0	19	1

Supplementary Table 3 Distribution of socio-demographic characteristics in the four segments (in %).

		Lowest latencies, least errors (n=187)	**Lowest latencies, most errors (n=240)**	**Highest latencies, least errors (n=244)**	**Highest latencies, most errors (n=183)**	**Total (n=854)**
Variable		%	%	%	%	%
Gender	Male	36	48	52	54	48
	Female	64	53	48	46	52
Education level	Low	9	19	13	30	17
	Middle	43	50	38	46	44
	High	48	31	49	25	39
Age	Young (<40)	46	42	32	25	36
	Middle (40-57)	39	35	40	28	36
	Older (>57)	16	23	28	46	28

Example: Based on the total sample, it is expected that all segments include 48% males, and 52% females. In the segment "highest latencies, least errors", we see that only 36% is male, and 64% is female. Therefore, there are relatively more females in this segment.

Chapter 7

General discussion

Overall aim

The overall aim of this thesis is to determine the overlap and the differences between diet-related sustainability as measured by environmental sustainability indicators and the consumer's perceptions of food-related sustainability. The first part of this thesis focused on diet-related sustainability, the second part of this thesis focused on consumer's perceptions of food-related sustainability. Figure 1 summarizes the main findings for the research questions on part 1 and 2:

1. What are the similarities and differences between the consumer's perceptions of food-related sustainability and the biophysical indicators of diet-related sustainability? (section 7.2)
2. What are the taste properties of healthy and sustainable diets? (section 7.3)
3. What are the consumers' taste preferences for sustainable foods? (section 7.3)
4. Which person-related determinants are the potential facilitators or barriers to sustainable food consumption? (section 7.4)

In part 1, diet-related sustainability, we used the biophysical indicators greenhouse gas emissions (GHGEs), land use (LU), and fossil energy use (FEU) to assess diet-related environmental sustainability. To assess the healthiness of diets, diet quality, we used the adherence to the Dutch food-based dietary guidelines as an indicator. Moreover, we used the taste database to study the taste properties of healthy and sustainable diets. The results show that a more sustainable and healthier eating pattern contains mostly neutral tastes, and less umami/salt/fat and bitter tastes than a more unsustainable and unhealthier eating pattern (**chapter 3**). Moreover, we found that higher educated consumers had healthier diets, but their diets were not more sustainable than diets of lower educated consumers (**chapter 2**).

Part 2 focused on consumer's perceptions of food-related sustainability. Our literature review showed that consumers had a very wide range of perceptions related to food sustainability. They covered the whole supply chain, and also included food characteristics (e.g., organic, local, ethically produced), and also specific food groups were mentioned (e.g., fruits and vegetables, and meat). Moreover, it was often reported that consumers perceived sustainable foods as healthy, natural, but also as expensive (**chapter 4**). Next, based on the outcomes of the review, an online questionnaire with an implicit association task was developed to study associations between sustainability aspects of foods and palatability, food sustainability knowledge, sustainable food attributes (i.e. palatability, perceived healthiness, perceived inconvenience, and affordability), and environmental responsibility as potential facilitators or barriers to sustainable food consumption. We collected data from a representative sample of the Dutch adult population (N=988). These data showed that sustainable aspects of foods were stronger associated with being palatable than unpalatable, both on a subconscious and conscious level (**chapter 6**) and that sustainable foods were perceived as both healthy and expensive (**chapter 5**). In addition, after applying a structural equation model on the data, it was confirmed that, compared to lower educated consumers, higher educated consumers had more knowledge about food sustainability, a more positive attitude toward food sustainability (**chapter 5**), and a greater intention to consume sustainable foods (**chapter 6**).

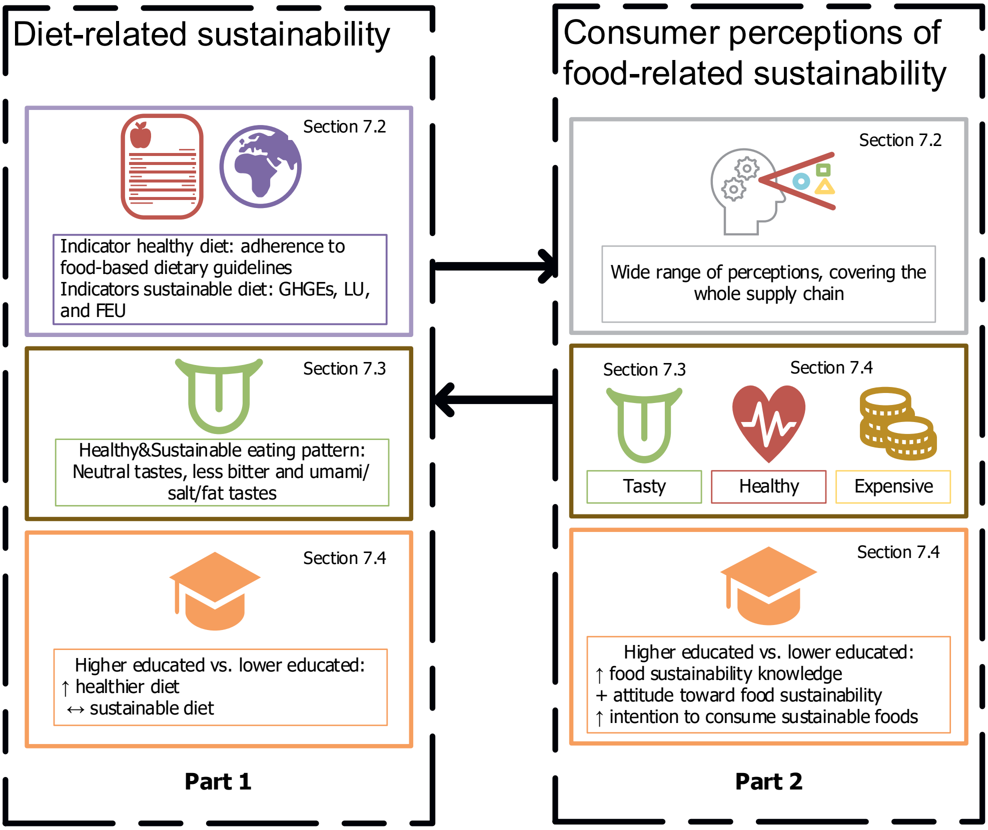


Figure 1 Main findings of this thesis. Diet-related sustainability was addressed in the first part of the thesis (left) and consumer perceptions of food-related sustainability in the second part of the thesis (right).

Diet-related sustainability and consumer's perceptions

Main results

In this section, we discuss the first research question "What are the similarities and differences between the consumer's perceptions of food-related sustainability and the biophysical indicators of diet-related sustainability?". To answer this question, we compared the results of **chapter 2**, **chapter 3**, and **chapter 4**. The literature review (**chapter 4**) showed that consumers have a wide range of perceptions, covering the whole supply chain, that is from production, transportation, the consumer, to waste management. Terms falling under the categories environmental impact, local and organic food choices and ethical production were the most frequently mentioned by consumers. In addition, some consumers are suspicious about sustainability; they perceive it as a hype, greenwashing, or they think food consumption is not related to the environment at all. In **chapter 2** and **chapter 3**, the biophysical indicators used to assess the sustainability of diets were GHGEs, LU, and FEU. The environmental impacts, using these indicators, were the highest for animal-based foods and the lowest for fruits, vegetables, and (tap) water. In conclusion, the consumer's perceptions and the biophysical indicators overlap, like coverage of the whole supply chain and fruits and vegetables, but there were also some differences, in which the consumer perceptions are broader, including for instance locality, organic food production and ethical concerns.

Methodological and conceptual considerations

This thesis only used the common biophysical environmental sustainability indicators GHGEs, LU, and FEU (**chapter 2 and chapter 3**). Other environmental sustainability indicators, not used in this thesis, such as loss of biodiversity, acidification, eutrophication, and (blue) water use may shed a different light on the sustainability of our eating patterns. For example, if we would have used (blue) water use, which include drinking water and irrigation water for agriculture, as an indicator for environmental sustainability, animal food products, fruits, and non-alcoholic beverages would have the largest contributions to water use (Hollander et al. 2021). This implies that fruits are not necessarily be considered very sustainable, although consumers perceive them as sustainable. Therefore, blue water use would prove interesting aspects to take into account and should be used as an important environmental sustainability indicator in future studies. Furthermore, no data were available for acidification, or eutrophication in the Dutch context. To get a complete overview of the environmental impact of eating patterns, future studies should focus on quantifying these indicators, as well as biodiversity loss.

At the start of this research, only comprehensive sustainability data were available for GHGEs, LU, and FEU. These existing LCA-databases were used to estimate the environmental impact of Dutch diets (Blonk et al. 2011) (version 2013 and 2014). In total, the database included the environmental impact of 203 food products in 2013 (**chapter 2**) and 254 food products in 2014 (**chapter 3**), which were estimated using attributional LCA. Extrapolation, i.e. imputation, was used to estimate the impacts of foods with similar product properties and/or ingredients. In this way, the impact of many foods eaten by the population was estimated. Although this method covers about 90 percent of the energy intake of foods (**chapter 3**), still 10 percent of energy intake is not covered; including mostly seeds and different types of flour. Moreover, in sustainability research it is essential to estimate the impacts of meat alternatives to give consumers a complete perspective in sustainable diets, and these are -for now- only limited available. With a growing variety in meat alternatives, it is suggested that in future studies the environmental impacts of these foods should be estimated. Excluding such foods would lead to underestimating the environmental impacts of these diets.

> *Box 1: Attributional LCA*
>
> *Attributional LCA gives an estimate of how much of the environmental impact belongs to a product, considering all stages of the product's life, from primary production to the consumer phase (Ekvall 2019). Moreover, it also considers the origin of foods as available on the Dutch market (van de Kamp et al. 2018b).*

The definition of a sustainable diet is very broad as it includes the environmental impact of diets, cultural acceptability, healthiness, and affordability (FAO 2010). In this thesis, we mainly focused on the environmental impact and healthiness of current existing eating patterns (**chapter 2** and **chapter 3**). These eating patterns are assumed to be culturally acceptable and affordable, however, in order to shift towards healthier and more sustainable diets, aspects such as acceptability and affordability should be guaranteed. Previously, cultural acceptability (i.e. respect for current dietary habits), animal welfare (e.g., animal life years suffered), cost of diets (e.g., food expenditures, cost of meals), and environmental costs (e.g., costs of environmental impact of diet) have been used as socio-cultural indicators to describe the sustainability of diets (Harrison et al. 2022), however, data on these indicators were not available in studying education differences (**chapter 2**) or the taste profiles of sustainable diets (**chapter 3**). In contrast, we focused on all sustainability aspects in studying consumer perceptions (**chapter 4** and **chapter 5**). Therefore, differences between diet-related sustainability and consumer perceptions were expected. Nevertheless, the aim in **chapter 4** was to provide an overview of all consumer perceptions of food-related sustainability, and that is why we included all sustainability aspects in **chapter 4** and **chapter 5**.

In this thesis, two different approaches were used to analyse consumer's perceptions of food-related sustainability. The systematic literature review used Grounded Theory and Cultural Domain Analysis to analyse both quantitative and qualitative results (**chapter 4**). Several food characteristics, such as local and organic foods were studied most extensively, and therefore, these characteristics could be overrepresented. This is the reason why we decided to ask Dutch consumers to formulate their related to food-related sustainability (N=988) (**chapter 5**). These perceptions were analysed using an inductive approach, creating categories from the data. The perceptions of Dutch consumers had similar trend as the systematic review regarding the food characteristics. Hence, there is no reason to believe that local and organic foods were overrepresented in the systematic literature review.

The question is, however, whether these consumer perceptions, like the notion that local and organic foods are sustainable, correspond to the scientific facts. Consumers mentioned that local foods are more sustainable because foods travel short distances, and consequently have lower environmental impacts (**chapter 4**). At face value it seems to be true, but the environmental impact of foods is determined by many other factors as well (Stein and Santini 2022) and only 6% of food-related GHGEs originate from transport (Ritchie 2020). For example, in the Netherlands, about 90% of the blueberries are imported from Peru, Chile, and South-Africa, and only 10% are produced in our country during the summer (GroentenFruit Huis 2022). Thus, eating locally produced foods is better for the environment because of fewer food miles, however, it matters more what type of food the consumer eats (i.e. plant-based foods vs. animal-sourced foods). In addition, consumers perceive organic foods as more sustainable, as they are produced without synthetic fertilizers, pesticides, or GMO (**chapter 4**), which is true according the organic production guidelines (European Commission n.d.). Indeed, organic foods requires less energy use, but no differences can be found in food-related GHGEs from organic or conventional food systems (Clark and Tilman 2017). Still, organic food production requires more land due to a mismatch in nutrient availability and demands in the soil, and as a consequence, the food production is less efficient (Clark and Tilman 2017). So, the question remains whether the extra land use outweighs the energy usage in organic food production, and therefore, it is, for now, impossible to conclude whether organic foods are more sustainable than conventional foods.

Conclusion

The consumer's perceptions of food-related sustainability and the used diet-related environmental sustainability indicators overlap to some degree. For instance, both biophysical indicators and consumer perceptions covered the whole supply chain, including food production, transportation, the consumer phase, and waste. However, there are clear differences between the consumer perceptions and the biophysical indicators used. Consumers have a very wide range of perceptions of food-related sustainability, which also include aspects of social and economic sustainability, such as fair working conditions and fair prices. These are not included in the biophysical indicators. Moreover, consumers perceive socio-cultural aspects (i.e., affordability and palatability), healthiness, and quality as important sustainable food attributes, which are also not covered in the environmental sustainability indicators. Last, organic and local foods are perceived as important food characteristics when describing sustainable foods, although organic and local foods might not necessarily be part of a sustainable diet.

To conclude, the biophysical indicators do not fully match consumers' perceptions, especially the person-related determinants are not included. In short, there is a gap between consumers' beliefs and the environmental sustainability indicators for estimating the sustainability of eating patterns. Clear indicators are needed to assess socio-cultural aspects and food characteristics could be useful for policymakers to help guide consumers toward more sustainable food choices.

Taste properties and taste preferences

Main results

In this section, we discuss the second and third research questions "What are the taste properties of healthy and sustainable diets?" and "What are the consumers' taste preferences for sustainable foods?". Regarding taste properties, more environmentally sustainable and healthier diets include more neutral tasting foods (45 en%) and less foods with umami/salt/fat tastes (17 en%) and bitter tastes (3 en%), compared to less environmentally sustainable and unhealthier diets (**chapter 3**). For the taste preferences, sustainable aspects of foods are more strongly associated with being palatable than with being unpalatable, and in line with this finding unsustainable aspects of foods were more strongly associated with being unpalatable, both on a conscious and subconscious level (**chapter 6**). Moreover, we showed that consumers believed that sustainable foods, in general, are palatable. The more positive the beliefs, the more positive were the attitudes towards perceived food sustainability.

Methodological and conceptual considerations

To assess the taste properties of sustainable and less sustainable diets in **chapter 3**, we calculated the average taste profile of individual foods consumed during the day. For this, we combined the taste values of foods from a taste database with food intake data from the NQ-plus study. The taste database includes the taste intensities of 469 foods, including the most consumed foods in the Netherlands (van Langeveld 2018). Even though a dietary taste pattern gives an average and reproducible taste profile, foods are often consumed in combination with other foods. For example, most traditional dinners in the Netherlands include neutral tasting foods (potato/vegetables) and umami/salt/ fat tasting foods (meat) (van Langeveld 2018, Heerschop et al. 2022). In addition, herbs and spices can be used to enhance the tastes of meals, and these are not included in the dietary taste profiles. Unfortunately, meat alternatives were not included in the taste database as they were reported not frequently enough (<60 times) in the Dutch food consumption survey of 2007-2010 to be included in the sensory tests (van Rossum et al. 2011, van Langeveld et al. 2018). The taste profiles of these foods were therefore missing, and it was not possible to categorize meat alternatives into the taste clusters. On the other hand, in our data they only represented 1 en% of intake. However, with a growing supply of meat alternatives, we foresee that these will be essential in assessing the taste profile of eating patterns in the future. Hence, data on meat alternatives should be added to the taste database to get a better idea of the dietary taste profile of sustainable diets.

Not only is the source of the taste values important, but also the dietary assessment method should be taken into account when interpreting the taste patterns of dietary patterns. We used two 24-hour recalls (24hRs) per participant to describe the amount of energy consumed from the different taste clusters. In general, 24hRs measure entire daily intakes, including foods that are not frequently eaten, but have large within-person variabilities, such as nuts, legumes, and fish (Brouwer-Brolsma et al. 2020). In contrast, another dietary assessment method, the Food Frequency Questionnaire (FFQ), measures long-term food intake in order to obtain data on usual intake with only one questionnaire, often with a reference period of one month. In an additional analysis, based on a FFQ in the same study population (NQ-plus study), it was found that a healthy and environmentally sustainable diet was mostly comprised of neutral tasting foods (43 en%), followed by foods from salt/umami/fat cluster (17 en%), sweet/sour cluster (14 en%), sweet/fat cluster (10 en%), fat cluster (10 en%) and bitter cluster (5 en%) (Ouwehand 2018). Hence, only small differences exist between the dietary taste profiles assessed via 24hRs and the FFQ, and therefore both 24hRs and the FFQ can be used to describe the taste profiles of diets high and low on environmental sustainability and health.

For the taste preferences, it is inherently difficult to conclude whether environmentally sustainable diets are palatable. Food palatability may be defined as "the hedonic evaluation of sensory factors, such as taste and smell of a food" (Yeomans 1998). A hedonic preference is person-specific and can also change over time. In **chapter 5** and **chapter 6**, we found that sustainable foods are perceived to be more associated with being palatable than with being unpalatable (**chapter 5 and chapter 6**), however, this finding may depend highly on the type of food a person has in mind when filling out our questionnaire. However, while questionnaires often ask for specific foods, an environmentally sustainable diet does not consist of single foods. Some people dislike the tastes of some sustainable foods, while other sustainable foods might be liked. It is therefore difficult to conclude, based on our data, whether diets that score high on environmental sustainability can also be palatable or equally liked as diets scoring lower on environmental sustainability.

Previously, unhealthy foods have been associated with being palatable, both on a conscious and subconscious level (Raghunathan et al. 2006). In **chapter 4**, more sustainable foods were also perceived as being more healthy. Following this reasoning, it would be logical that unsustainable foods would be perceived as palatable. However, unsustainable foods are more strongly associated with being unpalatable than with being palatable (**chapter 6**). This paradox might be explained by differences in level of comparison of taste between healthy foods and sustainable foods. Healthy foods (e.g., fruits and vegetables, lean meat) are compared with unhealthy foods (e.g., high energy-dense foods such as fried fries, hamburger, pizza), while sustainable foods (e.g., organic apples) are compared with the same foods without sustainability characteristics (e.g., non-organic apples). Besides the difference in level of comparisons, consumers also have different perceptions (**chapter 4**) and certain expectations of sustainable foods (e.g., natural, ethically produced) (Sidali et al. 2016). This might result in general positive associations with food sustainability (i.e. doing something good for the planet). Hence, to stimulate sustainable food choices, marketeers could use these positive aspects to promote healthy and sustainable food choices.

Conclusion

To conclude, we showed that a more healthy and environmentally sustainable diet includes more neutral and less umami/salt/fat and bitter tasting foods (**chapter 3**). Data on plant-based alternatives should be added to the taste database to get a better dietary taste profile for sustainable diets. In addition, sustainable foods are, both consciously and subconsciously, perceived to be more strongly associated with being palatable than with being unpalatable (**chapter 5** and **chapter 6**). However, this does not mean that all sustainable foods are perceived to be tasty, or that this translates into palatable diets.

Person-related determinants of food choice

Main results

In this section, we discuss the fourth research question "Which person-related determinants are the potential facilitators or barriers to sustainable food consumption?". For this question, we compare results from **chapter 2, chapter 4**, **chapter 5**, and **chapter 6**. The attitudes toward food sustainability were overall positive, and these attitudes were positively associated with beliefs about perceived healthiness, perceived palatability, food sustainability knowledge, and perceived environmental responsibility (**chapter 5**).

Moreover, sustainable foods were perceived to be healthy and palatable, but expensive (**chapter 4 and chapter 5**). In addition, food sustainability knowledge levels could be considered as "moderate" in our sample (average of 9/16 correct questions), with consumers that were highly educated being more knowledgeable (**chapter 5**). However, most consumers lack key knowledge on the actual impact of food consumption on planetary health (**chapter 4**). Furthermore, consumers with a higher education level identified themselves more frequently as following a flexitarian, vegetarian, or vegan diet (**chapter 5**). However, it appeared that consumers with a higher education level have on average a healthier eating pattern, but they not necessarily have a more sustainable diet than consumers with a lower education level (**chapter 2**).

Methodological and conceptual considerations

In this thesis, we measured only behavioural intention to consume sustainable foods but we did not measure actual behaviour. Upon starting the consumer study of **chapter 5** and **chapter 6**, it was still unclear how Dutch consumers would perceive sustainable foods, and therefore it was difficult to select survey items on sustainable food behaviour. It is critical to include the perceptions of the consumers to obtain intention-behaviour correspondence, instead of the researcher's perceptions on food sustainability. Therefore, we surveyed the consumer perceptions on food sustainability. In addition, in the end, the actual consumption of sustainable foods is the actual behaviour of interest. This can be measured food consumption surveys, although consumers consider more aspects of food sustainability to be important in sustainable foods than food groups alone, such as ethical production, local, organic, and seasonal foods (**chapter 4**). These product characteristics are not yet considered in measuring food consumption, and consequently, important aspects of social and economic sustainability are being missed.

Saying and doing are two different things. People may say that they intend to consume sustainable foods, but that does not mean that they are doing it. So therefore, a high score on the intention to perform a certain behaviour does not necessarily mean that one is performing the behaviour. In fact, in the food context, it is known that these two measures are only to a certain extent correlated, see for example a meta-analysis of McEachan et al. (2011) (r=0.44, CI=0.38-0.50). Although much research has been done to study the gaps between behavioural intention and actual behaviour (ElHaffar et al. 2020), it is still unknown how to bridge this gap between intention and behaviour. One example that could be of critical importance to close the gap is the physical environment, which may enable consumers to choose foods they prefer based on their availability and accessibility (e.g., the supermarket) (Pitt et al. 2017). To obtain correspondence between intended behaviour and actual behaviour, the intention should be activated in the physical environment in which the behaviour should take place (Fischer 2017). Consequently, it would have been better to collect data in the physical environment setting.

In addition, in **chapter 5**, we showed that perceived palatability, healthiness, inconvenience and price of sustainable foods play a key role in attitudes and perceived behavioural control. These, in turn, have positive associations with behavioural intention. Nevertheless, it is uncertain whether these factors influence actual sustainable behaviour. Furthermore, in **chapter 6**, sustainability aspects of foods were more strongly associated with "palatable" than with "unpalatable". However, these associations were not related to behavioural intention. The positive associations that consumers have with the palatability of sustainable foods are a good starting point for promoting sustainable foods, however our current survey also highlights the need to focus more on explicit food attributes as potential facilitators, such as beliefs about perceived health and palatability of sustainable foods. In contrast, beliefs about inconvenience and high prices should be addressed as barriers to consuming sustainable foods.

Higher educated consumers had more knowledge on food sustainability (**chapter 5**). Food sustainability knowledge is the first step in awareness to behave sustainably by influencing beliefs and attitudes, however, too much conflicting information can have adverse counter-effects (Longo et al. 2019). In this thesis, we assumed that higher-educated consumers have higher income levels, which increases the position that one occupies in society (Galobardes et al. 2006). However, compared to education level, other social determinants, such as income level or occupation status, may explain different aspects of the social-economic position. For instance, lower income levels are found to be related to poorer health status, mainly due to a decreased access to health care (Moore et al. 1992). Nonetheless, in general respondents are often reluctant to share information about the money earned or are not aware of their current income level (Moore and Welniak 2000, Davern et al. 2005). Likewise, occupational status, or prestige, determines income (MacDonald et al. 2009) and is associated with lower odds of having poor (self-reported) health (Fujishiro et al. 2010). Yet, indicators of occupation status are diverse, including for instance occupational complexity (Darin-Mattsson et al. 2017), current work, or workplace hazards (MacDonald et al. 2009). In this thesis, we did not consider income level or occupation status as an indicator of socio-economic position as these indicators are difficult to collect or to operationalize. Furthermore, consumers with lower socio-economic position, compared to higher socio-economic position, are less willing to act upon environmental behaviours due to costs. We know that price is an important factor in food choice (Steenhuis et al. 2011, Konttinen et al. 2021). Moreover, individual time preferences are probably more oriented to the present in consumers with lower socio-economic position, but sustainable behaviour has an impact on the long-term (Grandin et al. 2021). Therefore, education level is may be a stronger predictor of sustainable food behaviours than income levels (Grandin et al. 2021).

Conclusion

Overall, we can conclude that the most promising facilitators of sustainable food consumption are the beliefs about the healthiness and palatability. Moreover, high education level, via food sustainability knowledge, has the potential to facilitate sustainable food behaviour. However, thus far, on average, high educated consumers do not act accordingly. The potential barriers to consume sustainable foods included beliefs about inconvenience and high price of sustainable foods.

Methodological considerations

In this thesis, we examined the biologically determined predispositions and person-related determinants of behaviour within the Food Choice and Dietary Change Framework of Contento (2010). In order to fully understand the mechanisms behind sustainable food choices, other elements within this framework such as the social context, environmental determinants, and previous experiences should be taken into consideration as well. For example, the perceived availability of sustainable foods in the supermarket, influence of family networks or group identity, behaviour in the supermarket and in-home setting, and previous experiences with purchasing, cooking, and consuming of sustainable foods might further increase the understanding of underlying motives and barriers to sustainable food consumption.

A limitation of the framework of Contento (2010) is that it primarily considers the consumer choice perspective. In a food system perspective, however, other relevant aspects are societal environments, such as organizations, policies, infrastructure, and socio-cultural norms, and natural environments (FAO 2014). Even if consumers would like to change to healthier and sustainable diets, other actors, such as governments and policy makers must also play an enabling role. Consumers will not achieve major changes in the food system on their own.

We used a range of data and methodologies to answer our research questions from different perspectives. In the first part of this thesis, this included existing food consumption data (NQ-plus study and Dutch National Food Consumption Survey), environmental sustainability data (Blonk database), and the taste database (Mars et al. 2020). These databases were all merged on food level. In the second part of this thesis, we systematically reviewed the literature on perceptions of food-related sustainability and collected both quantitative and qualitative data. These data were summarized using both Grounded Theory and Cultural Domain Analysis. Grounded theory aims to develop and explain a phenomenon by identifying the key elements and explaining the relations of these elements to the context (Corbin and Strauss 1990), whereas Cultural Domain Analysis aims to understand how communities structure their world by searching for larger units of cultural knowledge, which are called domains (Borgatti 1994). Both approaches can deal with quantitative and qualitative data and both were needed to categorize consumer's perceptions into domains, using an iterative process. Additionally, we were interested in the subconscious associations between sustainability aspects of foods and palatability, and for this purpose, we used an implicit association test (IAT) paradigm. The IAT has been developed to measure subconscious associations without relying on explicit questions (Karpinski and Hilton 2001). Other implicit measures, such as the Single Target-IAT (ST-IAT) only considers one target stimulus, instead of two in the IAT (sustainable and unsustainable) (Karpinski and Steinman 2006). A newly developed tool to measure automatic responses to multiple attributes at the same time (IMPACT) might further explain the similarities and differences between explicit self-reported attitudes and subconscious responses (Altenburg and Spruyt 2022). In addition to the IAT, in the consumer survey, data were collected in a representative sample of the Dutch population to study the potential facilitators and barriers to sustainable food consumption. We chose the Theory of Planned Behaviour as a theoretical framework, as it has been used successfully to understand health-related behaviours (McEachan et al. 2011), and has been validated in pro-environmental behaviours (Arvola et al. 2008). The questionnaire in our research was designed to assess beliefs about food attributes, attitudes, subjective norms, and perceived behavioural control. Although these methodologies and theories helped to answer our research questions, integration of other relevant theories, such as the Norm Activation Model (Schwartz 1977), was not possible. The latter theory included ascribed responsibility and personal norms to explain behaviour, which was outside of the scope of our research.

In **chapter 5**, we chose to include environmental responsibility as a potential facilitator of sustainable food consumption. Although this term is not precisely defined, it is an important factor for people to turn thoughts into actions. Examining to which extent people feel responsible for the planet is therefore potentially an important factor to examine for understanding sustainable behaviour. Given the associations observed, it is of potential interest to refine the environmental responsibility scale by including other aspects of environmental responsibility, e.g. altruistic values, behaviour, and emotions. Such a new scale should be validated before largescale implementation.

And finally, many methods are based on product level, however, individuals do not eat single foods; they have an eating pattern. Consumers often choose foods based on habitual consumption practices. For example, in the NQ-plus study, about 43-58 unique foods (based on food codes) are consumed per person in three 24h Recalls. All foods together make up a consumer's diet. Just changing a few foods can make a big difference in the health and sustainability of diets. We make food choices several times a day: what to eat, when, how, how much and with whom? A switch from one serving of beef to another plant-based alternative or from a sugar-sweetened beverage to (tap) water could improve the healthiness and the environmental sustainability of the diet. Between individuals there are differences in food preferences, but in any diet, there will be foods that are both perceived as tasty and sustainable. This provides an opportunity to change toward healthy and sustainable diets in small steps.

Research implications and further research

In this thesis we illustrate that consumer research is essential to understand the determinants of healthy and environmentally sustainable diets. Food-based dietary guidelines should help consumers to make healthy and sustainable food choices. So far, the adherence to these guidelines is rather low, compared to current intakes of for instance fruits and vegetables, legumes, or meat in the Netherlands. This might be partly due to consumers' lack of understanding of what sustainability means. Following the food-based dietary guidelines would be relevant for consumers to reduce environmental impacts by increased consumption of plant-based foods, such as fruits and vegetables. Moreover, the current consumption of animal-based foods should be limited in line with the food-based dietary guidelines (Kromhout et al. 2016). Additionally, to gain better insight into the environmental impact of dietary patterns, sustainability characteristics such as organic farming and locality could provide relevant insights when monitoring food consumption data.

We also found that food sustainability is sometimes viewed with suspicion by consumers. For instance, some consumers believe there is no connection between food and the planet, perceive it as a hype or as greenwashing. This might be due to unfamiliarity with food sustainability (e.g., lack of knowledge) or the ambiguous meaning of the sustainability concept (e.g., efficient versus organic food production). To address consumer concerns, messages related to sustainability should be transparent, factual, and clearly communicated by governmental organizations and educational institutions as a starting point.

The higher educated, compared to the lower educated, have a better perceived health and higher life expectancy (Statistics Netherlands 2021, 2022). Our results align with this finding that higher educated consumers had healthier diets and more positive attitudes towards food sustainability and intentions to consume sustainable foods, than lower educated consumers. However, we found no difference in the overall environmental sustainability of diets of higher educated consumers compared to lower educated consumers (**chapter 2**), although differences exist in their consumption patterns. The intake of food in various food groups differed between education groups. Consumption of fruits, vegetables and fish was higher in higher-educated group, while the consumption of meat was higher in the lower-educated group. In addition, higher educated consumers had a better knowledge on sustainability of food products and were more likely to be flexitarian, vegetarian, or vegan.

This suggests that higher educated are more likely to have an increased health and environmental consciousness. Raising awareness is the first step to change food consumption behaviour. Hence, to diminish the effect of knowledge differences between education groups, health and sustainability campaigns should be focused on lower educated consumers.

So far, a positive attitude and enhanced knowledge on food sustainability are not sufficient to motivate consumers to eat more sustainably sourced foods. At the current moment sustainability is not considered to be very important food choice motive by many consumers. Given the findings on determinants and attitudes with regards to sustainable food choices, this poses the question what other barriers, besides high prices and inconvenience, play a role. Ideally, consumers should be stimulated to easily choose healthy and sustainable foods in the physical and food environment (e.g., supermarkets, in the home environment). Policymakers should encourage food producers and supermarkets to make healthy and sustainable foods available and accessible to consumers. Legislation is needed to provide financial incentives like taxes and subsidies that could be used to promote the consumption of sustainable foods at the expense of unsustainable foods (Broeks et al. 2020).

Another barrier to sustainable food consumption might be related to the decision-making process, in which there is a difference between short-term individual needs versus the long-term effects of our food consumption. As shown before, the immediate rewards of food choice, such as palatability, price, and convenience are often chosen instead of the benefits of health (Plazola and Castillo 2017). Adverse effects of unhealthy diets are one of the leading causes of death. However, the adverse effects of our food consumption patterns on the planet are often not apparent in a person's lifetime. Therefore, it could be important to align the self-interests and personal gains of environmentally friendly behaviour with the (shared) benefits of sustainable diets (e.g., environmentally responsible behaviour). Hence, in line with our findings on environmental responsibility, research into the overlap between the self-interests of individuals and altruistic values of environmentally responsible behaviour is needed.

Last, this thesis focused mainly on the adult population. It is vital to include the perceptions of younger-aged as these have the largest potential to be influenced, shaped, and steered towards healthy and sustainable food consumption. Nutrition, food, and environmental literacy should be included in the school programs, including primary and secondary education, for them to become more aware of the effects of global unhealthy and unsustainable eating practices. As far as we know, it is unknown how younger generations value and perceive food sustainability. To match current knowledge of children and adolescents with school programs, research needs to focus on (families with) these target groups.

Conclusion

This thesis provided insights into the overlap and differences between diet-related sustainability as measured by environmental sustainability indicators and consumer's perceptions of food-related sustainability. Both these concepts cover the whole supply chain, from food production to waste management. Most consumers are aware of the adverse effects of food production on the planet; however, they lack knowledge on the magnitude of these impacts, and the various aspects throughout the life cycle of a product. In addition, the consumer perceptions are broader than the environmental sustainability indicators, and therefore, ethically, organic, and locally produced food characteristics might be used as additional indicators when monitoring food consumption data.

There is an urgency to lessen the burden of our food production and consumption on the environment. This thesis shows that education level, but also the beliefs about palatability, perceived healthiness, perceived inconvenience and a high price of sustainable foods are important in sustainable food choices. Our habitual food choices could play an important role in reducing the burden on the environment. However, consumers choices themselves do not suffice to keep environmental footprints within planetary boundaries, and there are many more accountable actors in the food system (Biesbroek et al. 2023). A healthy and sustainable choice should be the tastiest and easiest, and for that, the government's first responsibility is to create policies to stimulate healthy and sustainable food production and food choices. Further consumer research is essential to uncover the facilitators and barriers to sustainable food choices.

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Summary

Current food systems are contributing to climate change, biodiversity loss, and deforestation. In order to protect the planet and to achieve food security for present and future generations, it is crucial to shift towards more sustainable eating patterns. Therefore, it is essential to understand what consumer perceptions are associated to this diet shift.

The overall aim of this thesis is to determine the overlap and differences between diet-related sustainability indicators and consumer's perceptions of food-related sustainability. Diet-related sustainability indicators are used to measure the environmental sustainability of diets, such as greenhouse gas emissions or land use, whereas consumer perceptions consist of views and beliefs about food sustainability. To this aim, we integrate multiple aspects of sustainable foods, with a focus on taste properties and socio-demographic characteristics. In the first part of this thesis, we focused on diet-related sustainability (chapter 2-3) and in the second part we focused on consumer's perceptions of food-related sustainability (chapter 4-6).

In **chapter 2**, it was investigated whether education differences exist in healthy and environmentally sustainable food consumption. The adherence to the Dutch dietary guidelines was used as a measure of diet quality (health), and greenhouse gas emissions was used as an environmentally sustainability indicator. We found that higher educated had healthier diets than lower educated, however, no differences in the environmental sustainability of the eating patterns could be identified.

In **chapter 3**, we studied the dietary taste patterns of healthy and environmentally sustainable diets and of less healthy and less environmentally sustainable diets. For this, we combined a taste database with food intake and sustainability data to study differences in the overall taste patterns of the diets. We found that healthier and more sustainable eating patterns included more neutral tastes, and less bitter and umami/salt/fat tastes compared to more unhealthy and less environmentally sustainable eating patterns. This suggests that taste profiles should be considered when proposing healthier and more environmentally sustainable menus and meals.

In **chapter 4**, we provided a systematic literature review of consumer perceptions. The consumer perceptions cover a very wide range, that includes most aspects of the food supply chain, e.g., food production, transportation, processing, the consumer beliefs, and waste. The environmental impact, (locally and organic) food choices and ethical food production are most frequently mentioned. Moreover, sustainable foods were perceived as healthy, natural, but expensive. In addition, we showed that consumers have difficulty to understand the concept of sustainability and lack knowledge on food-related sustainability topics, such as the environmental impact of their food choices. When making food choices, consumers consider price, taste and individual health more important than sustainability. It

would be useful for policymakers to communicate sustainability knowledge on environmental impacts in a transparent, evidence-based way to consumers.

In **chapter 5**, we investigated the potential facilitators and barriers to sustainable food consumption. We used the Theory of Planned Behaviour as a framework to examine whether attitudes, subjective norms, perceived behavioural control, and feeling responsible for the environmental had an effect on the intention to consume sustainable foods, which all did. We found that potential facilitators of sustainable food consumption included perceived healthiness and palatability, high education level, food sustainability knowledge, and environmental responsibility. These factors could be used to guide consumers towards more sustainable food choices. In addition, barriers to sustainable food consumption were perceived inconvenience and the price of sustainable foods. These aspects should be addressed by key stakeholders to facilitate sustainable food consumption.

Consumers do not entirely weigh all food choice motives when they purchase foods, but mainly rely on heuristics. Combining implicit and explicit measures could shed a light on the similarities and discrepancies. Therefore, in our last study, we assessed the implicit and explicit associations between sustainability aspects of foods and palatability (**chapter 6**). Sustainable aspects included nature preservation, apples from the region, recycling, local, seasonal product, animal welfare and unpacked. We showed that sustainable foods are more strongly associated with being palatable than with being unpalatable, both on a conscious and subconscious level. However, these associations did not strongly predict the intention to consume sustainable foods. Perceived health and price were the strongest predictors of behavioural intention to consume sustainable foods. In conclusion, perceived healthiness of sustainable foods could be used to guide consumers toward sustainable food choices.

This thesis provided insights into the overlap and differences between diet-related sustainability as measured by environmental sustainability indicators and consumer's perceptions of food-related sustainability. Both these concepts cover the whole supply chain, from food production to waste management. Most consumers are aware of the adverse effects of food production on the planet; however, they lack knowledge on the magnitude of these impacts, and the various aspects throughout the life cycle of a product. In addition, the consumer perceptions are broader than the environmental sustainability indicators, and therefore, ethically, organic, and locally produced food characteristics might be used as additional indicators when monitoring food consumption data.

There is an urgency to lessen the burden of our food production and consumption on the environment. This thesis shows that education level, but also the beliefs about palatability, perceived healthiness, perceived inconvenience and a high price of sustainable foods are important in sustainable food choices. Our habitual food choices could play an important role in reducing the burden on the environment. However, consumers choices themselves do not suffice to keep environmental footprints within planetary boundaries, and there are many more accountable actors in the food system. A healthy and sustainable choice should be the tastiest and easiest, and for that, the government's first responsibility is to create policies to stimulate healthy and sustainable food production and food choices.

Nederlandse Samenvatting

Ons huidige voedselsysteem draagt bij aan klimaatverandering, verlies aan biodiversiteit en ontbossing. Om onze wereld te beschermen, en om voedselzekerheid te garanderen voor huidige en toekomstige generaties, is het cruciaal om duurzamer te eten. Hiervoor is het belangrijk om te weten waar consumenten aan denken als het gaat over een duurzaam eetpatroon.

Het doel van dit proefschrift is om te bepalen wat de overeenkomsten en verschillen zijn tussen twee verschillende perspectieven van duurzaamheid: de duurzaamheid van eetpatronen en de percepties van consumenten. De duurzaamheid van eetpatronen wordt bepaald aan de hand van duurzaamheidsindicatoren, zoals broeikasgassen en landgebruik. De percepties van de consument bestaan uit de opvattingen en overtuigingen over duurzaamheid. Om de overeenkomsten en verschillen tussen deze twee perspectieven te bepalen, zijn verschillende aspecten van duurzame voeding meegenomen. Er is vooral gekeken naar smaakkenmerken en sociaal-demografische karakteristieken. In het eerste deel van dit proefschrift ligt de focus op de duurzaamheid van een eetpatroon (hoofdstuk 2-3) en in het tweede deel ligt de focus op de percepties van consumenten (hoofdstuk 4-6).

In **hoofdstuk 2** hebben we onderzocht of mensen met een hoger opleidingsniveau een gezonder of duurzamer eetpatroon hebben dan mensen met een lager opleidingsniveau. Hiervoor hebben we gekeken in hoeverre mensen eten volgens de richtlijnen voor goede voeding als een indicator voor gezonde voeding. De uitstoot van broeikasgassen - ontstaan bij de productie en consumptie van ons voedsel - hebben we gebruikt als een indicator voor duurzame voeding. We vinden dat mensen met een hoger opleidingsniveau een gezonder eetpatroon hebben vergeleken met mensen met een lager opleidingsniveau, maar dat er geen verschillen zijn in de duurzaamheid van deze eetpatronen.

In **hoofdstuk 3** hebben we gekeken of de smaken van een gezond en duurzaam eetpatroon verschillen van een minder gezond en minder duurzaam eetpatroon. Hiervoor hebben we de smaakintensiteit (hoe zoet, zuur, zout, bitter, umami of vettig een product is) van 469 voedingsmiddelen gebruikt. Producten die vergelijkbaar zijn qua smaakintensiteit zijn samengenomen, en daardoor zijn zes groepen ontstaan, namelijk 1) neutraal, 2) zoet/zuur, 3) zoet/vet, 4) umami/zout/vet, 5) bitter en 6) vet. Deze data hebben we gecombineerd met data over voedselinname. Zo kunnen we berekenen hoeveel (gram) en welk energiepercentage van de voedselinname afkomstig is uit de zes groepen. Voor het meten van de gezondheid van een eetpatroon hebben we dezelfde indicator gebruikt als hoofdstuk 2. Voor duurzaamheid is data over broeikasgassen, landgebruik en het gebruik van fossiele brandstof gecombineerd. We vinden dat gezondere en duurzame eetpatronen meer voedingsmiddelen met een neutrale smaakintensiteit bevatten, en minder voedingsmiddelen met bittere, en umami/zout/vet smaken dan een minder gezond en minder duurzaam eetpatroon. Dit duidt erop dat smaak mee moet worden genomen bij samenstellen van gezondere en duurzamere menu's en maaltijden.

In het tweede gedeelte van deze thesis hebben we ons gericht op de percepties die consumenten hebben ten opzichte van duurzame voeding. In **hoofdstuk 4** hebben we een overzicht gemaakt van deze percepties. De percepties van de consument zijn breed, en omvatten alle aspecten van de voedselketen, bijvoorbeeld productie, transport, bewerking, de voedselkeuzes van de consument en afval. De impact op ons milieu, (lokale en biologische) voedselkeuzes en eerlijke productie worden het vaakst genoemd. Daarbij wordt duurzame voeding gezien als gezond, natuurlijk, en duur. Helaas zien we ook dat consumenten belangrijke kennis missen op het gebied van duurzame voeding. Consumenten hebben moeite om het concept "duurzaamheid" te definiëren en om de impact op het milieu te schatten. Daardoor vinden consumenten op dit moment prijs, smaak en persoonlijke gezondheid belangrijker dan duurzaamheid bij voedselkeuzes. Het zou voor beleidsmakers nuttig zijn om kennis over duurzaamheid transparant en gebaseerd op wetenschappelijk bewijs te communiceren.

In **hoofdstuk 5** hebben we bestudeerd welke factoren een positieve of negatieve rol kunnen spelen bij duurzame consumptie. In het bijzonder gebruikten we de Theorie van Gepland Gedrag als theoretisch model om te bekijken of houdingen ten opzichte van duurzame voeding, subjectieve normen, waargenomen beheersing van gedrag of verantwoordelijkheid voor het milieu geassocieerd waren met de intentie om duurzame voeding te eten. Al deze factoren hebben een positief resultaat. Daarnaast vinden we dat ervaren gezondheid en smakelijkheid, een hoger opleidingsniveau, kennis over duurzame voeding en verantwoordelijkheid voor het milieu positief geassocieerd zijn met de houdingen ten opzichte van duurzame voeding. Deze factoren kunnen dan ook gebruikt worden om consumenten richting duurzamere voedselkeuzes te sturen. Aan de andere kant zijn ervaren ongemak en de prijs van duurzame voeding belemmeringen. Met deze aspecten moeten belanghebbenden rekening houden.

Consumenten maken niet geheel rationale keuzes als ze voedsel kopen, maar vertrouwen vooral op heuristieken of gewoontes. Het combineren van zowel onbewuste als bewuste metingen zou een licht kunnen werpen op de overeenkomsten en verschillen. In onze laatste studie zijn we daarom nagegaan wat de onbewuste en bewuste associaties zijn tussen aspecten van duurzaamheid en smakelijkheid (**hoofdstuk 6**). Aspecten van duurzaamheid zijn natuurbehoud, appels uit de regio, recyclen, lokaal, seizoensproduct, dierenwelzijn en onverpakt. We laten zien dat duurzame aspecten van voeding meer gerelateerd zijn aan smakelijk dan onsmakelijk, zowel op een bewust als onbewust niveau. Helaas verklaren deze associaties nauwelijks de intentie om duurzaam te eten. Ervaren gezondheid en prijs zijn de belangrijkste factoren voor de intentie om duurzaam te eten.

Kortom, ervaren gezondheid kan gebruikt worden om consumenten te helpen om duurzame keuzes te maken.

Het doel van deze thesis was te bepalen wat de overeenkomsten en verschillen zijn tussen twee perspectieven van duurzaamheid: de duurzaamheid van eetpatronen en de percepties van de consument. De overeenkomst is dat beide perspectieven de gehele voedselketen omvatten, van voedselproductie tot aan afvalverwerking. Wat betreft de percepties van de consument, zijn de meeste consumenten zich ervan bewust dat de productie van voedsel een negatief effect heeft op onze aard. Helaas missen consumenten kennis over de grootte van deze effecten binnen de voedselketen. De percepties van consumenten zijn breder dan de huidige duurzaamheidsindicatoren. Ethisch verantwoord, biologisch en lokaal geproduceerde voeding kunnen als aanvullende indicatoren worden gebruikt bij het monitoren van voedselconsumptiegegevens.

We begonnen deze thesis vanuit de wetenschap dat ons huidige voedselsysteem bijdraagt aan klimaatverandering, verlies aan biodiversiteit en ontbossing. Om onze wereld te beschermen, en om voedselzekerheid te garanderen voor huidige en toekomstige generaties, is het cruciaal om duurzamer te eten. De druk van onze voedselproductie en consumptie op het milieu moet daardoor dringend worden verminderd.

Deze thesis toont aan dat, naast de bredere consumentenpercepties, onderwijsniveau en de opvattingen over ervaren gezondheid, smakelijkheid, ongemak en prijs belangrijk zijn bij duurzame voedselkeuzes. Onze voedselkeuzes spelen een essentiële rol bij het verminderen van de druk op het milieu. Maar het alleen aan de keuze van de consument overlaten is echter niet voldoende om de ecologische voetafdruk binnen de duurzame grenzen te houden. Er zijn namelijk meer partijen die een rol spelen in het voedselsysteem. Een gezonde en duurzame keuze zou de lekkerste en makkelijkste moeten zijn. Het is de eerste verantwoordelijkheid van de overheid om beleid te maken, opdat gezonde en duurzame voedselproductie en -keuzes gestimuleerd kunnen worden.

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performed a meta-analysis of the socio-economic determinants of meat and pulses consumption in European countries. It was definitely challenging! Vera, je hebt de onmogelijke opdracht gekregen om alle percepties van >1000 consumenten te analyseren, met daarnaast een eigen onderzoek uit te voeren onder middelbare scholieren. Grote waardering dat dit is gelukt!
Zonder respondenten is het onmogelijk om consumentenonderzoek te doen. Ik bedank alle deelnemers van het onderzoek en de pilotstudie. Waar een Dries-weekend wel niet goed voor is!

Lieve roomies van 1044 (Moniek, Janet, Anne, Korrie, Charlotte, Annick, Fenna, Iris & Esther), het was fijn om een gezellige en veilige werkplek te hebben. De chit-chatjes, de lunchwandelingen, en natuurlijk pottenbakken, midgetgolven, potluck dinners, jeu-de-boulen en samen uit eten waren fantastisch om elkaar beter te leren kennen. We zaten allemaal in hetzelfde traject, en hoewel de onderwerpen uiteenliepen, we snapten elkaar volkomen. In het bijzonder wil ik graag Iris en Annick bedanken dat jullie mijn paranimfen wilden zijn!

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hebben! Lisa, jij maakt mijn fietstochtjes van 14km een stuk draaglijker. Laten we veel dubbeldates organiseren!

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About the author

Lenneke van Bussel was born in Zevenaar, the Netherlands on 29 december 1991. After receiving the Gymnasium degree at de Breul in Zeist, she moved to Wageningen to study at Wageningen University and Research. Lenneke obtained her Bachelor’s degree in Nutrition and Health with minors in the Psychobiology of Eating Behavior and Supply Chain Management in 2013.

Lenneke continued studying at Wageningen University and Research, Management, Economics and Consumer studies, with a specialization in Consumer studies. She did an internship at the National Institute for Public Health and the Environment (RIVM) on educational differences in healthy, environmental sustainable and safe food consumption in Dutch adults. For her thesis, she focused on the fruit and vegetable consumption through the lens of the life course perspective. She received her Master’s degree in Consumer studies in 2016.

In August 2017, she was appointed as a PhD candidate in the Division of Human Nutrition of Wageningen University and Research. In her PhD (2017-2022), she focused on diet-related sustainability of eating patterns and the consumer perceptions of food-related sustainability. Besides her research activities, she was involved in tutoring and supervising Master theses and presenting her work in poster presentations at Food2020 (Hohenheim, 2020) and the British Feeding and Drinking Group (2021, 2022).

In April 2023, Lenneke started as a researcher focusing on youth at Wageningen Food and Biobased Research in Wageningen.

List of publications

Publications in peer-reviewed journals

van Bussel LM, van Rossum CT, Temme EH, Boon PE, Ocké MC. Educational differences in healthy, environmentally sustainable and safe food consumption among adults in the Netherlands. Public Health Nutr. 2020 ;23(12):2057-2067. doi: 10.1017/S1368980019005214.

van Bussel LM, Kuijsten A, Mars M, van 't Veer P. Consumers' perceptions on food-related sustainability: A systematic review. Journal of Cleaner Production. 2022; 341: 130904. doi: 10.1016/j.jclepro.2022.130904.

van Bussel LM, Kuijsten A, Mars M, Feskens EJM, van 't Veer P. Taste profiles of diets high and low in environmental sustainability and health. Food Quality and Preference. 2019; 78:103730. doi: 10.1016/j.foodqual.2019.103730.

Expected publications

van Bussel LM, van der Lans I, Mars M, Kuijsten A, van 't Veer P. Perceptions and intentions to consume sustainable foods: Exploring associations with beliefs about food attributes, environmental responsibility and education though the Theory of Planned Behaviour. Human Nutrition and Health, Marketing and Consumer Behaviour, Wageningen University & Research, Wageningen.

van Bussel LM, Mars M, Kuijsten A, Jager, G, van 't Veer P. Implicit and explicit associations between sustainability aspects of foods and palatability. Exploring the differences in food attributes and socio-demographic characteristics. Human Nutrition and Health, Wageningen University & Research, Wageningen.

Overview of completed training activities

Discipline specific activities

Name of course/ meeting	Organizer	Year
Masterclass Healthy and Sustainable Diets: Synergies and Trade-offs	VLAG	2017
Symposium Nieuwe Wegen naar Gezonde Voeding	Schuttelaar Partners	2017
Eiwitdialogen, Wageningen Dialogues	WUR	2017
Symposium Foodture	Artesis Plantijn University College, Antwerp	2018
Symposium Sociology of Consumption and Households: Politics, Practices and Transformative Potential of Sustainable Diets	WUR	2018
Congress FOOD2030 (+ poster presentation)	University of Hohenheim, Stuttgart	2018
Dutch Nutritional Science Days	NWO	2018
Sensory Perception & Food Preference: The role of context	VLAG	2018
Healthy Food Design	VLAG	2018
PhD course Innovation towards plant-based consumption	Faculty of Food Science, Copenhagen	2018
WeVo bijeenkomst (Radboud)	WeVo, Nijmegen	2019
EuroSense	Elsevier (online)	2020
British Feeding and Drinking Group conference (+ poster presentation)	University of Leeds (online)	2021
WeVo bijeenkomst (Voedingscentrum)	WeVo, Den Haag	2022
British Feeding and Drinking Group conference (+ poster presentation)	University of Leeds (online)	2022
CS50's Introduction to Computer Science	Harvard University (EdX course)	2022

General courses

Name of course	Organizer	Year
VLAG PhD week	VLAG	2017
Project and Time Management	WGS	2018
Interpersonal Communication for PhD candidates	WGS	2018
Supervising BSc and MSc students	WGS	2018
Systematic approaches to reviewing literature	WGS	2018
PhD Carousel	WGS	2019

Optionals

Activity	Year
Preparing PhD research proposal	2017
Principles of Sensory Science (HNH-30506)	2017
Tasty talks, biweekly meeting	2017-2022
Menu-D, biweekly meeting	2017-2018
Training Compleat	2019

Teaching obligations

Practicals	Year
HNE-27806 General Medicine	2018-2019
HNE-22806 Food & Health	2018-2019

Supervision of MSc students	
Corinne Ouwehand	2018
Jana Schaarschmidt	2018
Cristina Alvarez	2019
Vera Komen	2022

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