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Sustainable HEalthy Diet practices: a cross-sectional analysis of an adult Greek sample

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Abstract

Background Sustainable nutrition is based on foods with a low environmental impact, accessible and affordable, ensuring protection of the biodiversity, while including the cultural elements of each geographical region. The present cross-sectional study aimed to evaluate adherence to a sustainable diet and the perceived environmental benefit of adopting a sustainable diet among adults in Greece.

Methods The Sustainable HEalthy Diet (SHED) questionnaire evaluated sustainable nutrition practices and awareness in a sample of 607 adult Greeks recruited through social media.

Results A positive association was revealed between healthy eating, a plant-based diet and organic awareness. Healthy eating was related to the consumption of low-salt and low-sugar products, avoiding added salt and ultra-processed foods (UPFs), as well as limiting sweets and soft drinks. Most participants (94.6%) were flexitarians, consuming meat instead of plant-based foods, although showing a preference for legumes over meat products. Most (86.8%) failed to meet the 5-a-day recommendations for fruit and vegetables, which were bought mainly from supermarket chains, with men resolving to electronic commerce purchases, while women preferring small, local grocery shops. Most responders consumed tap water (54.9%) and homemade meals daily (75.0%). Many participants (32.8%) reported separating and recycling food scraps at home, using neighborhood composters. When organic produce was selected, this involved mainly fruits and vegetables. Between men and women, the latter adopted a plant-based diet to a greater extent, consumed fewer soft drinks, were keener to consume local produce, limit meat intake and eat crops that are pesticide- and herbicide-free. Overall, Greek consumers show preference to local products. Most of them fail to compost and cut down on meat intake. The tool's internal consistency measured by Cronbach alpha was 0.702 and 0.736 for the healthy eating and sustainable eating domains respectively, 0.798 for the environmental domain, while the other domains had lower scores due to contradictory questions. Our Confirmatory Factor Analysis (CFA) demonstrated a good fit (CFI = 0.896, TLI = 0.87) with strong positive relationships between healthy eating, a plant-based diet and organic awareness.

Conclusions The results indicate that adult Greeks more easily implement some aspects of sustainable nutrition (organic, local foods), while others appear more difficult (compost, reduce meat intake). Nonetheless, the results can

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be useful in designing interventions to increase dietary sustainability awareness among Greeks, including educational programs and improved infrastructures.

Keywords Ultra-processed foods, Sugar, Salt, Meat, Vegetarian, Climate change, Food waste, Recycle, Food compost, Organic food, Plant-based meat alternative

Background

According to the Food and Agriculture Organization (FAO) [1], currently, the world faces several intertwined nutritional and environmental challenges, threatening human and planetary health. Climate change can affect both the quantity of grown food, but also, its quality. Drought can alter and reduce the concentration of essential nutrients–nitrogen (N) and phosphorus (P)– by up to 50% in plants such as legumes, cereals and grasses [2]. In parallel, low levels of Iron and Zinc, protein, and B-complex vitamins have been assessed in several crops as the epiphenomenon of increased atmospheric CO_2 concentrations [3–5]. Direct associations linking health, nutrition and the environment are apparent, forcing a swift in the food systems towards a direction improving all three parameters concomitantly. Research suggests that diets that negatively affect people's health are also those that carry the greatest environmental impact in terms of greenhouse gas emissions (GHG) land and water use. However, this association is not always linear [6].

The concept of sustainable nutrition has existed for decades now, linking the achievement of nutritional requirements with attaining the lowest possible environmental footprint [7]. It is based on foods with a low environmental impact, accessible and affordable, ensuring biodiversity protection and including the cultural elements of each geographical region [7]. Although the necessity for a shift towards sustainable nutrition is evident, the concept remains perplexing and ununderstood by many individuals. Various educational programs have been developed, and difficulties have been noted in their implementation [8]. For most consumers, knowledge of sustainable nutrition depends on their information-seeking, or related to their profession. For instance, in Spain, health professionals and health-related students appear to be more informed and tend to adhere more closely to sustainable nutrition standards than the general population [9].

In recent years, our knowledge of making healthier food choices has increased, but there still needs to be more awareness regarding the environmental impact of these choices [10]. Although consumers may be willing to change a few of their habits, they remain resistant to improving all their unhealthy habits. In parallel, some individuals appear keener to implement changes, while others show resistance [11]. The challenge lies in understanding what propels readiness to change among consumers concerning climate change. For this, it is important to assess population knowledge and the level of adherence to the principles of sustainable nutrition [10, 12]. The present cross-sectional study aimed to evaluate adherence to sustainable nutrition standards and the perceived environmental benefit of adopting a sustainable diet among Greek adults.

Methodology

Participants

Participants were recruited through online forums and social media advertisements from March until November 2022. The inclusion criteria involved adults in Greece willing to participate in the study. The study was designed, promoted and completed through online questionnaires, and responses were anonymous. Ethical permission was granted by the University of Thessaly (77/20.12.2024), and each participant provided consent prior to participation. A total of 608 participants were initially recruited, but due to missing data, the final sample consisted of 607 adults. Participant characteristics are presented in Table 1.

Tools

Socio-demographic and lifestyle data, including age, gender, education level, parenthood and following a special diet (e.g., vegan, vegetarian, pescatarian), were collected for all participants.

The Sustainable HEalthy Diet (SHED) [13] questionnaire was translated into the Greek language using the forward-backward translation and adapted to fit the Greek culture and diet, with permission from the authors. The questionnaire includes 30 questions divided into several domains assessing healthy diet, environment and sustainable nutrition, socio-cultural and socioeconomic factors, socio-cultural behavior and health, fluid consumption habits and the perceived environmental benefit [13]. The first two domains, namely healthy eating and sustainable eating, are reported on a Likert scale of 1–4, ranging from "Almost never", "Seldom", "Often", and "Almost always". Data regarding the consumption of ready meals (Ready meals score) (domain: Socio-cultural and Health) and soft drinks (soda score) are reported on a Likert scale of 1–6, ranging from "Never", "Rarely", "Occasionally", "Sometimes ", "Often", "Most of the time" "Daily or almost daily", whereas data on water consumption (water score) are reported on a Likert scale ranging between 1 and 4. The "buy fruits and vegetables (BFV)" score (domain: Socio-cultural and Socioeconomic)

Table 1 Baseline characteristics of the sample ($N=607$)

Gender	Men/Women/Other-NR (*n*)	182/419/6
Educational level	Middle school/high school/VET/University/Postgraduate/NR (*n*)	12/191/35/302/59/8
Age (years)		31.7 ± 11.7
Have children	Yes/No (*n*)	418/189
On a special diet	Flexitarian/Vegetarian/Vegan (*n*)	574/20/13

NR: not reported; VET: Vocational education and training

proposes eight distinct locations where consumers can purchase their produce. It is reported on a Likert scale ranging between 1 and 4. More questions include the plant-based self-assessment, which consists of a score assessing how often people consume plant-based products, reported on a visual analog scale (VAS) scale of 1–10. The sociocultural domain includes two multiple-choice questions, where people who purchase organic products specify the type of organic food they consume and the place of purchase. Finally, the environmental component includes questions regarding the availability of distinct kinds of recycling bins in the residency neighborhood. Questions regarding specific issues that are only applicable in Israel were either omitted, or adapted to the Greek alternative. This involved questions on purple and orange recycle bins, Israeli brands of soda, etc. Previous research has associated the SHED questionnaire with adherence to the Mediterranean diet, and the proportion of animal-sourced foods consumed [14].

Statistical analyses

Statistical analyses were performed utilizing the R language [15] [version 4.3.2 (2023-10-31), R Foundation for Statistical Computing, Vienna, Austria]. A p-value < 0.05 was considered statistically significant. Descriptive statistics were performed, and Mann-Whitney U or chi-squared tests were applied wherever appropriate to test if men and women responded differently to the questionnaire's domains. Participants not specifying their gender were excluded from the Mann-Whitney U and chi-square analyses.

Regarding the SHED questionnaire [13], we decided not to calculate the Index score but to evaluate each domain separately. This was agreed upon because specific aspects of the questionnaire were only applicable in Israel, which is the country where the tool was designed. Thus, calculating an index score while omitting particular score elements might be considered as arbitrary. As a result, the answers to the six main domains (healthy eating, sustainable eating, BFV score, ready meals, water score, soda score) were presented using Likert scale plots. The SHED index score [13] was calculated by Tepper et al. by performing a principle component analysis (PCA) on 17 items from healthy eating and sustainable eating domains, along with water score, soda score, recycling habits, BFV score, organic food consumption, ready meals and plant-based diet. PCA identified six components (eigenvalues > 1.0, loadings > 0.3) for a training set and was verified on a validation set. The final SHED Index was the standardized sum of these components.

Internal consistency was assessed using Cronbach's alpha [16]. Furthermore, a confirmatory factor analysis (CFA) was performed, utilizing the same observed variables previously provided by Tepper [13]. The CFA was conducted to validate the hypothesized factor structure of the model. The model included four latent variables (healthy eating, organic awareness, drinking habits and plant-based diet), with each latent variable represented by a set of observed variables. Factor loadings were used to examine the relationship between the latent and the observed variables. To allow for potential correlations between the latent variables, the oblimin rotation method (an oblique rotation) was applied. The CFA model was initially estimated using a training dataset, and its results were subsequently validated on an independent validation dataset to ensure generalizability.

To evaluate the model's goodness-of-fit, the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) were calculated. These indices, commonly used in CFA, provide insight into how well the hypothesized model fits the observed data, with values closer to 1 indicating a better fit [17, 18].

Results

Results of SHED's domains

The results of the SHED's first domain, namely healthy eating, are presented in Table 2. Most participants reported consuming meat instead of plant-based foods. Only 13.2% consumed the recommended five portions of fruit and vegetables daily. Women reported avoiding fatty meat often, and choosing instead beans, legumes, fish, poultry and low-fat meat. Nearly half of the participants preferred legumes over meat products and avoided ultra-processed foods (UPFs). The majority of the sample preferred low-salt products and showed interest in controlling the amount of salt they consume. Most participants were interested in consuming low-sugar foods while limiting the consumption of sugar-sweetened beverages (SSB) and sweets. Women almost always chose water as their main beverage. Details regarding the healthy eating domain are detailed in Table 2, and a visualization of the participants' answers is reported in Supplementary Fig. 1.

SHED's sustainable eating domain consists of 7 questions, and the answers of the participants herein are presented in Table 3 and Supplementary Fig. 2. Most respondents (67.2%) reported not separating and

Table 2 Answers regarding SHED's healthy eating domain (10 questions) ($N=607$)

Questions	Answer	Men (%)	Women (%)	*p* value	Total (%)	Total (*n*)
1. As a main course, I prefer and eat meat products (poultry, beef, fish) more times per week compared to plant-based food (grains, legumes, fruits and vegetables)	Almost never	3.3%	7.6%	< 0.001	6.6%	40
	Seldom	14.8%	25.3%		22.1%	134
	Often	59.9%	54.7%		56.2%	341
	Almost always	22.0%	12.4%		15.2%	92
2. In a course of a week, I eat more plant-based food (grains, legumes, fruits and vegetables) instead of animal source foods (meat, dairy products and eggs)	Almost never	8.8%	5.0%	< 0.001	6.1%	37
	Seldom	47.8%	32.2%		36.9%	224
	Often	35.2%	49.4%		45.1%	274
	Almost always	8.2%	13.4%		11.9%	72
3. I eat a variety of fruits and vegetables, at least 400 g, or 5 portions daily	Almost never	18.7%	17.7%	0.740	18.0%	109
	Seldom	35.2%	36.0%		35.9%	218
	Often	34.6%	32.7%		32.9%	200
	Almost always	11.5%	13.6%		13.2%	80
4. I try to avoid meat and fatty meat products and prefer instead beans, legumes, lentils, fish, poultry or low-fat meat	Almost never	22.5%	11.7%	< 0.001	15.0%	91
	Seldom	42.9%	31.7%		35.1%	213
	Often	28.0%	39.6%		36.1%	219
	Almost always	6.6%	16.9%		13.8%	84
5. I prefer buying and consuming low-salt products	Almost never	18.1%	22.4%	0.087	20.9%	127
	Seldom	25.8%	28.4%		27.8%	169
	Often	39.6%	36.3%		37.2%	226
	Almost always	16.5%	12.9%		14.0%	85
6.I try to avoid buying and consuming UPF products	Almost never	13.2%	12.4%	0.780	12.7%	77
	Seldom	31.3%	32.0%		32.0%	194
	Often	40.7%	39.1%		39.3%	239
	Almost always	14.8%	16.5%		16.0%	97
7. I prefer drinking water (or carbonated water) as a main beverage	Almost never	2.2%	3.3%	0.023	3.0%	18
	Seldom	11.5%	9.5%		10.2%	62
	Often	42.3%	31.3%		34.6%	210
	Almost always	44.0%	55.8%		52.2%	317
8. I choose low-sugar foods	Almost never	8.8%	9.3%	0.132	9.1%	55
	Seldom	26.9%	32.5%		31.1%	189
	Often	42.3%	40.8%		41.0%	249
	Almost always	22.0%	17.4%		18.8%	114
9. I limit the frequency of consumption of sweetened beverages and sweets	Almost never	9.3%	6.2%	0.301	7.2%	44
	Seldom	25.8%	23.4%		24.2%	147
	Often	40.1%	45.3%		43.7%	265
	Almost always	24.7%	25.1%		24.9%	151
10. I control the amount of salt I consume and limit adding salt to my meals	Almost never	16.5%	19.6%	0.884	18.5%	112
	Seldom	24.2%	22.2%		22.7%	138
	Often	41.2%	35.6%		37.2%	226
	Almost always	18.1%	22.6%		21.6%	131

SHED: Sustainable HEalthy Diet [13]; UPF: Ultra-processed foods

recycling food scraps at home. On the other hand, those who separated food scraps with a composter, utilized a neighborhood composter. Regarding the food source consumed, most participants preferred buying and eating food made in Greece, with the women being more inclined to consume local food. Additionally, women seemed more invested in limiting their meat consumption and eating crops that are low/free of pesticides and herbicides.

SHED's BFV domain includes eight questions assessing the source of the acquisition of fruit and vegetable products. As expected, most participants rarely self-grew fruits and vegetables, nor do they acquire them directly from the farm, the farmer, or a biological produce market. Instead, they preferred supermarkets or market chains. Women preferred shopping from small, non-chain grocery stores, while men utilized online delivery from supermarkets to a greater extent. Details of the

Table 3 Answers regarding SHED's sustainable eating domain (7 questions) ($N=607$)

Questions	Answer	Men (%)	Women (%)	*p* value	Total (%)	Total (*n*)
1. I separate waste and recycle food scraps at home with a composter (tool for producing organic fertilizer from food scraps)	Almost never	70.3%	65.9%	0.193	67.2%	408
	Seldom	14.3%	12.9%		13.2%	80
	Often	6.6%	8.8%		8.2%	50
	Almost always	8.8%	12.4%		11.4%	69
Compost location	Neighborhood				47.2%	75
	Private (backyard)				36.5%	58
	Home (indoors)				16.4%	26
2. I prefer buying and eating food made in Greece, as much as possible	Almost never	8.8%	4.1%	< 0.001	5.4%	33
	Seldom	23.6%	13.8%		16.8%	102
	Often	44.0%	51.8%		49.4%	300
	Almost always	23.6%	30.3%		28.3%	172
3. I limit my meat consumption	Almost never	28.0%	13.4%	< 0.001	17.6%	107
	Seldom	47.8%	38.7%		41.7%	253
	Often	19.2%	37.9%		32.1%	195
	Almost always	4.9%	10.0%		8.6%	52
4. I try to eat crops that are reduced or free of pesticides and herbicides	Almost never	21.4%	10.5%	0.009	13.7%	83
	Seldom	23.1%	27.4%		26.0%	158
	Often	39.0%	38.7%		38.9%	236
	Almost always	16.5%	23.4%		21.4%	130
5. I try to consume organic food products on a regular basis	Almost never	22.0%	16.5%	0.232	18.0%	109
	Seldom	31.3%	34.6%		33.6%	204
	Often	39.0%	38.4%		38.7%	235
	Almost always	7.7%	10.5%		9.7%	59
6. I am aware and act to reduce food waste in my close environment	Almost never	13.2%	4.8%	< 0.001	7.2%	44
	Seldom	28.0%	14.6%		18.8%	114
	Often	38.5%	51.3%		47.3%	287
	Almost always	20.3%	29.4%		26.7%	162
7. I eat plant-based foods as an alternative to meat on a regular basis	Almost never	35.2%	22.4%	< 0.001	26.2%	159
	Seldom	41.2%	35.3%		37.2%	226
	Often	19.2%	33.9%		29.2%	177
	Almost always	4.4%	8.4%		7.4%	45

SHED: Sustainable HEalthy Diet [13]

participant's answers are listed in Table 4, while the Likert plot visualizing the results is presented in Supplementary Fig. 3.

The ready meals domain consists of 6 questions assessing the frequency of consumption of ready or frozen meals compared to homemade meals (Table 5 and Supplementary Fig. 4). Most participants (75%) reported eating homemade food daily or almost daily, while the daily consumption of frozen or pre-prepared meals was low in the sample (< 1%). Women had a more active role in cooking, with 65.6% cooking food by themselves daily compared to approximately 1/5 of the men.

The water domain contained questions regarding water consumption (Table 6 and Supplementary Fig. 5). The results revealed that most participants (55%) preferred drinking unflavored tap water most of the time, with 40% of the respondents using home water filters. On the other hand, results of the soda score domain (Table 6 and Supplementary Fig. 6) revealed that nearly half of the sample consumed soft drinks rarely (47.8%), with 42.8% never opting for diet beverages. Between genders, men reported a higher frequency of soft drinks consumption than women.

SHED's socio-cultural domain consisted of 2 questions assessing the kind and source of organic foods consumed (Table 7). A preference was noted for buying biological produce from supermarkets (49.3%) or small shops (44.3%), while 15.7% of the sample did not buy organic products. Most participants consumed organic fruits and vegetables, while dairy followed closely with cereals and pulses, and meat products were the least consumed organic food.

In the next domain, participants were asked to rate what percentage of their diet consisted of plant-based food on a VAS scale (1–10). Nearly half of the respondents (53.6%) based 50–70% of their diet on plant-based foods. Men reported adopting a plant-based diet at a mean of 5.5 ± 2.2, whereas women incorporated

Table 4 Answers regarding SHED's BFV domain (8 questions) ($N=607$)

Question Where do you buy your fruits or vegetables	Answer	Men (%)	Women (%)	*p* value	Total (%)	Total (*n*)
1. Self-grow	Almost never	55.5%	58.2%	0.491	57.3%	348
	Seldom	21.4%	19.8%		20.1%	122
	Some of the time	17.6%	19.1%		18.8%	114
	Most of the time	5.5%	2.9%		3.8%	23
2. Direct delivery / Box from the farmer	Almost never	47.8%	43.2%	0.791	44.3%	269
	Seldom	19.8%	28.2%		25.9%	157
	Some of the time	28.0%	24.3%		25.5%	155
	Most of the time	4.4%	4.3%		4.3%	26
3. Buy directly at a farm	Almost never	45.6%	48.2%	0.356	47.1%	286
	Seldom	23.6%	26.0%		25.2%	153
	Some of the time	26.4%	21.7%		23.4%	142
	Most of the time	4.4%	4.1%		4.3%	26
4. At the market (chains)	Almost never	11.5%	14.1%	0.055	13.5%	82
	Seldom	20.9%	22.7%		22.1%	134
	Some of the time	39.0%	43.4%		42.0%	255
	Most of the time	28.6%	19.8%		22.4%	136
5. At a grocery store, or at a small, non-chain grocery store	Almost never	13.7%	10.0%	< 0.001	11.2%	68
	Seldom	28.0%	15.3%		19.1%	116
	Some of the time	46.2%	50.8%		49.4%	300
	Most of the time	12.1%	23.9%		20.3%	123
6. At a country store/green grocery (fruits & vegetables store)	Almost never	47.8%	49.2%	0.885	48.8%	296
	Seldom	31.3%	25.8%		27.5%	167
	Some of the time	17.0%	22.4%		20.8%	126
	Most of the time	3.8%	2.6%		3.0%	18
7. Supermarket– Home delivery	Almost never	75.8%	83.3%	0.040	80.9%	491
	Seldom	12.6%	7.6%		9.1%	55
	Some of the time	7.7%	6.2%		6.9%	42
	Most of the time	3.8%	2.9%		3.1%	19
8. Supermarket– Shop in person	Almost never	12.1%	11.9%	0.744	12.2%	74
	Seldom	14.8%	16.2%		16.0%	97
	Some of the time	35.7%	31.5%		32.8%	199
	Most of the time	37.4%	40.3%		39.0%	237

BFV: Buy fruits and vegetables; SHED: Sustainable HEalthy Diet [13]

significantly more plant-based products (6.4 ± 2.0, $p < 0.001$). Finally, SHED's environmental domain records the availability of organic, glass, paper recycling and plastic recycling bins (Table 7). Nearly all participants (90%) reported the availability of a blue bin in their neighborhoods, while organic waste separation was not common.

Internal consistency and CFA of the results

Regarding the internal inconsistency of the tool, the healthy eating and sustainable eating domains showed a Cronbach alpha of 0.702 and 0.736, respectively. For the environmental domain, a Cronbach alpha of 0.798 was calculated, while the other domains had lower scores, since the questions were contradictory.

The results of the CFA are detailed in Fig. 1. The CFI was 0.896, and the TLI was calculated at 0.87, indicating a good model fit. The latent variables included healthy eating, drinking habits, organic awareness and plant-based diet. The observed variables in each category were the same as the ones reported by Tepper [13]. The factor loadings for all latent variables revealed mostly strong relationships with their respective observed variables. The elaborate, plant-based diet demonstrated a strong, positive relationship (factor loadings: 0.69–0.82) with its observed variables "limit red meat", "prefer plant-based food", "avoid fatty meat", "follow the plant-based diet" and a negative loading with "prefer animal-based food". Organic awareness was strongly positively associated with its respective observed variables (choosing biological produce and consuming organic and food low in pesticides, with factor loadings: 0.62–0.87), while a weaker relationship was noted with composting (factor loadings: 0.2). Healthy eating demonstrated a strong relationship (factor loadings: 0.64–0.77) with preferring low-salt and low-sugar products, avoiding added salt and processed food, as well as with limiting sweets and soft drinks. On

Table 5 Answers regarding SHED's ready meals score (6 questions) ($N=607$)

Questions	Answer	Men (%)	Women (%)	*p* value	Total (%)	Total (*n*)
1. Eat pre-prepared meals - frozen	Never	14.8%	29.1%	< 0.001	24.9%	151
	Rarely	28.6%	27.9%		27.8%	169
	Occasionally	30.2%	21.7%		24.2%	147
	Sometimes	18.1%	15.8%		16.6%	101
	Often	7.7%	5.0%		5.9%	36
	Daily/almost daily	0.5%	0.5%		0.5%	3
2. Eat pre-prepared meals–chilled (packed)	Never	35.7%	61.6%	< 0.001	53.5%	325
	Rarely	25.3%	22.2%		23.1%	140
	Occasionally	18.1%	8.1%		11.2%	68
	Sometimes	9.3%	5.5%		6.8%	41
	Often	11.5%	2.1%		5.1%	31
	Daily/almost daily	0%	0.5%		0.3%	2
3. Eat homemade or home-cooked food (not necessarily at your home)	Never	0.5%	0%	< 0.001	0.2%	1
	Rarely	3.8%	1.0%		1.8%	11
	Occasionally	4.4%	0.2%		1.6%	10
	Sometimes	10.4%	3.1%		5.3%	32
	Often	22.0%	13.6%		16.1%	98
	Daily/almost daily	58.8%	82.1%		75.0%	455
4. Eat in restaurants or eateries, or cafeterias at work	Never	15.4%	28.4%	< 0.001	24.7%	150
	Rarely	17.0%	23.6%		21.4%	130
	Occasionally	22.5%	17.7%		18.9%	115
	Sometimes	19.2%	17.4%		18.1%	110
	Often	20.9%	9.8%		13.2%	80
	Daily/almost daily	4.9%	3.1%		3.6%	22
5.Cook food by myself (or take part in preparing it)	Never	7.1%	1.7%	< 0.001	3.3%	20
	Rarely	11.5%	2.1%		5.1%	31
	Occasionally	8.2%	4.8%		5.8%	35
	Sometimes	19.8%	7.2%		11.2%	68
	Often	26.4%	18.6%		20.8%	126
	Daily/almost daily	26.9%	65.6%		53.9%	327
6. Consume food cooked 1–3 days prior to eating	Never	4.9%	7.6%	0.476	6.8%	41
	Rarely	12.1%	15.0%		14.0%	85
	Occasionally	16.5%	13.1%		14.0%	85
	Sometimes	34.1%	31.3%		32.5%	197
	Often	23.1%	25.5%		24.7%	150
	Daily/almost daily	9.3%	7.4%		8.1%	49

SHED: Sustainable HEalthy Diet [13]

the other hand, healthy eating revealed a weaker relationship (factor loadings: 0.11–0.19) with consuming homemade meals. Regarding participants' drinking habits, the results showed a negative loading with preferring water and a positive loading with preferring SSB or artificial-sweetened beverages. Overall, a positive relationship was noted between healthy eating, a plant-based diet and organic awareness.

Discussion

The present study was the first to evaluate sustainable eating habits in the Greek population. Overall, the results revealed a positive association between healthy eating, plant-based diet and organic awareness. Healthy eating was related to the consumption of low-salt and low-sugar products, avoiding added salt and processed foods, as well as limiting sweets and soft drinks. Regarding the dietary habits of the sample, most participants consumed meat instead of plant-based products despite showing a preference for legumes over meat products. Most of the sample failed to meet the 5-a-day recommendations for fruit and vegetables. Fruits and vegetables were mainly bought from supermarket chains, with men being savvier in electronic commerce purchases, while women preferred small, local grocery shops. Most responders consumed tap water and homemade meals daily. With regards to recycling, many participants reported separating and recycling food scraps at home, using

Table 6 Answers regarding SHED's water (5 questions) and soda (2 questions) score domains ($N=607$)

Water score **Question: Kindly specify the type of water you drink and the frequency**	**Answer**	**Men (%)**	**Women (%)**	***p* value**	**Total (%)**	**Total (*n*)**
1. Unflavored tap water	Never	14.8%	17.9%	0.361	16.8%	102
	Seldom	12.6%	14.8%		14.0%	85
	Some of the time	15.9%	13.4%		14.3%	87
	Most of the time	56.6%	53.9%		54.9%	333
2. Home water filters	Never	26.4%	34.8%	0.150	32.1%	195
	Seldom	14.3%	13.8%		14.0%	85
	Some of the time	18.1%	11.7%		13.8%	84
	Most of the time	41.2%	39.6%		40.0%	243
3. Large bottled water cooler	Never	32.4%	46.5%	0.002	41.8%	254
	Seldom	36.8%	32.2%		34.1%	207
	Some of the time	21.4%	11.2%		14.3%	87
	Most of the time	9.3%	10.0%		9.7%	59
4. Bottled mineral water	Never	6.0%	5.7%	0.607	5.8%	35
	Seldom	24.2%	29.6%		28.2%	171
	Some of the time	41.8%	35.6%		37.6%	228
	Most of the time	28.0%	29.1%		28.5%	173
5. Bottled sparkling water	Never	40.7%	55.6%	< 0.001	51.4%	312
	Seldom	30.8%	27.2%		28.0%	170
	Some of the time	25.3%	13.1%		16.8%	102
	Most of the time	3.3%	4.1%		3.8%	23
Soda score **Question**: At what frequency do you drink…						
1. Soft drinks (for example Coca-Cola, Sprite, Nestea, etc.)	Never	19.2%	28.2%	0.002	25.5%	155
	Seldom	47.3%	48.4%		47.8%	290
	Some of the time	25.8%	19.3%		21.4%	130
	Most of the time	7.7%	4.1%		5.3%	32
2. Diet beverages (Diet Coke, Diet Sprite, Coke Zero, Pepsi Max, etc.)	Never	42.3%	43.2%	0.302	42.8%	260
	Seldom	25.8%	31.0%		29.3%	178
	Some of the time	17.6%	16.9%		17.5%	106
	Most of the time	14.3%	8.8%		10.4%	63

SHED: Sustainable HEalthy Diet [13]

neighborhood composters. The reported consumption of soda drinks was infrequent, and when organic produce was selected, this involved mainly fruits and vegetables. Between men and women, the latter adopted a plant-based diet to a greater extent, consumed fewer soft drinks, were keener to consume local produce, limit meat intake and eat crops that are pesticide- and herbicide-free.

Adherence to plant-based diets

Participants herein reported that meat prevailed over plant-based products in their everyday diet. Several studies have revealed that the Greek population has moved away from the traditional Mediterranean diet [19–21] towards a more Western diet prototype. The consumption of meat, dairy products and vegetables in the country increased rapidly between the 60s' and 80s', by 100–130%, while the intake of pulses and cereals declined significantly during the same period [22]. Interestingly, today, meat has the greatest share in food expenses within Greek households [23]. On the other hand, the intake of animal fats increased after the 80s', but did not replace the consumption of vegetable oils, such as olive oil [22]. Although the Mediterranean diet is plant-based, oscillations have been apparent in recent decades.

In the present sample, men reported consuming more meat, whereas women reported incorporating significantly more plant-based products than men. This aligns with previous studies revealing universal gender differences in meat consumption, with men consuming more meat across all continents [24]. Some scientists [25], argue that this is due to the hormonally-mediated immunosuppression experienced by women during menstruation, resulting in reduced meat intake. Nonetheless, research also shows that women appear to be more prosocially motivated to follow a plant-based diet–including a vegetarian one–compared to men and tend to adhere more strictly to such dietary patterns [26]. According to Stanley [27], diets interconnect with gender and identity. For instance, more masculine men exhibit a lower

Table 7 Answers regarding SHED's Socio-cultural score (2 questions) and environmental domain (4 questions) ($N=607$)

Socio-cultural score Questions	Answer	Men (%)	Women (%)	*p* value	Total (%)	Total (*n*)
1. When purchasing organic food, kindly specify where do you buy the products (more than one answer may be selected)	Self-cultivate	18.6%	20.5%	0.476	19.8%	120
	Directly from the farmer	35.2%	32.0%		32.6%	198
	Small shop in town	39.6%	47.0%		44.3%	269
	Super market	49.5%	49.9%		49.3%	299
	I don't buy bio produce	14.3%	16.4%		15.7%	95
	Social shop	2.2%	1.2%		1.5%	9
	Other	2.2%	4.1%		3.5%	21
2. Kindly specify the type of organic food you consume (more than one answer may be selected)	Vegetables	49.5%	55.6%	0.062	53.9%	327
	Fruits	44.9%	53.4%		51.6%	313
	Grains and legumes	20.3%	25.5%		24.2%	147
	Dairy products	25.8%	24.1%		24.5%	149
	Meat products	24.7%	16.0%		18.8%	114
Environmental domain Questions						
Is (or was) there separation of wet (organic) waste customary where you live?	Yes	14.8%	14.1%	0.908	14.5%	88
	No	85.1%	85.9%		85.5%	519
Is there a blue trash bin where you live?	Yes	91.2%	93.3%	0.458	92.6%	562
	No	8.8%	6.7%		7.4%	45
Is there a plastic bottles recycling bin where you live?	Yes	64.3%	60.1%	0.386	61.3%	372
	No	35.7%	39.9%		38.7%	235
Is there a glass trash bin where you live?	Yes	53.8%	57.5%	0.457	56.2%	341
	No	46.2%	42.5%		43.8%	266

SHED: Sustainable HEalthy Diet [13]

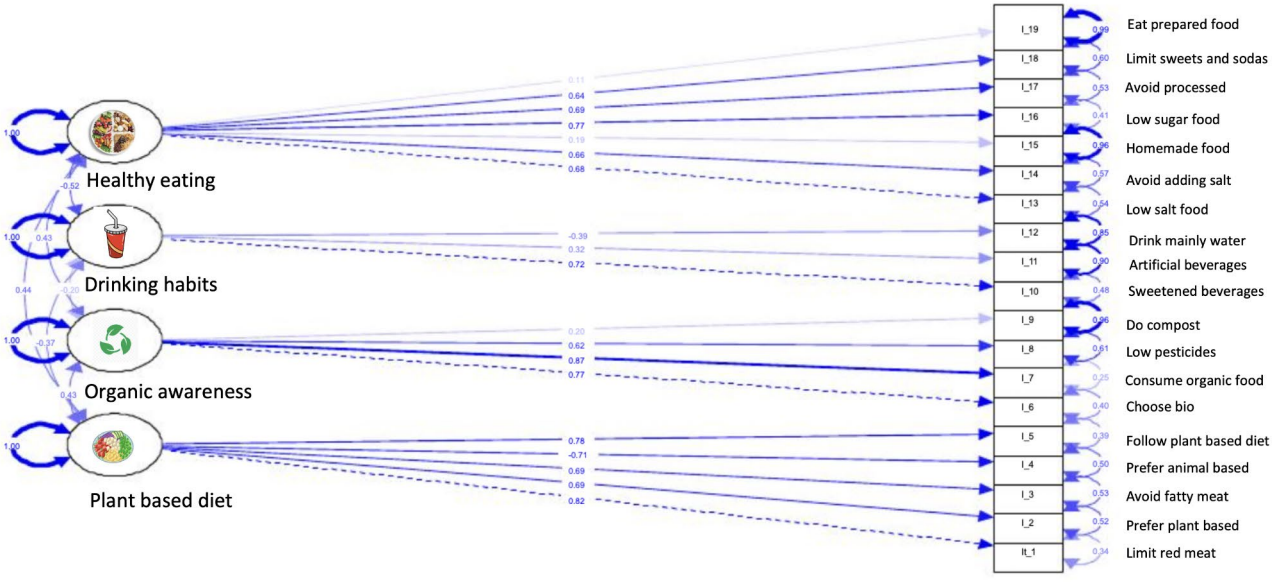

Fig. 1 Confirmatory factor analysis

possibility of reducing meat consumption or considering following a vegan diet and a greater belief that meat consumption is normal and essential [27]. In parallel, greater conformity to traditional gender roles seems to predict the frequency of meat consumption, as well as openness to more plant-based diets and vegetarianism [28]. Nonetheless, in the present sample, as in most of the world, fruit and vegetable consumption appears to remain below the recommendations [29].

Women herein reported regularly choosing plant-based foods as an alternative to meat. Recently, many products have been launched on the market with sensory attributes akin to animal products [30]. Although consuming plant-based meat alternatives (PBMAs) is associated with

several health benefits, ethical beliefs and sustainability, consumer knowledge has been shown to influence purchasing attitudes and consumption [31]. In parallel, it should be noted that PBMAs tend to contain more carbohydrates and sugars compared to meat and protein content is lower and less easily absorbed compared to the typical animal products [32]. Furthermore, we are still determining what the long-term intake of PBMAs brings and if nutritional deficiencies may be apparent. Research shows that when consumers have a choice, they choose first animal meat, then plant and finally artificial meat [33]. Important factors in the selection of alternative, plant-origin types of meat are the appearance and texture, but also their taste [34]. Consumers are likelier to choose PBMAs if they are very close in taste and appearance to the real meat [35]. However, the adoption of these new alternative protein sources may need to be faster as they require acceptance and integration into the dietary habits of people around the world.

Other healthy eating habits

Most participants herein reported avoiding added salt, sugar, SSB, sweets and UPFs. Previous research in the country revealed a high salt intake, greatly exceeding the World Health Organization (WHO) recommendation [36]. In contrast, European studies have shown that salt intake exhibits a geographical gradient, with Eastern European countries exhibiting the greatest consumption [37]. Overall, younger Greek adults appear to be better informed regarding the health benefits of reduced salt intake [38]. As for sugars, recent research [39] revealed that most young Greek adults are taking action to limit sugar intake despite needing to be made aware of the relevant WHO recommendations. Overall, in the present sample, healthy eating was related to the consumption of low-salt and low-sugar products, avoiding added salt and UPFs, as well as limiting sweets and soft drinks.

With regards to UPFs, even though most participants reported avoiding them, a recent study revealed that 70.2% of all foods included in the Mediterranean diet food pyramid were identified as UPFs [40], indicating that the shift towards a more processed diet may be inevitable. According to recent research [41], a modest decrease in UPF consumption in Europe over time, with few country exceptions. Interestingly, a higher sugar intake is associated with a greater energy share from UPFs [41]. Apart from their unhealthy dimension though, UPFs also threaten all dimensions of environment sustainability [42, 43], as lower UPF dietary contents are associated with lower diet-related environmental footprints. Similarly, consuming homemade meals, as reported herein by the majority of participants, reduces GHG and food costs, while increasing the nutritional value and adequacy of consumed foods [44, 45], adding sustainability points.

Regarding drinking habits, unflavored tap water was the most popular beverage consumed by participants "most of the time", many using home water filters to improve water quality. Tap water has also been reported to be the most popular beverage in previous studies conducted in Greece [46], Spain [47], and other countries [48]. Depending on the geographical region, a great sustainability benefit may be observed when consuming water from public supply compared to bottled water [49, 50]; however, various challenges are apparent when tap water is unsafe or of low-quality [51]. In Europe, improving access to tap water, upgrading water quality standards and promoting the benefits of tap water consist of priorities according to the Drinking Water Directive [52]. Participants rarely selected diet beverages, whereas soft drinks, in general, were more popular among men compared to women. Research is unanimous on the existence of a negative association between soft/SSB consumption and water drinking, with greater soft drink intake reducing the volume of water drank daily [53, 54]. The amount of tap water drank is related to the water safety perception of each individual [55], water access and the economic resources available [56, 57]. As such, those considering tap water unsafe, contaminated, or as having a "bad" taste are more likely to select bottled water or SSBs [54, 58].

Environmental benefits

Regarding the environmental benefit of following a sustainable diet, the respondents herein indicated a high perception regarding the need for reducing food waste. In contrast, more than 67% of the participants reported "almost never" composting. Overall, the sample showed eagerness to reduce food waste and consume food without pesticides, in a large proportion (74 and 60% respectively). Although self-efficacy, attitude and environmental concern are important components of food waste reduction [59], in the USA [60], guilt and setting a good example were superior motivators for reducing food waste compared to common environmental or economic factors.

In the present sample, nearly half of the participants try to choose organic foods, mainly fruit and vegetables. Consumer attitudes regarding organic foods are related to health benefits, local origin of food, environmental impact, and food safety [61]. Most consumers perceive organic foods as more natural, nutritious, and environmentally friendly than conventional ones [62]. In parallel, several factors influence consumers' attitudes toward purchasing organic foods, including knowledge, health consciousness, perceived norms, and perception of price influence [62]. Furthermore, consumer demand is apparent mainly in Western societies for low-pesticide produce as a compromise between organic and conventional

products, linking price and safety [63]. Organic produce bought from small local shops or large markets consists of a more sustainable option, supporting the economy of the local community at the same time. Also, many respondents purchase organic produce directly from the farmers, further increasing sustainability while promoting a circular economy. In China [64], perceived food quality was shown to mediate the association between environmental consciousness and intention to purchase organic foods. In contrast, in the present study, a positive relationship was noted between healthy eating, plant-based diet and organic awareness.

Over 90% of the participants had direct access to a blue recycle bin, and most used it greatly. At the same time, only 1/4 of the sample reported using it systematically. Unfortunately, though, most participants did not have access to liquid waste bins and may need to be made aware of their existence. In other countries, such as the UK [65], consumers have access to more diverse recycle bins (plastic, cardboard, metal, paper, and glass) and have been shown to use them more. Overall, the present study highlights the need for more recycling bins–including compost bins– in Greece to educate the public and meet sustainable goals. According to Jacobsen [66], avoiding plastic packaging and recycling behaviors are associated, based on shared motives and reasoning.

Viability

Sustainable dietary patterns should be designed to be specific to each specific environment, and therefore, there is no ideal dietary pattern for everyone. Our knowledge of healthier eating habits is constantly growing and choosing foods with a lower environmental impact. Still, we should remember the socio-economic dimensions of sustainability in this context [7, 67]. In the concept of sustainability, acceptable recommendations should be developed, specific to each geographical region, integrating the social, cultural and economic dimensions of each society [7, 68]. Sustainability must also consider gender and additionally the race of individuals, as well as the financial status of the country where the individuals reside. Research suggests that citizens are more compliant with governmental recommendations, which is a more realistic approach to improving health and protecting the environment [7].

More than half of the participants stated that environmental sustainability influences their food choices, indicating that they know the reciprocal relationship between food consumption and the environment. This is consistent with a recent study in which consumers identified dietary behaviors such as avoiding food transported by airplanes, choosing organic products, and eating a plant-based diet as having the greatest environmental benefit [69]. Consumers acknowledge the environmental benefit of most sustainable diet recommendations and report acting or trying to maintain the implemented change in their eating behavior. Many participants have already started adopting the recommendations to reduce food waste and avoid excessive packaging. In contrast, fewer Greeks seem to implement the recommendations on prioritizing plant-based proteins and choosing organic produce. This indicates that behaviors that do not require special knowledge and are closer to individuals' abilities are more easily adopted [70].

Supporting local products

Most participants preferred purchasing and consuming food made in Greece as much as possible. In Austria [71], purchasing local products consists of supporting the regional economy and agriculture, whereas shorter transport routes were identified as additional important contributors to supporting local products. Most people combine sustainability with local production [72]. According to Stein and Santini [73], however, local food should not be equated with sustainability. In many cases, local food cannot ensure food security, and it always has a low carbon footprint. Many diverse factors appear to influence the environmental sustainability of food systems aside from transportation [73]. As for social sustainability, supporting local food systems may enhance rural development and the sense of community [73]. Finally, as for economic sustainability, for some farmers, selling their produce through short supply chains might be of benefit, but one size appears to fit only some [73].

Sustainability and consumer food choices

Differences have been noted in the perceptions and priorities regarding sustainability, both individually and between countries, reflecting different social elements and cultures. Some countries may prioritize the protection of natural resources, as in the Netherlands, while in Denmark, the welfare of animals is the main priority. In France, eating seasonal and local foods is considered a priority [74]. In general, it needs to be clarified whether the concept of sustainability in food choice should be treated as a single and multidimensional concept or whether each aspect should be distinguished separately [75, 76].

Various socio-demographic variables influence consumers' knowledge, attitudes and behaviors regarding their food choices. Gender and educational level appear to affect adopting more sustainable dietary choices. In the study, just over 2/3 of the total participants were women, which indicates that they have more concerns about sustainable nutrition and can act accordingly, which is also revealed in the literature [77]. Women also appear more "accessible" to information on the impacts and benefits of meat consumption reductions, ecological

issues and animal welfare concerns and how it relates to meat consumption [35]. Nevertheless, the specific target group of interventions can be hindered in their decisions if the male partner or the children are negative in this direction. Likewise, the male partner may reduce meat consumption due to the influence of his partner [78].

What influences consumers to follow a sustainable diet is first to understand its meaning and then to make changes in this direction. What positively affects our understanding of the concept is that it should agree with how an official body such as the FAO defines it and acknowledge the health and planetary advantages gained by adhering to this diet [79]. Negative factors include conflicting interests and choice uncertainty [79].

Cultural adaptation of dietary assessment tools

The present study aimed to translate and adapt the SHED questionnaire in the Greek setting. This specific questionnaire was chosen for its comprehensiveness in assessing dietary sustainability, providing insight on many distinct aspects of sustainable nutrition. Cultural adaptation consists of a very useful procedure in nutritional assessment. When tools are used intact without cultural adaptation, this may introduce reporting bias in the results [80]. The SHED does not calculate CO_2 emissions from foods imported from other countries as other indexes do, thus the cultural adaptation was relatively easy. Furthermore, it was successful in depicting the fact that most Greeks use tap water as it is considered as "clean".

Limitations of the present study

The present study had a cross-sectional design, which is the most appropriate to answer the research question. However, the sample was not random but rather purposeful, with most participants being women who belonged to the < 55 years age group, thus being technologically savvy and able to answer online questionnaires. Most participants herein were university graduates, and a small percentage held a master's/doctoral degree. Studies associate educational level with a tendency to select more sustainable foods and an increased perception of the effects of excessive meat consumption and its replacement with substitute products [81]. Last but not least, we have previously outlined the limitations of all questionnaires and indexes evaluating sustainable diets [7]. Unfortunately, at the moment, none of the available tools can cover all aspects of sustainability and reveal robust associations with population health. We are still in the process of designing appropriate tools for dietary sustainability, adhering to the principles of nutritional epidemiology.

Conclusions

The present study aimed to record and present the sustainable nutrition practices of adult Greeks, their beliefs and their perception regarding the environmental impact using a specific tool. Some aspects of sustainable nutrition are more easily implemented and understood by adult Greeks, while others appear more difficult to realize and execute. Aspects like recycling, composting, reducing meat intake and increasing the consumption of plant-based foods seem to be suboptimal in the country, requiring improvement. The results can be useful in designing interventions to increase dietary sustainability awareness among Greeks, including educational programs and improved infrastructures.

Supplementary Information

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Supplementary Material 1

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Author contributions
IA, ArGk, TV, VAM, DGG and MGG wrote the main manuscript. AG and KMK performed the statistical analyses, created the figures, designed the tables and drafted the results. SPM and AlGi recruited participants, collected the data and created the database used for the analyses. IA, DPB, TV, VAM additionally performed a literature review to support drafting the manuscript. DPB, VAM, DGG and MGG conceived and supervised the study. All authors reviewed the manuscript.

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Data availability
Data can be provided after communication with ArGk and KMK.

Declarations

Ethics approval and consent to participate
This study follows the Declaration of Helsinki and all participants in the study provided their written informed consents before their participation. All procedures of the study were approved by the University of Thessaly (77/20.12.2024).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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