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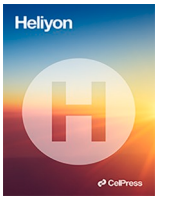

Research article

A sustainable and healthy diet: Personality, motives, and sociodemographics

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ABSTRACT

Background: Sustainable and healthy food choices have usually been studied by investigating either consumer choices concerning one product or product group. To investigate dietary patterns are more complex but may be more useful to promote dietary changes among consumers.
Objectives: To identify existing dietary patterns, and to investigate the importance of personality traits, food choice motives, and sociodemographic variables in adopting these patterns.
Methods: A food frequency questionnaire and principal component analysis were used to identify dietary patterns. The importance of food choice motives, sociodemographics, and personality traits were investigated by using ordinary least squares. The personality traits were measured by the Big Five model, and food choice motives were measured by a set of twelve food values.
Results: Three patterns were found and labelled as sustainable, traditional, and unsustainable. The sustainable pattern was positively associated with respondents who were younger, married, females, and having higher income and education. It was also positively associated with openness to experience, conscientiousness, and perceived environmental impact, and it was negatively associated with convenience and price.
Value: The results may be used to target consumer groups for information and marketing activities.

1. Introduction

The global food system is responsible for more than a third of total greenhouse gas (GHG) emissions [1]. Population growth and expected income growth will result in increased global food consumption with further increasing GHG emissions, biodiversity loss, freshwater and land use, and other environmental problems. Given these problems, a major challenge is to provide the global population with healthy diets from sustainable food production systems [2].

To promote health and sustainability, Willett et al. [2] proposed a diet based on a high consumption of fruits and vegetables, whole grains, legumes, nuts, and unsaturated oils; a low to moderate consumption of seafood and poultry; and a low consumption of red meats, processed meats, added sugar, refined grains, and starchy vegetables. With exceptions related to meat, fish, and starchy vegetables, the qualitative recommendations of Willett et al. [2] are in line with the current Norwegian dietary guidelines [3]. However, these guidelines do not focus on sustainability, and they are under revision based on the new Nordic Nutrition Recommendations (NNR) [4]. Blomhoff et al. [4] recommended a predominantly plant-based diet with high intake of vegetables, fruits, berries, pulses, potatoes, and whole grains; ample intake of fish and nuts; moderate intake of low-fat dairy products; limited intake of red meat and

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poultry; and minimal intake of processed meat, alcohol, and processed foods containing high amounts of fats, salt, and sugar. The NNR are on public hearing before the new national recommendations with associated quantifications will be updated by the end of 2024 [5].

The NNR have been criticized, and the revised national guidelines are likely to take natural conditions, the interests of farmers, and consumer acceptance more into consideration. Norwegian wild fisheries and aquaculture provide large quantities of fish and there is little arable land of which two-thirds is only suitable for grass production. Under these conditions, a balanced diet with a higher consumption of fish, starchy vegetables, and some consumption of meat and dairy products from grass-fed ruminants may be recommended. In Norway, the agricultural sector is considered to be crucial for enhancing food production, ensuring self-sufficiency, and fostering value creation [6]. Key stakeholders in the agri-food industry advocate for reducing greenhouse gas emissions through technological advancements rather than cutting meat production [6]. Moreover, for many consumers a sustainable and healthy diet also includes dimensions related to the use of pesticides and antibiotics, novel production technologies, and food culture. Norwegian agriculture is characterized by relatively little use of pesticides and antibiotics, and genetic modification is banned. Furthermore, many consumers support local food production to preserve the cultural landscape and biodiversity, even though the total environmental impact may be higher, see for example [7]. Given these considerations, many consumers are uncertain about the environmental and health effects of different diets [8].

Sustainable and healthy dietary choices have mainly been studied by either investigating choices concerning one perceived sustainable product or product group, or by investigating curtailment strategies of a product with perceived negative environmental impact [9]. To study the sustainability and healthiness of one product is well defined but may be limited in scope given that the diet of an individual consists of many products. To investigate and evaluate more complex patterns of consumption may be more useful to promote dietary changes among consumers. Moreover, these patterns may be more stable over time than the choice of one product.

This study has two objectives. First, principal component analysis (PCA) is used to identify existing dietary patterns as measured in a food frequency questionnaire (FFQ), and the sustainability and healthiness of these dietary patterns are discussed. PCA is commonly used to identify existing patterns in a FFQ by replacing food items that are highly correlated in consumption frequencies with indexes called principal components. These components are commonly referred to as dietary patterns, and we will use this term. However, these dietary patterns is only a subset of the complete diet of an individual.

Second, the roles of sociodemographic variables, personality traits, and food choice motives in adopting the dietary patterns are investigated. The effects of sociodemographic variables and personality have been investigated in several studies [10–12], while the effects of food choice motives are less investigated. For example, in a recent review of 307 quantitative studies on vegetarianism and veganism from 1937 to 2022, motivations were presented in 39 %, values were presented in 21 %, and personality traits were presented in 10 % of the studies [13]. However, these studies mainly used a few variables to measure motives, and to our knowledge the entire food value system of individuals, as a source of food choice motives, has not been investigated.

Our findings shed light on the what, who, and why aspects of food consumption. Dietary patterns reveal what people typically eat, while sociodemographic characteristics and personality traits describe who these people are. Food choice motives explain why certain dietary patterns are adopted, and may offer insights into factors that might promote more sustainable and healthy diets and prevent less healthy and unsustainable diets.

In the next section, the personality traits and choice motives included in this study are briefly outlined. Section 3 briefly describes a conceptual model for the choice of a dietary pattern based on subjective beliefs about the attributes of the food items included in the pattern. Section 4 describes the variables, measurements, and statistical models employed. The results are presented in Section 5 and discussed in Section 6.

2. Food choice motives and personality traits

Individual values and beliefs motivate intentions and ultimately form behaviors as described by Ajzen's theory of planned behavior [14]. Studies have found that values such as universalism, concerns about the environment, animal rights, health values and health consciousness, and green perceived value influence attitudes towards and intention to consume organic food [15–18]. Specifically, Yang et al. [18] found that health values and health consciousness had substantial impacts on healthy eating beliefs, and healthy eating beliefs induced intention and actual consumption of organic food through personal norms and awareness of consequences.

Lusk and Briggeman [19] suggested a set of food values. These values represent the underlying preferences over an intermediary value system that consumers develop in their food-related decision making process and can be viewed as more abstract food quality attributes [19]. Lusk [20] showed that the specified food values, as measured in a survey, were significantly related to actual purchase behaviors as measured in scanner data, and thus exhibited external validity, and reflected consumers' food choice motives and subjective beliefs about food products. Studies have found that food values are important in determining preferences, demand, and willingness to pay for food products such as beef, chicken, and milk [21,22]; organic food [19,20,23]; functional snack [24]; and genetically modified food [25]. The food values in Ref. [19] were slightly revised by Bazzani et al. [23] who included twelve values: safety, nutrition, naturalness, environmental impact, taste, appearance, convenience, animal welfare, origin, fairness, price, and novelty. Some of these food values relate to specific product attributes (e.g., taste) while other are more complex (e.g., environmental impact), and these values represent our food choice motives.

Personality was defined by Roberts [26] as: "relatively enduring patterns of thoughts, feelings, and behavior that reflect the tendency to respond in certain ways under certain circumstances." One of the most widely accepted taxonomy of personality is the Big Five model including the traits openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism (OCEAN). The OCEAN traits have been associated with preferences for different types of food, dietary patterns, and other aspects of food-related

preferences and behavior. Recent examples include [27–31]. Gustavsen and Hegnes [28] found that openness to experience was positively, and extraversion was negatively associated with the attitudes towards organic foods. Nystrand et al. [32] found that personality traits also had an indirect effect on food consumption frequency through considerations of future health outcomes of the food consumption. Their result indicate that conscientiousness, agreeableness, and neuroticism have a positive indirect effect on consumption frequency of functional food via consideration of future consequences. In their systematic review about associations between personality traits and diets, Diop et al. [33] found that extraversion, openness, agreeableness, and conscientiousness frequently were positively related with healthy dietary behavior and negatively related with fat consumption, eating problems, and obesity. They found the opposite associations for neuroticism.

Previous studies have found that personality traits influenced the importance ranking of general values and food values [34,35]. Given the interrelationships between food values and personality traits, it is of interest to include both sets of variables in models of food consumption behavior.

3. Conceptual model

According to Lancaster [36], a consumer gains utility from a product's attributes. As discussed by Lusk [20] and Pappalardo and Lusk [24], a consumer's assessment of the attributes of the product is subjective. Based on this subjectivity, they developed a conceptual model using subjective expected utility (SEU) theory [37] to explain the associations between food values and the demand for food.

Following Pappalardo and Lusk [24] a respondent i can consume $j = 1, \ldots, J$ food products, each with $k = 1, \ldots, K$ food values. Denote the utility obtained from food value k as $U(FV_k)$. Let P_{ij}^k be the subjective probability that product j provides food values k. The subjective expected utility that respondent i gets from product j is $SEU_{ij} = \sum_{k=1}^{K} P_{ij}^k U_i(FV_k)$. Product A will be chosen over B when $SEU_{iA} > SEU_{iB}$, i.e., when $\sum_{k=1}^{K} (P_{iA}^k - P_{iB}^k) U_i(FV_k) > 0$. In this model, food choices depend on both the desirability of all the food values and the subjective belief (or probability) regarding the differences in content of each food value between the two food products.

A dietary pattern can be viewed as the result of decisions to consume a certain group of food items with correlated consumption frequencies. It is assumed that each dietary pattern can be analyzed separately. In our statistical model described below, the choice of a single product is replaced by the choice of a dietary pattern.

4. Material and methods

The Norwegian Monitor Survey (NMS) is a nationally representative and repeated cross-sectional survey of adults aged 15–95 years, which has been conducted every second year since 1985. NMS covers a broad set of topics including food preferences, food attitudes, food shopping behavior, a food frequency questionnaire (FFQ), and all the major food and beverage producers in Norway subscribe to the survey. Data from the survey has been widely used in consumer research, see for example [27]. Ipsos Norway recruited respondents through a short telephone interview, and those who accepted to participate received a paper-based questionnaire of about 150 pages.[1] We only had access to anonymous data, and specific ethical approval was not required for this research. Data from the 2015 survey was used, and the dataset included 3981 respondents [38].

4.1. Measures

Gender, education, marital status, and presence of children aged 15 years or less were represented by dummy variables as defined in Table 1. The log of the annual income of the household and the age of the respondent were included as continuous variables.

Each respondent was presented with a set of twelve food values with the descriptions shown in Table 1. From this set, they were asked to choose the most and least important values when purchasing food. The choices were effect coded with the score −1 for the least important, 1 for the most important, and zero for the other values. Following [19], we will refer to these effect coded scores as importance scores. These scores sum to zero across all food values by construction and one food value must be excluded from the regression analysis to avoid perfect multicollinearity.

A short version of the Big Five personality model developed by Ref. [39] was included in the NMS for 2015.[2] This version was based on the 20 items shown in Table 2. Each item was constructed using a scale from 1 (the item does not describe me at all) to 7 (the item describes me very well). Each trait was constructed by taking the mean values of the responses to the four associated items, and the scores of negative worded items were reversed.

The FFQ in NMS have questions about consumption frequencies of 387 food and beverages. Consumption frequencies were derived from the question: "How often do you eat the relevant product." The response alternatives were: daily, 3–5 times a week, 1–2 times a

[1] The survey samples are weighted according to a matrix for age, gender and region based on census data from Statistics Norway (proportional post-stratification) [67]. Hellevik [67] demonstrated that the weighting in general has little impact on the results from the NM sample. We did not use weights in the analysis of the data.

[2] This short version was specifically developed for large scale survey studies in the general population where time is limited. Engvik and Clausen [39] showed that this version reached adequate levels of psychometric properties such as structural validity, factor divergence, maximal representation, test-retest reliability, and criterion validity.

Table 1
Variable description and descriptive statistics of sociodemographic variables and food values[a].

Variable	Description	Mean	SD
Age	Age in years	46.75	17.55
Income[b]	Log of the net (before tax) annual income of the household income	6.49	0.65
Gender	1 = if male	0.48	0.50
Education	1 = if has a university degree	0.59	0.49
Marital status	1 = if married or cohabitant	0.65	0.48
Children	1 = if live with children aged15 years or less	0.31	0.46
Taste	The flavor of the food in your mouth	0.25	0.44
Safety	Eating the food will not make you sick	0.12	0.38
Nutrition	Amount and type of fat, protein, etc.	0.11	0.36
Animal welfare	Well-being of farm animals	0.04	0.33
Naturalness	Made without modern food technologies like genetic engineering, hormone treatment and food irradiation	0.04	0.35
Price	Price you pay for the food	0.01	0.40
Appearance	The food looks appealing and appetizing	−0.01	0.33
Environmental impact	Effects of production on the environment	−0.04	0.27
Fairness	Farmers, processors and retailers get a fair share of the price	−0.04	0.36
Origin	Whether the food is produced locally, in Norway, or abroad	−0.04	0.45
Convenience	How easy and fast the food is to cook and eat	−0.06	0.36
Novelty	The food is something new that you have not tried before	−0.39	0.49

Notes.
[a] Based on 3210 respondents. For the food values, the importance scores, which range from −1 to 1 and sum to 1 are reported.
[b] The net (before tax) annual income of the household measured in eleven interval categories ranging from less than 100,000 NOK to more than 2,000,000 NOK. Each household's income was set to the midpoint of the income group, and the log of this income was used in the analysis. For the highest and lowest income groups, the censoring point was set as the income, and observations with missing income (4 %) were categorized in the median income category; between 600,000 and 799,000 NOK (the average rate in June 2020 was1 NOK = 0.1047 USD).

Table 2
The OCEAN traits

Trait	APA definition[a]	Items[b]
Openness to experience	The tendency to be open to new aesthetic, cultural, or intellectual experiences	• Original with new ideas • Lively imagination • Likes to speculate and play with ideas • Few artistic interests
Conscientiousness	The tendency to be organized, responsible, and hardworking	• Do a thorough job • Careless • Usually have a messy life • Make plans and follow them up
Extraversion	An orientation of one's interests and energies toward the outer world of people and things rather than the inner world of subjective experience	• Talkative • Tends to be quiet • Shy • Outgoing and social
Agreeableness	The tendency to act in a cooperative, unselfish manner	• Helpful and selfless towards others • Can be cold and aloof • Considerate and friendly to most people • May sometimes be rude
Neuroticism	A chronic level of emotional instability and proneness to psychological distress	• Depressed • Relaxed, cope well with stress • Worries too much • Gets nervous easily

Notes.
[a] Definitions according to American Psychology Association's (APA) dictionary of psychology [41].
[b] Items are adjusted based on BFI-20 developed by Ref. [39].
Source: The table is Table 1 in Ref. [27] who based it on [40].

week, 2–3 times a month, once a month, 3–11 times a year, seldom, and never. These intervals were converted to weekly consumption frequencies.[3] Sometimes a question, about the consumption frequency of a category of foods (e.g., meat) was followed by questions about the items included in the category (e.g., minced meat). In these cases, the category was excluded to avoid double counting (8 items). Alcoholic beverages (24 items) were also excluded.[4] Furthermore, we excluded 40 items, which less than 10 % of the sample consumed more than once a month and were left with 315 items.

Our population was defined as adults aged between 18 and 80 years. Respondents older than 80 years were excluded (71 respondents) due to possible health conditions that were likely to affect their dietary pattern. Respondents younger than 18 years were excluded (137 respondents) since they might not be fully responsible for their diet. Respondents who had missing values on all the items associated with one or more of the OCEAN traits were excluded (50 respondents). Respondents who chose more than one food value as the most and/or least important, chose the same food value as most and least important, or did not choose any of the food values were excluded (496 respondents). Following Hansson and Galanti [42], we replaced missing values in FFQ by zero consumption, and respondents who had missing values for more than half of the food items in FFQ were excluded (17 respondents). The remaining sample consists of 3210 respondents used in the statistical analysis.

4.2. Statistical models

A FFQ record the consumption frequency of many items, and PCA is a widely used and data-driven method to derive dietary patterns from FFQ in nutrition research, see for example [10–12,43–45]. For a review of statistical methods for dietary pattern analysis see Ref. [46].[5]

The objective of PCA is to reduce the number of observed items to a smaller subset of principal components where the first component account for the most variance, the second component accounts for the second most variance, and so on. Three somewhat ad hoc criteria are frequently used to determine the number of components: (1) Kaiser rule: retaining components with eigenvalues above 1, (2) retaining the components to the left of the 'elbow' in the scree plot, and (3) aiming to achieve highest percentage of total variance while taking into account the interpretability of the components [46–48]. Once k principal components are retained, scores can be predicted for each component and individual. These principal components are referred to as dietary patterns. Higher predicted score for a dietary pattern indicates stronger adherence to the pattern. A more detailed mathematical specification for the PCA and predicted scores is provided in the Appendix.

The predicted component scores, CS, were used as the dependent variable in an ordinary least squares (OLS) regression for each dietary pattern, $CS_i^D = \beta^D x_i + e_i^D$, where β is the vector of coefficients, x is the vector of the variables provided in Tables 1 and 3, e an error term, subscript i denotes respondent, and top script D denotes a dietary pattern.[6] Identical effects of sociodemographics, personality, and food values within each dietary pattern were assumed and different effects between the patterns were allowed for. The food value price was excluded to avoid perfect multicollinearity. The OCEAN traits were standardized to have zero mean and a unit SD. All data preparations and statistical analyses were done using Stata.

In the context of our conceptual model personality traits and socioeconomic variables can be viewed as control variables in the estimation of the effects of food values. The estimated parameters associated with the food values reflect both the desirability of a food value and the subjective beliefs about the content of the food value. For example, a positive (negative) association between the food value environmental impact and a diet high in the consumption frequency of vegetables suggests that ceteris paribus (a) the respondent believes that a higher intake of vegetables is significantly better (worse) for the environment, and (b) as the respondent assigns higher importance to the environmental impact relative to price, the consumption frequency of vegetables increases (decreases).[7]

[3] One month was defined to have four weeks and one year to have 12 months. The midpoints were used to construct the frequencies such that daily was converted to 7 times per week, 3–5 times per week was converted to 4 times, 1–2 times per week was converted to 1.5 times, 2–3 times per month was converted to 0.625 times per week, once per month was converted to 0.25 times per week, 3 to 11 times per year was converted to 0.146 times per week, rarely was converted to 0.03 times per week, and never was converted to 0 times per week.

[4] As pointed out by a referee, alcoholic beverages should have been included because their consumption raise sustainability as well as health issues.

[5] PCA aggregates items with correlated consumption frequencies into components or dietary patterns. However, a limitation of PCA is that the identified patterns capture only a fraction of all the items included in the FFQ [68]. Nonetheless, PCA is valuable for identifying the existing dietary patterns without imposing any prior theory or restrictions on consumption patterns [68]. Alternative methods like cluster analysis or making an index for a healthy and sustainable diet could alternatively been used to detect the dietary patterns. However, cluster analysis is more aimed at segmentation than to create a few dietary patterns from 315 food items, and the used FFQ does not have any information on quantities, which makes the calculation of an index problematic.

[6] Other studies have also used the predicted scores from a PCA on FFQ data to investigate factors influencing individuals' dietary patterns such as the importance of food environment, proximity to food sources, dietary knowledge, or personality traits, see for example [12,69].

[7] As pointed out by a reviewer, it is not straightforward to go from a product to a dietary pattern. For example, not all vegetables in a diet may be equally favorable for the environment (e.g. avocados versus carrots). One could also argue that not all carrots are equally favorable for the environment (e.g., organic versus conventional carrots). These problems are important and an interesting topic for future research.

Table 3
Descriptive statistics and correlation matrix of the OCEAN traits[a].

			Correlation matrix[d]				
Mean and SD[b]		α[c]	O	C	E	A	N
Openness to experience	4.27 (1.22)	0.68 (0.63)	1.00				
Conscientiousness	5.23 (0.93)	0.54 (0.57)	−0.07*	1.00			
Extraversion	4.76(1.30)	0.80 (0.78)	0.11*	0.12*	1.00		
Agreeableness	5.46 (0.91)	0.58 (0.63)	−0.01	0.34*	0.25*	1.00	
Neuroticism	3.11 (1.26)	0.75 (0.73)	0.02	−0.20*	−0.29*	−0.20*	1.00

Notes.
[a] Based on 3210 respondents.
[b] Mean values with standard deviations in the parentheses.
[c] Cronbach's alpha values for the standardized items with the corresponding values as reported in Ref. [39] in the parentheses.
[d] Correlation matrix of the constructed traits. An asterisk indicates significant correlation at the 5 % significance level.

5. Results

5.1. Descriptive statistics

The variable descriptions, mean values, and standard deviations of the sociodemographic variables and the importance scores of the food values are shown in Table 1. The average respondent was almost 47 years old, and about half the sample was female. Almost 60 % of the respondents had a university degree, 65 % were married or had a cohabitant, and 31 % were living with one or more children aged 15 years or less. Respondents with a higher education were overrepresented. About 37 % of the Norwegian adult population (16+ years) have completed higher education [49] as compared with 65 % of the respondents. The average age of the respondents was 47 years as compared with a population average of 40.5 years [50]. This higher average age in the sample is mainly due to the exclusion of respondents below 18 years. About 19 % of the population was below 18 years [49].

Food values are listed in order of importance in our sample. On average, taste was the most important food value (importance score 0.25), and novelty was the least important food value (importance score −0.39). Safety and nutrition were ranked as the second and third most important food values.

The mean values, standard deviations, Cronbach's alpha reliability coefficients, and the correlation matrix of the constructed OCEAN traits are shown in Table 3. Respondents scored high on conscientiousness and agreeableness and low on neuroticism. The alpha values were slightly below 0.6 for conscientiousness and agreeableness, however, the values were similar to the values reported by Engvik and Clausen [39]. Several correlations among the traits were significant, but none was above $|0.34|$.

5.2. PCA and sustainability of diets

Initially, 315 food items were included in the PCA. These items were tested by the Bartlett test of sphericity, and no intercorrelations among the variables was rejected (p-value = 0.00). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy also showed sufficient intercorrelations among the variables to employ PCA ($KMO = 0.86$) [48].

As discussed above, three criteria were used to determine the number of dietary patterns: Kaiser rule, visual examination of a scree plot, and total interpretable variance percentage. A PCA with 315 items resulted in eigenvalues of 15.59, 12.48, 9.59, 4.33, 4.17, and 3.72 for the first six components, and the scree plot of the eigenvalues suggested retaining three or four principal components. The fourth component neither substantially increased the total variance explained nor demonstrated a distinctive meaningful pattern, and three principal components were retained. These components were rotated using an orthogonal varimax rotation. The food items with low rotated factor loadings on all components ($<|0.3|$, 202 items), or cross loadings (two or three factor loadings $>|0.3|$, 8 items) were excluded from the model. The final three component solution was based on 105 items. Following the literature, we refer to these components as dietary patterns, or simply diets.

The three dietary patterns found by the orthogonally rotated three-factor PCA model based on 105 food items are summarized in Table 4.[8] The table lists the items that characterized each pattern as measured by a rotated factor loading above $|0.3|$. Each dietary pattern was given a name based on how well the included items reflected the health and sustainability recommendations discussed in the introduction. For each diet, the items are sorted from the largest to the smallest factor loading. For example, in the sustainable diet, the loading for lettuce is largest and for banana smallest. The proportion of the variance explained by each factor varies between 5 % (traditional diet) and 8 % (sustainable and unsustainable diets), and jointly they explain about 21 % of the variance among the 105 food items.[9]

There were 34 items with high factor loadings ($> |0.3|$) in the sustainable diet including different types of fresh fruits and vege-

[8] The analysis was also carried out using nonorthogonal rotations, and the results were similar. The correlation between the predicted score after orthogonal and non-orthogonal rotations was above 0.95 for each factor. Detailed estimation results are provided in Table A1 in the Appendix.
[9] The share of explained variance is relatively low but similar to other studies that have used PCA on FFQ data, see for example [10,11,44,45]. Low shares of explained variation is also typical in social sciences where information is less precise [48].

Table 4
The three dietary patterns obtained from the PCA

Sustainable[a]	Traditional[a]	Unsustainable[a]	
Lettuce	Cooked potato	American dishes	Minced pork
Garlic	Meatballs	Taco sauce in glass	Hotdog buns
Onion	Potato	Mexican dishes	Bakery products from convenience stores
Bell pepper	Beef patty	Hamburger	Snacks from convenience stores
Fresh spices	Pollock fillet	Italian dishes	Fresh pasta
Olive oil	Fish gratin/pie	Minced meat	Energy drinks
Raw vegetables	Flat bread	Frozen pizza	Beef
Tomato	Lamb/pork/beef baked in oven	French fries	Iced tea
Avocado	Fish pudding	Dry pasta	Ready-to-eat sauce
Cucumber	Traditional Norwegian dishes	Lasagna	Cakes from mix
Balsamic vinegar	Fish balls	Homemade spaghetti	Ketchup
Fried vegetables	Rice pudding	Homemade pizza	Hotdogs
Rapeseed oil	Mashed potato	Pizza bun	Frozen ready meals
Rocket salad	Sauerkraut	Sausages	Canned meals
Squash/eggplant	Homemade cakes	Ready-to-eat spaghetti	Iced coffee
Vegetarian dishes/soups/pies	Pork chop	Ready-to-eat stew	Milkshake or smoothie
Parmesan and/or mozzarella cheese	Fish cake	Ready-to-eat noodle soup	Coca cola with sugar
Homemade dressing	Homemade jam	Noodles	
Fresh mixed fruits	Waffle	Shredded pizza cheese	
Soybean oil	Vegetable stew	Candy from the shelf	
Mushroom	Homemade bakery	Corn	
Apple	Aged yellow or white cheese	Snacks from gas stations	
Mango	Pollock	Toast with cheese	
Melon	Root vegetables	Chips	
Asparagus	Potato bread (lefse)	Packaged candy	
Beans		Lean minced meat	
Natural yoghurt		Wraps	
French dishes		Potato chips, low fat	
Oatmeal		Sprite with sugar	
Raspberry			
Crème fraiche			
Wok			
Blueberry			
Banana			

Notes.
[a] The dietary patterns obtained from the PCA based on 105 food items and based 3210 observations. For each dietary pattern, the food items with rotated factor loadings above |0.3| on the associated dietary pattern are listed. They are sorted in descending order of the magnitude of each loading. The full estimation results are shown in Table A1 in the Appendix.

tables, beans, oatmeal, vegetable oil, a few dairy products, but little or no meat and fish. This diet seems to result in relatively low GHG emissions and be healthy.

There were 25 items with high factor loadings in the traditional diet including traditional dishes such as meatballs, beef patties, oven-baked pork/lamb/beef, fish cakes, fish balls, pollock, potato bread, and flat bread. This diet also included traditional vegetables such as various forms of potatoes, root vegetables, vegetable stew, and sauerkraut. However, it was relatively high in the consumption of red meat and some meat products, and the diet was too high in meat consumption to be considered as healthy and sustainable.

There were 46 items with high factor loadings in the unsustainable diet. This diet was associated with high consumption of beef, minced beef, minced pork, hamburgers, hotdogs, and grilled sausages. The diet also included many mixed dishes such as American dishes, Mexican dishes, and ready-to-eat meals like frozen pizza. Many of these items are associated with excess packaging, included meat and a lot of sugar but little fruits or vegetables. The diet is inconsistent with a sustainable and healthy diet.

5.3. OLS regressions

The estimated coefficients and the associated standard errors for each diet are reported in Table 5.[10] The constant terms reflect each diet's score for a hypothetical and non-existent single female respondent with zero age, no university degree, 1 NOK annual income, no children, zero score on all personality traits and for whom all food values have zero importance score. Price was excluded to avoid perfect multicollinearity, and the coefficients of the food values are relative to the importance of price.

In the sustainable dietary pattern, 19 % of the variance was explained. The pattern was positively associated with higher income,

[10] For each dietary pattern, three models were estimated: Model 1 including only sociodemographic variables, Model 2 including sociodemographic variables and the OCEAN traits, and Model 3 including sociodemographic variables, the OCEAN traits, and the food values. Wald tests of no joint significance of the additional variables rejected Model 1 ($\rho < 0.00$) and Model 2 ($\rho < 0.00$) in favor of Model 3, and we report the results of Model 3.

Table 5
Estimated coefficients and standard errors[a].

	Sustainable		Traditional		Unsustainable	
	Estimate	SE	Estimate	SE	Estimate	SE
Constant	−0.72*	0.20	−1.18*	0.16	0.83*	0.17
Age	−0.00*	0.00	0.02*	0.00	−0.03*	0.00
Income	0.12*	0.03	0.02	0.03	0.07*	0.03
Gender	−0.42*	0.04	0.18*	0.03	0.26*	0.03
Education	0.33*	0.03	−0.26*	0.03	−0.03	0.03
Marital status	0.10*	0.04	0.14*	0.04	0.10*	0.03
Children	0.03	0.04	0.15*	0.03	0.24*	0.03
Openness to experience	0.14*	0.02	−0.03*	0.02	0.02	0.01
Conscientiousness	0.05*	0.02	−0.03	0.02	−0.03*	0.01
Extraversion	0.04	0.02	0.03*	0.02	0.07*	0.01
Agreeableness	0.00	0.02	0.06*	0.02	−0.01	0.01
Neuroticism	0.01	0.02	0.02	0.02	0.06*	0.01
Nutrition	0.37*	0.06	−0.08	0.05	−0.28*	0.05
Naturalness	0.27*	0.06	0.04	0.06	−0.23*	0.05
Animal welfare	0.15*	0.07	0.02	0.06	−0.20*	0.05
Fairness	0.21*	0.06	0.18*	0.06	−0.20*	0.05
Origin	0.10	0.05	0.27*	0.05	−0.18*	0.04
Convenience	−0.17*	0.06	0.05	0.06	−0.03	0.05
Appearance	0.07	0.06	0.03	0.06	−0.12*	0.05
Safety	0.13*	0.06	0.08	0.05	−0.09	0.05
Novelty	0.20*	0.05	0.08	0.05	−0.03	0.04
Environmental impact	0.40*	0.07	−0.08	0.07	−0.25*	0.06
Taste	0.08	0.05	−0.08	0.05	−0.07	0.05
R^2	0.19		0.23		0.46	

Notes.
[a] OLS regressions using 3204 observations. Six observations were removed as outliers. An asterisk indicates significance at the 5 % level. Heteroscedasticity robust standard errors are reported. The food value price was excluded to avoid perfect multicollinearity.

females, higher education, lower age, and marriage. Openness to experience and conscientiousness were also positively associated with the sustainable pattern. A one SD increase in the scores of openness to experience was associated with 0.14 SD increase in the score of this pattern. This is the largest marginal effect of an OCEAN trait for any diet. The marginal effects of food values ranged from −0.17 (convenience) to 0.40 (environmental impact). A one unit increase in the importance score of convenience (relative to the importance of price), decreased the score of the sustainable pattern by 0.17 SD, and a one unit increase in the importance score of environmental impact increased the score of this pattern by 0.40 SD. Environmental impact, nutrition, naturalness, fairness, novelty, animal welfare, and safety all had positive associations with the sustainable pattern. Convenience was the only food value with a negative association with this dietary pattern.

In the traditional dietary pattern, 23 % of the variance was explained. The pattern was positively associated with higher age, males, lower education, presence of children, and marriage. Openness to experience was negatively and extraversion and agreeableness were positively associated with this pattern. Agreeableness was the trait with the largest marginal effect (0.06). Only two food values had a significant positive association with this pattern. A one unit increase in the importance score of origin and fairness increased the score of the traditional pattern by 0.27 and 0.18 SD, respectively.

In the unsustainable dietary pattern, 46 % of the variance was explained. The diet was positively associated with lower age, higher income, males, marriage, and presence of children. Conscientiousness was negatively and extraversion and neuroticism were positively associated with the unsustainable diet. Extraversion was the trait with largest marginal effect (0.07). Nutrition, environmental impact, naturalness, animal welfare, fairness, origin, and appearance were all negatively associated with this pattern. These negative values indicate that increases in the importance of nutrition, environmental impact, naturalness, and so on, relative to the importance of price, significantly decreased the score of the unsustainable pattern. Alternatively, an increase in the importance of price, relative to these food values, increased the score of the unsustainable pattern. This implies that respondents perceived the unsustainable diet to be a relatively cheap dietary pattern. The marginal effects ranged from −0.12 (appearance) to −0.28 (nutrition).

6. Discussion

Sociodemographic variables were significantly associated with the dietary patterns, and several of these associations are consistent with previous results. Studies have frequently found positive associations between being female, having higher income, or having higher education and more healthy or plant-based diets, whereas being male, being younger, or having lower education have frequently been associated with a high consumption of meat, snacks, or fast foods [12,51–54]. However, some evidence suggests that younger individuals tend to show a positive association with consuming sustainable food options, such as organic and local food [51], as well as adopting a vegetarian diet [53]. Different demographic and socioeconomic factors influence the adoption of each identified dietary pattern. These diverse effects demonstrate that empirically derived dietary patterns can be useful in targeting information to different relevant groups as also emphasized by Ref. [54].

Each personality trait was significant for at least one dietary pattern. The positive association between openness to experience and the sustainable diet was quite strong. This association is consistent with associations between openness and healthier diets or high consumption frequencies of fruits and vegetables that have been reported in several studies [10–12,31,55,56]. The effects of conscientiousness, agreeableness, and neuroticism are in line with previous results who have found that conscientiousness and agreeableness are positively associated with generally healthier or plant-based diets, and negatively associated with less healthier diets, whereas neuroticism has been found to have the opposite association with such dietary patterns [10–12,31,55]. Our results concerning the relationships between personality traits and dietary patterns align closely with those reported in Ref. [31] suggesting that Individuals with low agreeableness, conscientiousness, and openness, and high neuroticism may derive greater benefits from dietary interventions. As discussed in Ref. [31], these associations are expected to be consistent across different socioeconomic statuses.

Extraversion was positively associated with the traditional and unsustainable patterns. Ambiguous effects of extraversion have also been found in Ref. [56] who reported a positive association between extraversion and high consumption of both meat and vegetables.

Personality-targeted marketing have been shown to affect attitudes, intentions, and purchases of consumer products [57]. Extraversion and neuroticism were associated with a higher score on the unsustainable pattern, and openness to experience was associated with a higher score on the sustainable pattern. To encourage extroverted or neurotic individuals to consume more sustainable substitutes, or to encourage less open individuals to consume more of fruits and vegetables, persuasion strategies can be tailored according to personality. Personality traits can, for example, be predicted through online behavior on Facebook or other platforms, see for example [58,59].

In consumer behavior, food values are recognized as influential drivers of consumer behavior and purchasing decisions. Purchasing decisions are viewed as a mean to achieve desired outcomes, shedding light on why certain products are preferred over others [24]. Food values are considered to be more stable than preferences for specific food attributes or products [19,23,24], and consistently influence food choices across various contexts [19]. Connecting food values with dietary patterns provide insights into consumers' subjective beliefs regarding dietary patterns. Subjective beliefs are fundamentally different than preferences and failure to distinguish between the two may lead to misinterpretations regarding the factors driving the adoption of different dietary patterns [20].

Environmental impact, nutrition, naturalness, fairness, novelty, animal welfare, and safety were more important than price for consumption of the items in the sustainable pattern. Price was the most important value in for consumption of the items in the unsustainable pattern. Increasing the price of less healthy and less sustainable food items could motivate consumers towards reducing the consumption of these items. For example, taxation of sugar-sweetened beverages has been found to be effective in reducing their consumption [60,61]. In a Norwegian context, sugar taxes have been found to be well targeted for reducing the consumption of carbonated soft drinks among households who consume large quantities of such beverages [62]. However, in line with the results for the sustainable pattern, subsides for fruits and vegetables did not increase the consumption among low-consuming households substantially [62].

Fairness and origin were emphasized over price for the items in the traditional pattern. These motives may be related to support for local food production, cultural landscape, and biodiversity. Given these motives, information regarding GHG emissions from livestock production may play a role. Production of beef results in higher GHG than pork or poultry [63], and diets replacing ruminant meat with pork and poultry can reduce diet-related GHG emissions by up to 35 % [64].

7. Conclusions

Dietary patterns constructed from a wide range of food items were investigated with a focus on the what, who, and why aspects of food consumption. The what aspect was investigated by using a FFQ and PCA. Three dietary patterns emerged. The diets were labelled as: sustainable with a high in consumption of fresh fruits and vegetables, traditional with a high in consumption of traditional meat- and fish-based dishes and various form of root vegetables, and unsustainable with a high in consumption of red meat and fast food. The who aspect was investigated by analyzing the importance of sociodemographic characteristics and personality traits for consuming food included in each of the patterns. The why aspect was investigated by analyzing the importance of food values in these patterns.

Sociodemographic characteristics, personality traits, and food values explained 19–46 % of the variance in the three patterns. The sustainable pattern was positively associated with higher income, females, higher education, lower age, and marriage. The traditional pattern was positively associated with higher age, males, lower education, the presence of children, and marriage. The unsustainable pattern was positively associated with lower age, higher income, males, marriage, and the presence of children. All the personality traits were significant in at least one pattern and openness to experience had the strongest association with the sustainable pattern.

This study has some limitations. First, the FFQ only included consumption frequencies and not quantities. This makes the construction of a useful indexes on healthy and sustainable eating difficult. Second, consumption away-from home was not a part of the survey and some other items like consumption of seasonal fruits and vegetables were not included. Third, alcoholic beverages were excluded from the analysis. Alcoholic beverages have been less discussed in the context of the sustainability literature, however, they raise sustainability as well as health issues. Fourth, it is not straightforward to go from one product to a diet. For example, not all vegetables in a diet may be equally favorable for the environment, and such aggregation issues are interesting topics for further research related to sustainability and health. Fifth, other relevant factors related to food consumption, such as the price and availability, were not a part of the survey. The lack of availability of healthy foods has been an important topic in the US food desert literature [65], and real prices are also important for food choices [66]. These variables could potentially be correlated with some of the included variables resulting in biased results. However, some potential sources of biases may be less prevalent in Norway where problems associated with food deserts or absolute poverty are less important than in many other countries [23]. Sixth, the elicitation

method used to identify the relative importance of food values only identified the most and the least important food values for each respondent. This format did not provide any individual-specific information about the relative importance of the ten other food values. A repeated best-worst scaling approach might be preferred but would be quite time consuming in a survey covering many topics [19, 23]. Finally, the OCEAN traits were measured using a short version of the Big Five personality model. More extensive versions would capture personality more precisely and might detect stronger associations, however, such versions are difficult to implement in a survey covering many topics.

This study found that price and information are important. Price was the main motive for adopting the unsustainable pattern. Given the high importance of the price, increasing the price of less healthy and less sustainable food seems to be an effective policy in improving the diet. This policy might be coupled with increased income support to poor households who find more sustainable choices too costly. Furthermore, given the importance of environmental impact and nutrition, information about the nutritional and environmental benefits of a sustainable dietary pattern is important. One source of information will be the revised nutritional guidelines, which are planned to be updated by the end of 2024 [5]. The novelty aspect of this pattern also suggests that information on the integration of a variety of fruits and vegetables in the diet as well as increased availability of easy and tasty recipes for plant-based food may be effective tools.

Future research could investigate the potential of personality and motivation oriented persuasion strategies to effectively influence food consumption patterns. Studying the long-run effectiveness of such targeting could be of substantial importance to establish a sustainable food consumption pattern in the population.

Data availability statement

The data supporting this study is owned by the Norwegian Institute of Bioeconomy Research (NIBIO) and was utilized under license for this specific study. The data associated with our study has not been deposited into a publicly available repository, and the authors are not authorized to share or make the data available.

Ethics statement

Norwegian Monitor Survey is a syndicated Ipsos study. Ipsos complies with the Data Protection Act and is obliged to comply with the European Data Protection Regulation (GDPR) regarding the processing of personally identifiable information. Ipsos AS is a member of the Norwegian Market Analysis Association (NMF) and is Quality Management System (ISO 9001) and Market, Opinion and Social Services (ISO 20252) certified. Ipsos is also a member of European Society for Opinion and Marketing Research (ESOMAR) and follows the guidelines set by ESOMAR. These guidelines regulate issues of ethics and confidentiality in market research. Further Ipsos AS has their own data protection officer (DPO). Consent from participants were obtained according to GDPR and ISO 20252 guidelines.

CRediT authorship contribution statement

Aida T. Ardebili: Writing – original draft, Software, Methodology, Data curation, Conceptualization. **Kyrre Rickertsen:** Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e31326.

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