Appetite 194 (2024) 107194

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Select dietary changes towards sustainability: Impacts on dietary profiles, environmental footprint, and cost

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ARTICLE INFO

Handling editor: Kathleen Keller

Keywords:
Sustainability
Healthy diet
Dietary change
Food system
Dietary substitution analysis

ABSTRACT

Healthy sustainable diets have the power to improve dietary intakes and environmental resource use. However, recommendations for improving food choices need to consider the effects of any changes across multiple dimensions of health, environmental sustainability, and dietary cost to promote long-lasting behaviour change. The aim of this study was to identify differences between original diets, and the diets that can be achieved through the implementation of select small dietary changes towards sustainability. Twelve hypothetical sustainable actions were investigated for the potential effects of these actions on dietary markers (protein, saturated fat, sugars, salt, iron, and calcium), environmental footprints (greenhouse gas emissions, freshwater withdrawals, and land use), and dietary cost. Dietary data from 1235 individuals, aged 19–94 years, participating in the UK National Diet and Nutrition Survey (2017/19) provided the original diet. Dietary changes were implemented as required by each sustainable action, and differences between the original diet and each new diet were investigated. Results revealed benefits to dietary markers and environmental characteristics from eleven sustainable actions (range: $F(1,728) = 5.80$, $p < .001$ to $F(1,506) = 435.04$, $p < .001$), but effects were stronger for some actions than for others. Greatest benefits for all three outcomes were found for actions which reduced meat consumption and/or replaced meat with pulses or eggs. The remaining sustainable actions tended to be beneficial for improving outcomes individually or to some degree. Our results demonstrate the possible impacts of a number of small sustainable dietary actions for dietary, environmental, and cost outcomes, and provide a hierarchy of actions based on benefit. Findings may facilitate dietary behaviours towards improved health, whilst also offering fruitful contributions towards environmental footprint targets in the UK.

1. Introduction

Healthy, sustainable, and affordable diets are urgently required (Murray et al., 2020). Numerous studies demonstrate that diets worldwide are higher in saturated fats, salt, and sugars than is recommended for health (Davies, 2013; Siddiqui, Salam, Lassi, & Das, 2020), and despite links between a healthier diet and reduced risk from several chronic conditions (e.g., cardiovascular disease, type 2 diabetes, and certain cancers), many people still over or under-eat certain food items (Murray et al., 2020; Sotos-Prieto et al., 2017). Sustainability concerns, similarly, are high. The global food system is currently responsible for approximately one third (34%) of global anthropogenic greenhouse gas emissions (GHGEs) (Clark et al., 2020; Crippa et al., 2021) with the greatest contributions coming from high demands for meat and dairy products (Hyland et al., 2017; Poore & Nemecek, 2018; Scarborough et al., 2014), and differential demands even within food groups (e.g., chicken versus beef) (Poore & Nemecek, 2018; Vieux et al., 2012). As the global population grows, increasing agricultural, industrial, and domestic demands for water, water stress (based on the ratio of freshwater withdrawals to renewable freshwater sources (Harris et al., 2020), and the risk of water scarcity are also becoming common concerns (Harris et al., 2020; Larbey & Weitkamp, 2020). At the same time, the increasing demand for food must be met on decreasing per-capita areas of available land (Aleksandrowicz et al., 2016).

Defined as *"diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations, sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair, and affordable; nutritionally adequate, safe, and healthy; while optimising natural and human resources"* (Food and Agriculture Organization of the United Nations, 2010, p.9). Sustainable diets have the power to improve dietary

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https://doi.org/10.1016/j.appet.2023.107194
Received 3 October 2023; Received in revised form 13 December 2023; Accepted 22 December 2023
Available online 27 December 2023
0195-6663/

Abbreviations

CH_4	Methane
CO_2	Carbon Dioxide
CO_2eq	Carbon Dioxide Equivalents
FAO	Food and Agricultural Organisation
GHGEs	Greenhouse Gas Emissions
LCA	Life Cycle Assessment
m^2	Meters Squared
NDNS	National Diet and Nutrition Survey
N_2O	Nitrous Oxide
PHE	Public Health England

intakes from a health and environmental perspective. However, the term "sustainable diet" is multi-faceted and complex (Macdiarmid et al., 2012; Steenson & Buttriss, 2020), and past research has shown that the understanding of the concept of sustainable diets is poor (Whittall et al., 2023). Many misconceptions are also found which could contribute to the barriers towards improving intakes (Llanaj and Hanley-Cook, 2021; Mann et al., 2018).

Notably, the value of making dietary changes is often underestimated. The value of reducing meat consumption for improving climate change, for example, is often undervalued by the general population (Froggatt et al., 2014; Truelove & Parks., 2012), and individuals report a sense of futility or feeling that they alone cannot make a difference (Macdiarmid, 2014; Seves et al., 2017; Whittall et al., 2023). However, despite this mention of futility, research has suggested that individuals are willing to make subtle small changes to their diets towards sustainability (Aleksandrowicz et al., 2016; Allen & Prosperi, 2016; Vanhonacker et al., 2013; Whittall et al., 2023). Small changes have been shown to be more effective at securing long-lasting change in dietary behaviours (Hill et al., 2003), and reportedly have impacts on diet and health (Hill et al., 2003; Hills et al., 2013; Rodearmel et al., 2007; Stroebele et al., 2009). Stroebele et al. (2009) found that the small changes approach was effective in significantly reducing total energy intake and increasing physical activity, with the reduction of total energy intake being larger than expected. Findings showed that people seemed to understand the simple messages and translate these into desirable behaviour changes, which could be maintained long-term. Some research has investigated the impacts of reducing meat consumption, and eating more legumes for health and the environment (Foyer et al., 2016; Westhoek et al., 2014), but there is very little work exploring the impact of, and directly comparing, a variety of small dietary changes on these outcomes (Milner & Green., 2018). Consumers may be more willing to undertake some actions compared to others, thus, additional benefit may be gained from providing a variety of actions in the form of a hierarchy.

Changes, furthermore, must be manageable for the population. With 4.2 million people in the UK currently living in food poverty (Department for Work and Pensions, 2021), increases in dietary costs will not be feasible (Reynolds et al., 2019; Tong et al., 2018). The notion that engaging in sustainable dietary behaviours may be considered a privilege, limited to those who can afford it in terms of health, time, and cost is significant. Weber et al. (2022) appreciates the necessity of recognising that not all individuals in society can prioritise sustainable food consumption over other essential dietary needs, even if they desire to do so. Therefore, practical recommendations to suit individual budgets are needed for successful long-term change.

This study investigated the impacts of twelve small dietary changes for dietary, environmental, and cost benefits. We aim to provide clear, accessible information for each potential dietary change, allowing consumers to make informed choices based on personal gain (e.g., health benefits, or reduced dietary cost), as this is vital to long-lasting behaviour change (Dornhoff et al., 2020; Tobler et al., 2011). All impacts were also summed across all three outcomes to provide a hierarchy of benefit. It was hypothesised that all sustainable dietary changes will improve dietary, environmental, and cost outcomes. It was also hypothesised that there will be differences between the sustainable actions on the degree of impact they may have on each outcome. All hypotheses were specified before the data were collected.

2. Methods

The present study utilised existing data from the National Diet and Nutrition Survey (NDNS) for the UK, to investigate the dietary, environmental, and cost differences between original diets and the diets that can be achieved through the implementation of small changes. We considered twelve possible dietary changes and solutions that we will call 'sustainable actions' throughout this paper. To allow adequate distinction between the effects of all sustainable actions, actions were implemented across entire diets. In this respect, the *absolute* effects demonstrate the value of the dietary shift but may not be the result of a 'small' dietary change, at least not for some individuals. Absolute effects demonstrate the value of the dietary shift. *Relative* effects demonstrate the value of one action compared to another. Thus, if the sustainable actions are implemented as small changes, e.g., for one main meal per week, the relative effects demonstrate those of greatest benefit compared to the others. "Small changes" refers to changes that could be implemented with limited cost or effort, although everyone's definitions of a small change, limited cost, and limited effort will differ. The small changes outlined in this paper, would also apply proportionally if an individual followed one of the changes to a lesser degree (e.g., reduced meat consumption by 10% instead of 20%) so each of the changes could be viewed as a direction of travel rather than steps of pre-determined size.

2.1. Population sample and dietary data

Dietary data were derived from the UK population participating in the NDNS during waves 10–11 (2017–2019), so no participants were recruited specifically for our study. The NDNS is a rolling programme of cross-sectional self-reported surveys with 1235 individuals aged 19–94 years (507 males (mean (*SD*) age = 50.4 (17.9) years; 728 females (mean (*SD*) age = 48.9 (17.8 years). It constitutes nationally representative dietary intake data and provides the most recent, accessible source of dietary data for the UK population, before the COVID-19 pandemic occurred (Public Health England, 2019). The NDNS data provides quantities (in grams) of all food and drink items consumed over 4 consecutive days, per main food group (e.g., vegetable), sub food group (e.g., carrots), and per individual food item (e.g., carrots raw). Information from McCance and Widdowson's 'The Composition of Foods' book 6th edition (2014) was then used to calculate the energy and nutrient composition of each dietary entry. All reported foods were used to compile the data set for this study, with the exception of those with insufficient food descriptions. Records of outliers and potential under-reporters were checked for coding errors but were not excluded, as we preferred to use the complete NDNS data set to ensure greater generalisability to the general UK population and to reduce bias.

2.2. Sustainable actions

We investigated twelve hypothetical sustainable actions, as shown in Fig. 1. These sustainable actions were identified from a review of literature on sustainable eating (Akhtar & Isman., 2018; Audsley et al., 2010; Berners-Lee et al., 2012; Berners-Lee, 2020; Clune et al., 2017; Crippa et al., 2021; Frankowska et al., 2019; Garnett, 2011; Gephart et al., 2021; Horgan et al., 2016; Hyland et al., 2017; Macdiarmid, 2014; Masset et al., 2014; Oonincx et al., 2010; Poore & Nemecek, 2018; Röös et al., 2015; Scarborough et al., 2014; Wilson et al., 2019) and focused

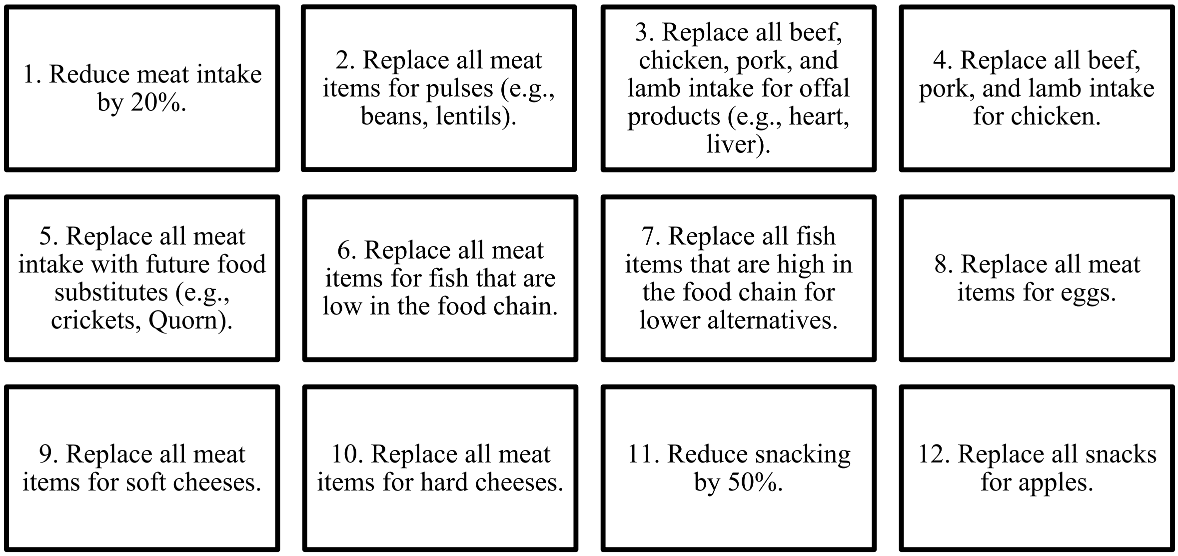

Fig. 1. The twelve hypothetical sustainable dietary actions. Sustainable action five defines 'future foods' as foods which can be produced in a significant volume, which are often land-efficient alternatives for traditional animal-sourced foods, but can be produced with key environmental benefits while providing essential nutrients (e.g., crickets, larvae, mealworms) (Parodi et al., 2018).

on the concept of small dietary changes. Small changes typically involve behaviours that individuals already undertake and have been argued as more feasible to achieve and maintain than large changes, following feelings of success and increased self-efficacy (Hills et al., 2013). We also incorporated the notion of moving between product categories e.g., meat to pulses as this has been found to be successful for encouraging sustainable eating practices (Hoek et al., 2017).

Consideration of published studies and commentary allowed us to identify 12 actions that may hold potential to improve the sustainability of diets, while the range and diversity of all possible solutions cannot be digested within the bounds of this article.

We tested the feasibility of our sustainable actions during a public talk with 31 participants. The sustainable actions were displayed to participants, and we asked whether they thought they were acceptable, and likely to be followed. Responses confirmed our choice of actions. Additional actions were also discussed, but difficulties implementing these with the existing data set precluded the inclusion of these.

2.3. Dietary impacts

Impacts on several markers of a healthy diet were investigated: protein, saturated fat, sugars, salt, iron, and calcium. These markers were chosen as National dietary data shows that the UK population is consuming more saturated fat, sugars, and salt, but insufficient calcium and iron than is recommended for health (Caraher & Hughes., 2019; Whitton et al., 2011) and while protein consumption is often adequate, concerns over low protein consumption are also prevalent for some population groups, including children, older adults, and those following a vegan diet (Bakaloudi et al., 2021; Morris et al., 2020). Past research has also indicated that concerns about protein adequacy can act as barriers to reducing meat consumption or consuming more sustainable diets (Circus & Robison., 2019; Hartmann & Siegrist., 2017).

2.4. Environmental footprint

We considered GHGEs, freshwater withdrawals, and land use as markers of environmental impact, largely due to data availability. The GHGEs of the foods are expressed as carbon dioxide equivalents (CO_2eq), and include emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Poore & Nemecek, 2018). These data were based on outputs from partial or complete Life Cycle Assessments (LCA), compiled from published literature (Akhtar & Isman., 2018; Audsley et al., 2010; Berners-Lee et al., 2012; Berners-Lee, 2020; Clune et al., 2017; Crippa et al., 2021; Frankowska et al., 2019; Garnett, 2011; Gephart et al., 2021; Horgan et al., 2016; Hyland et al., 2017; Macdiarmid, 2014; Masset et al., 2014; Oonincx et al., 2010; Poore & Nemecek, 2018; Röös et al., 2015; Scarborough et al., 2014; Wilson et al., 2019) and the Hestia Database (https://www.hestia.earth). LCA is a comprehensive, internationally standardised method for assessing the environmental impact of a product or system over its whole life: from production and distribution through to consumption and disposal. Freshwater withdrawals are measured in litres per 100g of food product (1/100g). Land use is measured in meters squared (m^2) per kilogram of a given food product. Value indicators were defined by using the average value of all reported values across all relevant publications. Global average data were used when country-specific estimates of environmental footprints were not available.

2.5. Dietary cost

To estimate the cost of each diet, food prices for individual items were collected (during the period June–July 2022) from www.trolley.co.uk, which reports grocery item pricing at all major UK supermarkets including Tesco, Sainsbury's, Asda, Aldi, Morrisons, Ocado, Waitrose, Poundland, Co-op, Iceland, B&M, and Wilko. In total, 330 prices for 110 food products were collected, and were adjusted for the weight of individual food items. The average of all collected prices per food (UK pounds per kilogram) was used.

2.6. Implementation of the sustainable actions

Effects of each sustainable action were investigated by first assessing the dietary impacts, environmental footprint, and cost of the existing diet. Next, several dietary substitution outcome analyses were conducted, where select food items and/or quantities were substituted for original food items, as dictated by each sustainable action. Substitutions were made per portion, for example, for sustainable action 2, 1 portion (100g) meat was substituted with 1 portion (80g) pulses. Analyses were also conducted on a weight-for-weight basis, where, for example, for sustainable action 2, 100g meat was substituted with 100g pulses. These secondary analyses were done to represent a straightforward dietary swap. However, we are aware that most foods are consumed in portions, thus, the results of the straightforward swap are presented in the supplementary materials for interest.

2.7. Data analysis

The analysis plan was pre-specified in advance of data collection. Impacts of all substitutions were investigated for impacts on dietary and environmental markers using MANOVA, and for dietary cost using t-tests, to explore the differences between original UK diets and the diets that can be achieved following implementation of each sustainable action. Data were first described using means and standard deviations, and checked for the assumptions for parametric tests. Separate analyses were conducted for dietary markers, environmental markers, and dietary cost, and significant main effects were subsequently investigated for effects on each of the environmental characteristics (GHGEs, freshwater withdrawals, and land use) and each of the dietary markers (protein, saturated fat, sugars, salt, iron, and calcium), as appropriate. Analyses were conducted twice, once for males and once for females, considering the different dietary attitudes and intakes often reported between genders (Grymislawska et al., 2020; Public Health England, 2019).

Effects were then scored based on the statistical significance of the impact they had on the dietary markers, environmental, and cost outcomes. Each effect was scored either −1 (red), 0 (white), 1 (green) depending on whether the new diet had a statistically-significant (*$p < .05$, **$p < .001$) negative, neutral, or positive effect, respectively, on each outcome versus the original diet. Scores for diet, environment, and cost were then calculated by adding all components and dividing by the number of components to provide a score from −1 to 1, for each outcome, and these scores were then also added to provide an overall score from −3 to +3 for effects on health, environment, and cost together. Higher scores denote dietary profiles that are healthier, use less environmental resources, and are of lower cost.

Data extraction and searching was done for all included data between April and August 2022, by one investigator (DJG) with repeated feedback on the extraction process and extracted content from both co-authors (JB, KMA). The study was given ethical approval by the Research Ethics Committee of Bournemouth University, UK, prior to commencement (ID: 42948). All data were analysed using SPSS 28 and Microsoft Excel.

3. Results

Mean (and standard deviation) for the six dietary markers, the three components of environmental footprint, and for dietary cost for the original diet and for each new diet using substitutions based on standard portion sizes are given in Tables 1 and 2, for the data from males and females respectively. Pillai trace statistics for all complete MANOVA models are given in Supplementary Tables S1 and S2. Pillai's trace is the sum of variance which can be explained by the calculation of discriminant variables, thus, the closer Pillai's trace is to 1, the stronger the evidence that the explanatory variable has a statistically significant effect on the values of the outcome variables. All overall models were statistically significant, with the exception of that for sustainable action 11 (reduce snacking by 50%). Analyses using substitutions conducted on a weight-for-weight basis where these differ from those on standard portion sizes are given in the Supplementary Materials, Tables S3–S6.

4. Discussion

This study used a substitution approach to determine the effects of select dietary changes to six dietary markers, three markers of environmental footprint, and cost of the average UK diet. Results revealed benefits to the dietary markers and environmental characteristics with eleven of the twelve different sustainable actions investigated, but effects were stronger for some actions than for others. Using these specific markers, compared to the original diet from the NDNS, the sustainable actions most beneficial for future health, environmental, and dietary cost outcomes together for the general UK population were*: replacing all meat items for eggs, replacing all meat items for pulses, replacing all meat items for hard or soft cheeses, and reducing meat consumption by 20%.* These sustainable actions offered a new diet that was cheaper, of a lower environmental footprint, and was largely healthier considering the markers investigated. All diets contained adequate protein and calcium, and most had less saturated fat, salt, and sugar. The rest of our sustainable actions had some impacts in the desired direction or tended to be beneficial for improving either environmental, health, or cost outcomes individually.

Out of all our sustainable actions it is evident that those with efforts to reduce meat consumption and/or switch from meat consumption to other more sustainable protein sources, such as eggs, and pulses, are the most influential for all outcomes together. Repeated previous work also demonstrates this association between meat consumption and healthy sustainable dietary consumption (Macdiarmid et al., 2016; Sanchez-Sabate & Sabaté, 2019). The health benefits of eggs, pulses, and dairy foods, and the environmental benefits of egg and pulse consumption are also well recognised (Foyer et al., 2016; Hartmann & Siegrist., 2017; Horgan et al., 2016; Macdiarmid et al., 2012; Macdiarmid, 2014; Röös et al., 2015; Seves et al., 2017; Westhoek et al., 2014). Our study adds to these previous findings by demonstrating the value and the comparability of these approaches in dietary, environmental, and cost outcomes when considered together. Notably, our study also demonstrates the value of these specific substitutions, compared to those that involve switching from the consumption of specific types of meat to the consumption of other types of meat, namely chicken, fish, or future foods. Caution should be exercised here considering the specific and limited markers of both diet and environmental impact that we considered, but the low relative impact of these actions involving alternative meat sources is notable.

The relatively low impact of replacing all ruminant beef, pork, and lamb intake for chicken is of particular interest. All actions were considered to be 'sustainable', so were likely to impact environmental markers, and the extent of this impact may reflect by specific aspects of the environment investigated, but this one action had lower environmental benefits than almost all other actions investigated. This is important as a societal shift from eating beef to eating chicken has previously been considered a key factor in encouraging healthy sustainable diets (Connolly et al., 2022). A variety of mixed-methods studies have found that public perceptions around meat consumption are affiliated with personal, social, and cultural values (Dagevos, 2021; Macdiarmid et al., 2016; Whittall et al., 2023), thus researchers have suggested the replacement of animal meats with the meats of other animals of comparable cultural acceptance and meaning. Changing patterns in meat consumption show that people are thinking about the environmental impact of what they eat (Macdiarmid et al., 2016; Whittall et al., 2023), however, our findings would suggest that the benefits of these changes in meat consumption may be small compared to those that can be achieved through reducing the consumption of all meat by 20% and/or the consumption of other non-meat protein sources (Lima et al., 2022; McDermott & Wyatt., 2017; Onwezen et al., 2021). With an interest in impact or value, focus on these alternative protein sources (e.g., eggs and pulses) may achieve greater results.

Some benefits, furthermore, were found for all actions, excepting one. These findings demonstrate a level of flexibility for consumers, in the possible changes that they can make to achieve a healthier and more sustainable diet. Dietary guidelines focus on national goals for health to prevent disease and deficiencies in the population, but they tend not to consider the social, personal, economic, and cultural aspects of our dietary choices (Shepherd, 1999). Eating habits are socially constructed, and food can be an important part of people's identity, as above, and it has been recognised for a long time that for many people these concerns matter more than nutrition or the environment (Bisogni et al., 2002). This study demonstrates that a range of sustainable actions can be

Table 1

Means, standard deviations, and significance – current UK diet versus different sustainable actions: ***Male*** *(N=507). *p < .05 **p < .001.*

		Protein (g)	Saturated Fat (g)	Total Sugars (g)	Salt (mg)	Iron (mg)	Calcium (mg)	Dietary Score	CO_2 (CO_2-eq/kg)	Freshwater Withdrawals (l/100g)	Land Use (m^2)	Environmental Score	Item Cost (per 100g)	Cost Score	Overall Score
Original UK Diet	Mean	149.53	20.66	54.09	995.54	27.84	148.61		45.99	782.73	83.45		5.25		
	SD	152.38	23.65	46.11	790.12	46.43	123.31		50.54	979.40	123.55		4.02		
S1: Reduce meat items by 20% (100g portion size)	Mean	119.63	16.53	43.27	796.43	22.27	118.88		36.79	626.18	66.76		4.20		
	SD	121.91	19.92	36.89	632.09	37.14	98.64	0.00	40.43	783.52	98.84	1.00	3.21	1.00	**2.00**
	p	<.001**	0.002*	<.001**	<.001**	0.03*	<.001**		<.001**	0.005*	0.01*		<.001**		
S2: Replace all meat items for pulses. (80g portion size)	Mean	53.34	6.12	54.09	390.75	12.50	156.43		8.81	629.12	12.85		2.61		
	SD	34.54	4.98	46.14	476.38	9.55	120.70	0.16	6.31	535.53	11.78	1.00	1.78	1.00	**2.16**
	p	<.001**	<.001**	0.76	<.001**	<.001**	0.30		<.001**	0.002*	<.001**		<.001**		
S3: Replace all beef, chicken, pork, & lamb intake for offal (100g portion size)	Mean	197.75	34.15	58.39	903.00	33.90	487.15		25.67	511.68	75.30		4.97		
	SD	174.93	34.80	48.68	753.69	35.95	594.07	0.48	36.54	780.30	91.63	0.66	3.80	0.00	**1.14**
	p	<.001**	<.001**	0.14	0.05*	0.02*	<.001**		<.001**	<.001**	0.23		0.26		
S4: Replace all ruminant beef, pork, and lamb intake for chicken. (100g portion size)	Mean	143.67	18.18	54.02	851.33	27.25	144.62		38.75	729.91	72.90		5.07		
	SD	151.31	23.64	46.13	758.19	46.64	123.08	0.16	46.44	986.39	124.02	0.33	3.79	0.00	**0.49**
	p	0.53	0.09	0.98	0.003*	0.84	0.60		0.01*	0.39	0.17		0.47		
S5: Replace all meat intake with future food substitutes. (100g portion size)	Mean	227.48	42.95	54.00	857.17	29.88	754.56		8.81	159.66	49.71		52.59		
	SD	182.02	38.16	46.12	718.60	26.75	668.59	0.33	8.03	139.56	42.81	1.00	51.30	-1.00	**0.33**
	p	<.001**	<.001**	0.97	0.004*	0.39	<.001**		<.001**	<.001**	<.001**		<.001**		
S6: Replace all meat items for fish that are low in the food chain. (100g portion size)	Mean	114.24	14.94	54.00	722.24	6.84	143.85		18.61	342.34	33.48		4.44		
	SD	95.68	12.29	46.12	665.20	4.83	119.42	-0.16	14.08	287.66	28.91	0.66	3.05	0.00	**0.50**
	p	0.03*	0.13	0.56	<.001**	0.03*	0.90		<.001**	<.001**	0.58		0.59		
S7: Replace all fish items that are high in the food chain for lower alternatives. (100g portion size)	Mean	126.78	15.46	55.69	606.41	8.87	529.09		35.97	559.09	36.08		3.95		
	SD	108.95	13.85	47.36	545.80	6.27	578.14	0.16	41.21	483.57	46.53	0.00	3.07	1.00	**1.16**
	p	0.89	0.39	0.99	<.001**	<.001**	<.001**		0.40	0.99	0.65		<.001**		
S8: Replace all meat items for eggs. (120g portion size)	Mean	61.55	9.84	54.62	559.69	11.97	208.25		12.21	533.39	12.79		2.64		
	SD	40.83	8.93	46.11	582.62	9.27	174.34	0.16	9.35	507.46	11.77	1.00	1.79	1.00	**2.16**
	p	<.001**	<.001**	0.85	<.001**	<.001**	<.001**		<.001**	<.001**	<.001**		<.001**		
S9: Replace all meat items for hard cheeses. (30g portion size)	Mean	54.98	15.45	54.54	680.12	8.65	442.95		12.67	424.06	15.51		2.74		
	SD	35.21	15.23	46.12	639.09	9.25	478.11	0.16	8.69	513.21	12.84	1.00	1.81	1.00	**2.16**
	p	<.001**	<.001**	0.87	<.001**	<.001**	<.001**		<.001**	<.001**	<.001**		<.001**		
S10: Replace all meat items for soft cheeses. (30g portion size)	Mean	52.86	14.32	54.51	640.02	8.56	297.58		11.75	418.29	14.69		2.78		
	SD	34.42	13.68	46.12	597.13	9.28	297.26	0.16	7.76	515.24	13.26	1.00	1.83	1.00	**2.16**
	p	<.001**	<.001**	0.88	<.001**	<.001**	<.001**		<.001**	<.001**	<.001**		<.001**		
S11: Reduce snacking by 50% (100g portion size)	Mean	126.75	14.24	51.25	1012.43	7.14	134.81		37.75	553.88	34.48		4.46		
	SD	109.27	13.58	45.58	802.78	5.79	120.06	0.16	41.69	483.53	46.29	0.00	3.39	0.00	**0.16**
	p	0.89	0.02*	0.12	0.13	0.26	0.19		0.88	0.86	0.91		0.69		
S12: Only snack on apples (100g portion size)	Mean	137.04	14.50	53.06	869.13	7.22	139.61		29.22	505.09	33.73		4.60		
	SD	116.05	14.60	45.84	733.19	5.66	119.60	0.16	33.89	424.68	42.51	0.66	3.58	0.00	**0.82**
	p	0.18	0.06	0.36	<.001**	0.35	0.50		<.001**	0.05*	0.70		0.82		

Statistical significance of all t-tests on dietary cost (new diet vs current UK diet) are also given in column 14. Statistical significance of all tests per dietary component and all environmental components are given in columns 3–8 and 10–12, respectively. Sustainable actions were scored either −1 (red), 0 (white), 1 (green) depending on whether the new diet had a statistically significant positive, neutral, or negative effect, respectively, on each outcome versus the original diet. Scores for cost, environment, and dietary profile were then calculated by adding all components and dividing by the number of components to provide a score from −1 to 1, for each outcome, and these scores were then also added to provide an overall score from −3 to +3. Higher scores denote dietary profiles that are healthier, use less environmental resources and are of lower cost. **CO_2-eq/kg** (GHGE impact per kilogram of a given food product), **l/100g** (freshwater withdrawals are measured in litres per 100g of a given food product), and m^2 (land use is measured in meters squared per kilogram of given a food product).

Table 2

Means, standard deviations, and significance – current UK diet versus different sustainable actions: ***Female (N = 728)***. *$*p < .05$ $**p < .001$.*

		Protein (g)	Saturated Fat (g)	Total Sugars (g)	Salt (mg)	Iron (mg)	Calcium (mg)	Dietary Score	CO_2 (CO_2-eq/kg)	Freshwater Withdrawals (l/100g)	Land Use (m^2)	Environmental Score	Item Cost (per 100g)	Cost Score	Overall Score
Original UK Diet	Mean	148.38	19.42	57.06	975.14	22.17	143.73		41.44	744.81	86.25		4.87		
	SD	108.37	17.88	46.18	769.72	32.18	120.48		36.50	676.77	89.19		3.11		
S1: Reduce meat items by 20% *(100g portion size)*	Mean	113.14	12.11	57.06	888.05	14.84	129.84		38.65	700.60	64.15		4.05		
	SD	79.02	10.22	46.18	703.04	4.09	117.45	-0.32	35.50	666.72	85.99	1.00	3.09	1.00	**1.68**
	p	<.001**	<.001**	0.99	0.55	<.001**	<.001**		<.001**	<.001**	<.001**		<.001*		
S2: Replace all meat items for pulses. *(80g portion size)*	Mean	50.50	6.08	57.78	419.20	11.35	148.29		8.56	563.46	12.86		2.64		
	SD	32.75	4.89	46.20	546.68	11.35	120.01	0.16	6.50	384.86	12.49	1.00	1.86	1.00	**2.16**
	p	<.001**	<.001**	0.76	<.001**	<.001**	<.001**		<.001**	<.001**	<.001**		<.001**		
S3: Replace all beef, chicken, pork, & lamb intake for offal *(100g portion size)*	Mean	175.81	28.77	56.97	866.14	32.46	369.97		28.53	581.98	77.04		4.82		
	SD	132.67	25.42	46.18	736.45	26.51	432.51	0.16	32.22	649.14	71.38	1.00	3.20	1.00	**2.16**
	p	<.001**	<.001**	0.97	0.25	<.001**	0.65		<.001**	<.001**	<.001**		<.001**		
S4: Replace all ruminant beef, pork, and lamb intake for chicken. *(100g portion size)*	Mean	123.46	14.92	56.97	783.23	21.72	136.66		32.27	610.02	57.06		4.74		
	SD	107.58	17.86	46.18	716.67	32.26	119.83	0.33	34.04	676.66	87.14	0.33	3.01	0.00	**0.66**
	p	0.92	0.003*	0.97	<.001**	0.79	0.68		0.002*	0.66	0.06		0.86		
S5: Replace all meat intake with future food substitutes. *(100g portion size)*	Mean	201.71	37.50	56.97	830.60	26.28	661.18		8.98	164.72	44.50		45.53		
	SD	135.00	27.28	46.18	705.07	18.95	480.82	0.48	8.10	145.89	31.84	1.00	36.23	-1.00	**0.52**
	p	<.001**	<.001**	0.97	0.004*	0.003*	<.001**		<.001**	<.001**	<.001**		<.001**		
S6: Replace all meat items for fish that are low in the food chain. *(100g portion size)*	Mean	102.26	13.25	56.97	711.08	16.76	137.06		17.23	319.51	30.03		4.21		
	SD	72.82	9.12	46.18	666.69	13.99	120.15	0.00	12.06	230.21	22.58	0.66	2.69	0.00	**0.66**
	p	0.006*	0.05*	0.28	<.001**	<.001**	0.68		<.001**	<.001**	0.92		0.59		
S7: Replace all fish items that are high in the food chain for lower alternatives. *(100g portion size)*	Mean	112.37	13.58	59.62	636.69	8.73	547.15		30.41	497.59	31.18		3.68		
	SD	81.32	11.41	48.48	618.83	5.17	622.54	0.16	29.54	353.55	36.09	0.00	2.45	1.00	**1.16**
	p	0.82	0.22	0.99	<.001**	<.001**	<.001**		0.16	0.99	0.49		<.001**		
S8: Replace all meat items for eggs. *(120g portion size)*	Mean	61.00	10.85	57.36	635.61	10.67	214.67		12.91	440.83	12.79		2.68		
	SD	38.21	8.73	46.18	608.41	6.64	161.78	0.16	8.63	353.77	12.48	1.00	1.87	1.00	**2.16**
	p	<.001**	<.001**	0.89	<.001**	<.001**	<.001**		<.001**	<.001**	<.001**		<.001**		
S9: Replace all meat items for hard cheeses. *(30g portion size)*	Mean	51.98	14.66	57.04	685.39	7.81	411.86		12.11	374.82	15.32		2.76		
	SD	33.18	13.15	46.18	640.46	6.70	392.14	0.00	7.97	367.40	13.43	1.00	1.89	1.00	**2.00**
	p	<.001**	<.001**	0.88	<.001**	<.001**	0.17		<.001**	0.01*	<.001**		<.001**		
S10: Replace all meat items for soft cheeses. *(30g portion size)*	Mean	49.25	13.22	57.36	634.04	7.69	225.65		10.94	367.43	14.26		2.81		
	SD	32.44	11.44	46.18	607.49	6.75	172.14	0.16	7.17	370.21	12.94	1.00	1.91	1.00	**2.16**
	p	<.001**	<.001**	0.89	<.001**	<.001**	<.001**		<.001**	<.001**	<.001**		<.001**		
S11: Reduce snacking by 50% *(100g portion size)*	Mean	112.30	12.14	53.53	937.73	6.53	127.82		32.17	490.94	29.54		4.19		
	SD	81.84	11.02	45.40	796.32	4.35	121.90	0.33	30.29	353.39	35.56	0.00	2.90	0.00	**0.33**
	p	0.80	<.001**	0.01*	0.04*	0.04*	0.07		0.78	0.72	0.84		0.51		
S12: Only snack on apples *(100g portion size)*	Mean	118.41	12.68	55.79	842.16	6.64	131.43		26.84	452.47	30.41		4.30		
	SD	79.83	10.66	45.94	749.38	4.04	118.71	0.33	23.80	316.08	30.59	0.66	2.79	0.00	**0.99**
	p	0.23	0.005*	0.12	<.001**	0.10	0.22		<.001**	0.01*	0.76		0.92		

Statistical significance of all t-tests on dietary cost (new diet vs current UK diet) are also given in column 14. Statistical significance of all tests per dietary component and all environmental components are given in columns 3–8 and 10–12, respectively. Sustainable actions were scored either −1 (red), 0 (white), 1 (green) depending on whether the new diet had a statistically significant positive, neutral, or negative effect, respectively, on each outcome versus the original diet. Scores for cost, environment, and dietary profile were then calculated by adding all components and dividing by the number of components to provide a score from −1 to 1, for each outcome, and these scores were then also added to provide an overall score from −3 to +3. Higher scores denote dietary profiles that are healthier, use less environmental resources and are of lower cost. **CO_2-eq/kg** (GHGE impact per kilogram of a given food product), **l/100g** (freshwater withdrawals are measured in litres per 100g of a given food product), and **m^2** (land use is measured in meters squared per kilogram of given a food product).

implemented for some impact. This gives more choice and freedom to the individual and may further encourage individual efforts to adopt realistic climate-friendly eating habits (Cordts et al., 2014; Graça et al., 2019; Macdiarmid et al., 2016; Mann et al., 2018; Waldman et al., 2023).

This variety in effect, further, supports previous work suggesting that the concept of sustainable eating is multifaceted and complex (Macdiarmid et al., 2012; Steenson & Buttriss., 2020). Past research shows that consumers may be willing to make changes towards their diet, but they remain inactive due to a lack of understanding of what a sustainable diet involves (Mann et al., 2018; Riley & Buttriss., 2011; Whittall et al., 2023)

An important strength of this study is the investigation of realistic UK diets across multiple dimensions of dietary profile, environmental sustainability, and dietary cost, while previous research has tended to focus on these dietary or environmental concerns in isolation (Donati et al., 2016; Macdiarmid, 2014). However, our analyses also have several limitations that will limit interpretation of our findings, and many of these relate to data availability and quality. The food diary method used in the NDNS has been shown to underestimate food consumption and may not represent people's usual dietary patterns due to social desirability effects (Macdiarmid & Blundell., 1998). Despite this limitation, the NDNS presently constitutes the only nationally representative dietary data for the UK population. Accurate information of environment effects is also difficult to gain, due to many contributors to environmental footprints and the changing effects of these contributors with time, changes to farming, food processing, storage, and transportation practices and technologies. Every effort was made to use current, context-specific data on the environmental footprints of foods, although it was not always possible to use GHGEs, freshwater withdrawals, or land use estimates that represented the country of origin of a particular food. The environmental data necessarily came from multiple sources and the methods used may not always have been comparable, which will also have led to some inconsistencies in our estimations. Caution should also be exercised considering our consideration of only select environmental and dietary markers, while other factors may be of greater importance or influence in other countries or in certain population groups. The extrapolation of our results is also limited by the fact that we only considered select sustainable actions. Possible actions such as consuming seasonal fruits and vegetables or buying foods farmed in the UK, for example, were not open to investigation within the NDNS data set, but would also be of interest. We are aware, furthermore, that categorising food as good or bad in terms of healthiness or environmental impact is an oversimplification, that could easily be misinterpreted (Lobstein & Davies., 2009). It is also important to note that the profiles of food items included are indicative and calculated on averages, while differences within food categories may exist: for example, an organic chicken may have a different dietary, environmental, and cost profile compared to a battery-farmed chicken. Our measures of each food item are a broad evaluation that may not mirror the exact reality of individual purchases. Comparison of the results based on the method for the substitution demonstrates the importance of the methods used.

5. Conclusions

Several select dietary changes, labelled 'sustainable actions' e.g., 'Replace all meat items for pulses', were substituted into an average UK diet to determine the impact of these dietary changes on various dietary markers, environmental characteristics, and dietary cost. Greatest benefits on all three outcomes were found for the actions which reduced meat consumption and/or switched from consuming meat to consuming other more sustainable protein sources, such as eggs and pulses. Some benefits were found however for all actions, demonstrating the value of dietary change, and offering some level of flexibility for the consumer.

Ethical statement

The study was given ethical approval by the Research Ethics Committee of Bournemouth University, UK, prior to commencement (ID: 42948).

CRediT authorship contribution statement

Danielle J. Guy: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Jeffery Bray:** Supervision, Writing – review & editing. **Katherine M. Appleton:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data used for this work currently exists in the public domain, as referenced throughout the article

Acknowledgements

We would like to thank Professor Berners-Lee (Small World Consulting Ltd, Lancaster University) for his help sourcing the environmental footprint data for soft cheeses.

This work was undertaken as part of a PhD by DJG, supervised by JB and KMA at Bournemouth University. The study was presented at the 47th Annual Meeting of the British Feeding and Drinking Group, held in April 2023, Leeds, UK.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2023.107194.

Sources of support

This work was supported by Bournemouth University, UK. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Akhtar, Y., & Isman, M. B. (2018). Insects as an alternative protein source. In *Proteins in food processing* (pp. 263–288). Woodhead Publishing.

Aleksandrowicz, L., Green, R., Joy, E. J., Smith, P., & Haines, A. (2016). The impacts of dietary change on greenhouse gas emissions, land use, water use, and health: A systematic review. *PLoS One, 11*(11), Article e0165797. https://doi.org/10.1371/journal.pone.0165797

Allen, T., & Prosperi, P. (2016). Modeling sustainable food systems. *Environmental Management, 57*(5), 956–975. https://doi.org/10.1007/s00267-016-0664-8

Audsley, E., Brander, M., Chatterton, J. C., Murphy-Bokern, D., Webster, C., & Williams, A. G. (2010). *How low can we go? An assessment of greenhouse gas emissions from the UK food system and the scope reduction by 2050*. Report for the WWF and Food Climate Research Network.

Bakaloudi, D. R., Halloran, A., Rippin, H. L., Oikonomidou, A. C., Dardavesis, T. I., Williams, J., & Chourdakis, M. (2021). Intake and adequacy of the vegan diet. A systematic review of the evidence. *Clinical nutrition, 40*(5), 3503–3521.

Berners-Lee, M. (2020). *How bad are bananas?: The carbon footprint of everything*. Profile Books.

Berners-Lee, M., Hoolohan, C., Cammack, H., & Hewitt, C. N. (2012). The relative greenhouse gas impacts of realistic dietary choices. *Energy Policy, 43*, 184–190. https://doi.org/10.1016/j.enpol.2011.12.054

Bisogni, C. A., Connors, M., Devine, C. M., & Sobal, J. (2002). Who we are and how we eat: A qualitative study of identities in food choice. *Journal of Nutrition Education and Behavior, 34*(3), 128–139.

Caraher, M., & Hughes, N. (2019). Tackling salt consumption outside the home. *BMJ*, 364.
Circus, V. E., & Robison, R. (2019). Exploring perceptions of sustainable proteins and meat attachment. *British Food Journal, 121*(2), 533–545.
Clark, M. A., Domingo, N. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., … Hill, J. D. (2020). Global food system emissions could preclude achieving the 1.5 and 2 C climate change targets. *Science, 370*(6517), 705–708.
Clune, S., Crossin, E., & Verghese, K. (2017). Systematic review of greenhouse gas emissions for different fresh food categories. *Journal of Cleaner Production, 140*, 766–783.
Connolly, G., Clark, C. M., Campbell, R. E., Byers, A. W., Reed, J. B., & Campbell, W. W. (2022). Poultry consumption and human health: How Much is really Known? A Systematically searched Scoping review and research perspective. *Advances in Nutrition, 13*(6), 2115–2124.
Cordts, A., Nitzko, S., & Spiller, A. (2014). Consumer response to negative information on meat consumption in Germany. *The International Food and Agribusiness Management Review, 17*, 83–106, 1030-2016-82984.
Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. J. N. F. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. *Nature Food, 2*(3), 198–209.
Dagevos, H. (2021). Finding flexitarians: Current studies on meat eaters and meat reducers. *Trends in Food Science & Technology, 114*, 530–539.
Database, H.. https://www.hestia.earth.
Davies, A. R. (2013). Food futures: Co-Designing sustainable eating practices for 2050. *EuroChoices, 12*(2), 4–11. https://doi.org/10.1111/1746-692X.12029
Department for Work and Pensions. (2021). *Households below average income (HBAI) statistics*. London: HM Government.
Donati, M., Menozzi, D., Zighetti, C., Rosi, A., Zinetti, A., & Scazzina, F. (2016). Towards a sustainable diet combining economic, environmental and nutritional objectives. *Appetite, 106*, 48–57. https://doi.org/10.1016/j.appet.2016.02.151
Dornhoff, M., Hörnschemeyer, A., & Fiebelkorn, F. (2020). Students' conceptions of sustainable nutrition. *Sustainability, 12*(13), 5242.
Food and Agriculture Organization of the United Nations. (2010). *International Scientific Symposium. Biodiversity and sustainable diets – United against Hunger*. Rome: FAO Headquarters.
Foyer, C. H., Lam, H. M., Nguyen, H. T., Siddique, K. H., Varshney, R. K., Colmer, T. D., & Considine, M. J. (2016). Neglecting legumes has compromised human health and sustainable food production. *Nature Plants, 2*(8), 1–10.
Frankowska, A., Jeswani, H. K., & Azapagic, A. (2019). Life cycle environmental impacts of fruits consumption in the UK. *Journal of Environmental Management, 248*, Article 109111.
Froggatt, A., Wellesley, L., & Bailey, R. (2014). *Livestock–climate Change's Forgotten sector: Global public Opinion on meat and dairy consumption*.
Garnett, T. (2011). Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? *Food Policy, 36*, S23–S32.
Gephart, J. A., Henriksson, P. J., Parker, R. W., Shepon, A., Gorospe, K. D., Bergman, K., & Troell, M. (2021). Environmental performance of blue foods. *Nature, 597*(7876), 360–365.
Graça, J., Godinho, C. A., & Truninger, M. (2019). Reducing meat consumption and following plant-based diets: Current evidence and future directions to inform integrated transitions. *Trends in Food Science & Technology, 91*, 380–390.
Grymislawska, M., Puch, E. A., Zawada, A., & Grymislawski, M. (2020). Do nutritional behaviours depend on biological sex and cultural gender? *Advances in Clinical and Experimental Medicine, 29*, 165–172. https://doi.org/10.17219/acem/111817
Harris, F., Moss, C., Joy, E. J., Quinn, R., Scheelbeek, P. F., Dangour, A. D., & Green, R. (2020). The water footprint of diets: A global systematic review and meta-analysis. *Advances in Nutrition, 11*(2), 375–386.
Hartmann, C., & Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends in Food Science & Technology, 61*, 11–25.
Hills, A. P., Byrne, N. M., Lindstrom, R., & Hill, J. O. (2013). 'Small changes' to diet and physical activity behaviors for weight Management. *Obesity Facts, 6*(3), 228–238.
Hill, J. O., Wyatt, H. R., Reed, G. W., & Peters, J. C. (2003). Obesity and the environment: Where do we go from here? *Science, 299*(5608), 853–855.
Hoek, A. C., Pearson, D., James, S. W., Lawrence, M. A., & Friel, S. (2017). Shrinking the food-print: A qualitative study into consumer perceptions, experiences and attitudes towards healthy and environmentally friendly food behaviours. *Appetite, 108*, 117–131.
Horgan, G. W., Perrin, A., Whybrow, S., & Macdiarmid, J. I. (2016). Achieving dietary recommendations and reducing greenhouse gas emissions: Modelling diets to minimise the change from current intakes. *International Journal of Behavioral Nutrition and Physical Activity, 13*(1), 1–11.
Hyland, J. J., McCarthy, M. B., Henchion, M., & McCarthy, S. N. (2017). Dietary emissions patterns and their effect on the overall climatic impact of food consumption. *International Journal of Food Science and Technology, 52*(12), 2505–2512. https://doi.org/10.1111/ijfs.13419
Larbey, R., & Weitkamp, E. (2020). Water scarcity communication in the UK: Learning from water company communications following the 2018 heatwave. *Frontiers in Environmental Science, 8*, Article 578423.
Lima, M., Costa, R., Rodrigues, I., Lameiras, J., & Botelho, G. (2022). A Narrative review of alternative protein sources: Highlights on meat, fish, egg, and dairy Analogues. *Foods, 11*(14), 2053.
Llanaj, E., & Hanley-Cook, G. T. (2021). Adherence to healthy and sustainable diets is not differentiated by cost, but rather source of foods among young adults in Albania. *British Journal of Nutrition, 126*(4), 591–599.
Lobstein, T., & Davies, S. (2009). Defining and labelling 'healthy'and 'unhealthy'food. *Public Health Nutrition, 12*(3), 331–340.
Macdiarmid, J. I. (2014). Seasonality and dietary requirements: Will eating seasonal food contribute to health and environmental sustainability? *Proceedings of the Nutrition Society, 73*(3), 368–375. https://doi.org/10.1017/S0029665113003753
Macdiarmid, J., & Blundell, J. (1998). Assessing dietary intake: Who, what and why of under-reporting. *Nutrition Research Reviews, 11*(2), 231–253.
Macdiarmid, J. I., Douglas, F., & Campbell, J. (2016). Eating like there's no tomorrow: Public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. *Appetite, 96*, 487–493. https://doi.org/10.1016/j.appet.2015.10.011
Macdiarmid, J. I., Kyle, J., Horgan, G. W., Loe, J., Fyfe, C., Johnstone, A., & McNeill, G. (2012). Sustainable diets for the future: Can we contribute to reducing greenhouse gas emissions by eating a healthy diet? *The American journal of clinical nutrition, 96*(3), 632–639.
Mann, D., Thornton, L., Crawford, D., & Ball, K. (2018). Australian consumers' views towards an environmentally sustainable eating pattern. *Public Health Nutrition, 21*(14), 2714–2722. https://doi.org/10.1017/S1368980018001192
Masset, G., Soler, L. G., Vieux, F., & Darmon, N. (2014). Identifying sustainable foods: The relationship between environmental impact, nutritional quality, and prices of foods representative of the French diet. *Journal of the Academy of Nutrition and Dietetics, 114*(6), 862–869.
McDermott, J., & Wyatt, A. J. (2017). The role of pulses in sustainable and healthy food systems. *Annals of the New York Academy of Sciences, 1392*(1), 30–42.
Milner, J., & Green, R. (2018). Sustainable diets are context specific but are they realistic? *The Lancet Planetary Health, 2*(10), e425–e426.
Morris, S., Cater, J. D., Green, M. A., Johnstone, A. M., Brunstrom, J. M., Stevenson, E. J., & Corfe, B. M. (2020). Inadequacy of protein intake in older UK adults. *Geriatrics, 5*(1), 6.
Murray, C. J., Aravkin, A. Y., Zheng, P., Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M., & Borzouei, S. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: A systematic analysis for the global Burden of disease study 2019. *The Lancet, 396*(10258), 1223–1249. https://doi.org/10.1016/S0140-6736(20)30752-2
Onwezen, M. C., Bouwman, E. P., Reinders, M. J., & Dagevos, H. (2021). A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. *Appetite, 159*, Article 105058.
Oonincx, D. G., Van Itterbeeck, J., Heetkamp, M. J., Van Den Brand, H., Van Loon, J. J., & Van Huis, A. (2010). An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PLoS One, 5*(12), Article e14445.
Parodi, A., Leip, A., Slegers, P. M., Ziegler, F., Herrero, M., Tuomisto, H., Valin, H., Commission, E., Scientific, C., Lucia, S., Services, E., & Program, M. (2018). Future foods: Towards a sustainable and healthy diet for a growing population. *Nature Sustainability, 1*(12), 782–789.
Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science, 360*(6392), 987–992.
Public Health England. (2019). September 9. UK: National Diet and Nutrition Survey. GOV https://www.gov.uk/government/collections/national-diet-and-nutrition-survey.
Reynolds, C. J., Horgan, G. W., Whybrow, S., & Macdiarmid, J. I. (2019). Healthy and sustainable diets that meet greenhouse gas emission reduction targets and are affordable for different income groups in the UK. *Public Health Nutrition, 22*(8), 1503–1517. https://doi.org/10.1017/S1368980018003774
Riley, H., & Buttriss, J. L. (2011). A UK public health perspective: What is a healthy sustainable diet? *Nutrition Bulletin, 36*(4), 426–431. https://doi.org/10.1111/j.1467-3010.2011.01931.x
Rodearmel, S. J., Wyatt, H. R., Stroebele, N., Smith, S. M., Ogden, L. G., & Hill, J. O. (2007). Small changes in dietary sugar and physical activity as an approach to preventing excessive weight gain: The America on the Move family study. *Pediatrics, 120*(4), e869–e879.
Röös, E., Karlsson, H., Witthöft, C., & Sundberg, C. (2015). Evaluating the sustainability of diets–combining environmental and nutritional aspects. *Environmental Science & Policy, 47*, 157–166.
Sanchez-Sabate, R., & Sabaté, J. (2019). Consumer attitudes towards environmental concerns of meat consumption: A systematic review. *International Journal of Environmental Research and Public Health, 16*(7), 1220.
Scarborough, P., Appleby, P. N., Mizdrak, A., Briggs, A. D., Travis, R. C., Bradbury, K. E., & Key, T. J. (2014). Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. *Climatic Change, 125*(2), 179–192.
Seves, S. M., Verkaik-Kloosterman, J., Biesbroek, S., & Temme, E. H. (2017). Are more environmentally sustainable diets with less meat and dairy nutritionally adequate? *Public Health Nutrition, 20*(11), 2050–2062.
Shepherd, R. (1999). Social determinants of food choice. *Proceedings of the Nutrition Society, 58*(4), 807–812.
Siddiqui, F., Salam, R. A., Lassi, Z. S., & Das, J. K. (2020). The intertwined relationship between malnutrition and poverty. *Frontiers in Public Health, 8*. https://doi.org/10.3389/fpubh.2020.00453
Sotos-Prieto, M., Bhupathiraju, S. N., Mattei, J., Fung, T. T., Li, Y., Pan, A., & Hu, F. B. (2017). Association of changes in diet quality with total and cause-specific mortality. *New England Journal of Medicine, 377*, 143–153. https://doi.org/10.1056/NEJMoa161350
Steenson, S., & Buttriss, J. L. (2020). The challenges of defining a healthy and 'sustainable' diet. *Nutrition Bulletin, 45*(2), 206–222. https://doi.org/10.1111/nbu.12439

Stroebele, N., De Castro, J. M., Stuht, J., Catenacci, V., Wyatt, H. R., & Hill, J. O. (2009). A small-changes approach reduces energy intake in free-living humans. *Journal of the American College of Nutrition, 28*(1), 63–68.

Tobler, C., Visschers, V. H., & Siegrist, M. (2011). Eating green. Consumers' willingness to adopt ecological food consumption behaviors. *Appetite, 57*(3), 674–682.

Tong, T. Y., Imamura, F., Monsivais, P., Brage, S., Griffin, S. J., Wareham, N. J., & Forouhi, N. G. (2018). Dietary cost associated with adherence to the Mediterranean diet, and its variation by socio-economic factors in the UK Fenland Study. *British Journal of Nutrition, 119*(6), 685–694.

Truelove, H. B., & Parks, C. (2012). Perceptions of behaviors that cause and mitigate global warming and intentions to perform these behaviors. *Journal of Environmental Psychology, 32*(3), 246–259. https://doi.org/10.1016/j.jenvp.2012.04.002

Vanhonacker, F., Van Loo, E. J., Gellynck, X., & Verbeke, W. (2013). Flemish consumer attitudes towards more sustainable food choices. *Appetite, 62*, 7–16.

Vieux, F., Darmon, N., Touazi, D., & Soler, L. G. (2012). Greenhouse gas emissions of self-selected individual diets in France: Changing the diet structure or consuming less? *Ecological Economics, 75*, 91–101. https://doi.org/10.1016/j.ecolecon.2012.01.003

Waldman, K. B., Giroux, S., Blekking, J. P., Nix, E., Fobi, D., Farmer, J., & Todd, P. M. (2023). Eating sustainably: Conviction or convenience? *Appetite, 180*, Article 106335.

Weber, A., Linkemeyer, L., Szczepanski, L., & Fiebelkorn, F. (2022). "Vegan Teachers make Students Feel really bad": Is Teaching sustainable nutrition Indoctrinating? *Foods, 11*(6), 887.

Westhoek, H., Lesschen, J. P., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, D., & Oenema, O. (2014). Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. *Global Environmental Change, 26*, 196–205.

Whittall, B., Warwick, S. M., Guy, D. J., & Appleton, K. M. (2023). Public understanding of sustainable diets and changes towards sustainability: A qualitative study in a UK population sample. *Appetite*, Article 106388.

Whitton, C., Nicholson, S. K., Roberts, C., Prynne, C. J., Pot, G. K., Olson, A., & Stephen, A. M. (2011). National diet and nutrition survey: UK food consumption and nutrient intakes from the first year of the rolling programme and comparisons with previous surveys. *British journal of nutrition, 106*(12), 1899–1914.

Wilson, N., Cleghorn, C. L., Cobiac, L. J., Mizdrak, A., & Nghiem, N. (2019). Achieving healthy and sustainable diets: A review of the results of recent mathematical optimization studies. *Advances in Nutrition, 10*(Supplement_4), S389–S403.