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Review

What factors influence sustainable and healthy diet consumption? A review and synthesis of literature within the university setting and beyond

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ABSTRACT

Globally, typical dietary patterns are neither healthy nor sustainable. Recognizing the key role of dietary change in reducing noncommunicable disease risk and addressing environmental degradation, it is crucial to understand how to shift individuals toward a sustainable and healthy diet (SHD). In this literature review, we introduced the concept of a SHD and outlined the dietary behaviors necessary to transition toward SHD consumption; we reviewed the literature on factors that may influence sustainable (and unsustainable) dietary behaviors in adults; and we developed a novel scoring system to rank factors by priority for targeting in future research. Given the significant potential to promote a sustainable and healthy dietary transition on the university campus—where factors that may impact dietary behaviors can be targeted at all levels of influence (i.e., individual, interpersonal, environmental, policy)—we narrowed our focus to this setting throughout. Aided by our novel scoring system, we identified conscious habitual eating, product price, food availability/accessibility, product convenience, self-regulation skills, knowledge of animal ethics/welfare, food promotion, and eating norms as important modifiable factors that may influence university students' dietary behaviors. When scored without consideration for the university population, these factors were also ranked as highest priority, as was modified portion sizes. Our findings offer insight into factors that may warrant attention in future research aimed at promoting SHDs. In particular, the high-priority factors identified from our synthesis of the literature could help guide the development of more personalized dietary behavioral interventions within the university setting and beyond.

Abbreviations: ACM, all-cause mortality; CVD, cardiovascular disease; DONE framework, Determinants of Nutrition and Eating framework; FAO, Food and Agriculture Organization of the United Nations; GHGe, greenhouse gas emissions; LL, living lab; NCD, noncommunicable disease; PHD, Planetary Health Diet; RCT, randomized controlled trial; SHD, sustainable and healthy diet; T2DM, type 2 diabetes mellitus; WHO, World Health Organization.

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1. Introduction

Noncommunicable diseases (NCDs) are responsible for 3 of 4 deaths globally and, despite progress, the prevalence of NCD-related morbidity remains high [1,2]. Dietary risk factors are an important determinant of NCD risk, and it is estimated that healthier diets could prevent 1 of 5 deaths globally [3]. Typical dietary patterns also damage the environment: the global food system contributes to roughly one-third of all anthropogenic greenhouse gas emissions (GHGe) [4], uses ~70% of freshwater [5], and inhabits ~50% of ice-free land surface [6]. Cognizant that diet is a major determinant of human and planetary health, shifting toward a sustainable and healthy diet (SHD) is an important solution to these interconnected issues.

The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) conceptualize an SHD as a nutritious diet that promotes long-term human health, has a low environmental impact, is affordable, and is adaptable to local contexts and cultures [7]. The Planetary Health Diet (PHD), proposed by the EAT-*Lancet* Commission, provided the first example of a globally applicable SHD with quantified food group intake recommendations and placed a firm focus on healthful plant-source food consumption while limiting animal-source food consumption [5,8]. Although there are some questions regarding its nutritional adequacy [9], adoption of the PHD, or an equivalent SHD, should improve nutrient intakes relative to current diets while significantly reducing the burden of diet-related NCDs and environmental impacts [5,10,11]. The PHD, and recent adaptations of it, therefore offer guidance regarding the direction that Western diets must shift toward (i.e., richer in healthful plant-source foods and lower in animal-source foods; particularly red and processed meats) [5,12–16].

Although change is needed across the food system, from production to policy, it is important to consider the role of the individual consumer. Socioecological models of dietary behavior, such as the Determinants of Nutrition and Eating (DONE) framework, acknowledge the interplay between policy, environmental, interpersonal, and individual factors in determining the dietary behaviors of individuals [17]. Likewise, dual-process theories acknowledge that human behavior can be influenced by many factors (including those posited by the DONE framework), proposing that it is guided by conscious and nonconscious processes [18]. Ultimately, researchers must acknowledge the complexity of human behavior to successfully catalyze a shift toward SHDs.

This literature review will first introduce the SHD concept and briefly discuss the rationale for targeting the university setting in the promotion of SHDs. Then, we will present a broad review of the literature pertaining to the factors that may influence sustainable (and unsustainable) dietary behaviors in adults, while highlighting those identified in the university population. Following this, we will present a novel scoring system and use it to rank factors identified in our review by their priority for targeting in future research. Last, we will discuss how our insights may help guide the design of future interventions aimed at promoting SHDs.

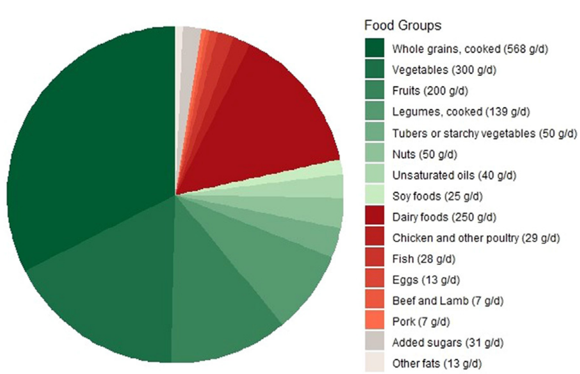

Fig. 1 – Food group components of the Planetary Health Diet [5]. Food group components are presented as the proportion recommended (using the midpoint recommendation) relative to the total diet (in g/d). However, because whole grains and legumes are recommended as dry weights, they were converted to cooked weights by multiplying the dry weights recommended by 2.45 for whole grains (i.e., the average value of cooking factors for brown rice, wild rice, and whole wheat pasta) and 2.77 for legumes (i.e., the average value of cooking factors for various beans and lentils, excluding soy beans) [172]. Green, plant-source food groups; red, animal-source food groups; gray, miscellaneous food groups. This figure was created in RStudio version 4.3.0 (Posit Software) using the ggplot2 package from the tidyverse suite of packages [173].

2. What is a sustainable and healthy diet?

With the global population projected to peak at 9.7 billion in 2064 [19], ensuring everyone has access to a healthy and nutritious diet will unavoidably impact the environment. However, it is possible—and necessary—to minimize this impact through the global adoption of an SHD [5]. As mentioned, an SHD has been characterized as a diet rich in healthful plant-source foods and low in animal-source foods. This is partly because, as a general statement, animal-source food production disproportionately impacts the environment [20–23], and as diets become more plant-based, major environmental impacts are reduced in a stepwise fashion [10,24]. Of all animal-source foods, ruminant meats (e.g., beef, lamb) and some dairy foods stand out as particularly environmentally intensive [20,23]. In fact, red meat and dairy production alone accounted for ~57% of agricultural GHGe in 2020 [25] through the combination of direct livestock methane emissions (via enteric fermentation) and indirect carbon emissions from deforestation for pastureland and feed crop production [20,26]. However, anomalies within food categories exist. For example, although milk is more environmentally intensive than plant-based milk alternatives (e.g., soy milk), it has a lower environmental impact relative to other dairy foods (e.g., cheese, butter) [20,23]. As such, the PHD (Fig. 1) permits moderate intakes of dairy foods (i.e., 250 g/d; range, 0–500 g/d) but strictly limits beef and lamb (i.e., 7 g/d; range, 0–14 g/d) [5].

Given the lower environmental impact of plant-based diets and the human health benefits associated with their consumption, plant-source foods form the base of recent SHD conceptions. Dybvik et al. [27] recently reported a reduced risk of total cardiovascular disease (CVD) (–15%), coronary heart disease (–21%), and stroke (–10%) for vegetarians compared with nonvegetarians in their meta-analysis of 13 cohort studies. Likewise, a recent systematic review and meta-analysis that included more than 2 million individuals from 76 publications reported reductions in the risk of CVD, type 2 diabetes mellitus (T2DM), cancer, and all-cause mortality (ACM) for greater compared with lower adherence to plant-based dietary patterns derived using *a priori* diet indices, as well as for the consumption of vegan and vegetarian diets compared with nonvegetarian diets [28]. Similar findings have been reported for greater adherence to dietary patterns rich in fruits, vegetables, legumes, nuts, whole grains, unsaturated vegetable oils, fish, and lean meat or poultry (when included) [29–31]. Importantly, the health benefits of plant-based diets are contingent on healthful plant-source foods dominating the diet: diets lower in animal-source foods but higher in unhealthful plant-source foods (e.g., refined grains, sweets/desserts) are associated with an increased risk of CVD, T2DM, cancer, and ACM [32–34]. However, substituting even modest amounts of certain animal-source foods (i.e., red and processed meat, poultry, eggs, butter) with healthful plant-source foods (i.e., whole grains, nuts, legumes, olive oil) was associated with a reduced risk of CVD, T2DM, and cancer in a recent meta-analysis of 37 studies [35], underscoring the importance of the replacement food(s) when reducing animal-source food consumption. Naturally, the plant-source foods recommended by the PHD are those that have been associated with positive health outcomes (Fig. 1) [5]. Given the focus on reducing diet-related environmental impacts, and not solely improving human health, SHDs such as the PHD differ somewhat in composition compared with other healthy dietary patterns (e.g., lower in red meat), despite sharing many characteristics [36]. It is therefore unsurprising that global adoption of the PHD may reduce the incidence of premature deaths by ∼19% to 24% per year [5], and greater adherence to PHD indices has been associated with reductions in the risk of morbidity and mortality from various NCDs, as well as ACM, in various populations [37–45].

Despite the emphasis on plant-source food consumption, current SHD conceptions do not totally eschew animal-source food consumption. Indeed, the PHD (Fig. 1) and other SHDs include moderate amounts of dairy foods and low-to-moderate amounts of poultry and seafood [5,12–16]. The inclusion of such foods within SHD conceptions highlights a balance between nutritional and environmental impacts because a minimum intake of animal-source foods is necessary to achieve nutritional adequacy without the consumption of fortified foods and/or supplements [10]. Dairy foods are a notable exemplar because they provide critical nutrients (e.g., calcium, iodine) that are not as reliably found in foods with a lower environmental impact, such as plant-based milk alternatives [46]. The specific proportion of animal-source foods included in an SHD may vary according to population- and context-specific factors. For example, although the PHD was modeled to be nutritionally adequate on a population level [5,10], it may fall short for certain nutrients (e.g., iron, zinc, calcium, vitamin B_{12}) for some individuals, and particularly for nutritionally vulnerable populations (e.g., menstruating females) [9]. Therefore, the inclusion of a greater quantity of animal-source foods beyond PHD midpoint recommendations would likely be necessary to ensure nutritional adequacy in such individuals if consuming an unfortified diet [9]. Vitamin D is another nutrient in which an SHD may not meet requirements as usual intakes are already very low globally [47]. In fact, Fouillet et al. [48] excluded vitamin D from their modeling paper because "*…its reference value is known to be much too high to be reached by a non-fortified diet alone,*" finding that unfortified diets consisting of up to 80% plant protein can be otherwise nutritionally adequate while still being deemed culturally acceptable (to French adults). Despite questions surrounding the nutritional adequacy of SHDs, these diets will improve the nutrient supply of most nutrients relative to typical Western diets [10,11]. In addition, consumption of fortified foods and/or supplements may be required to achieve nutritional adequacy and are known to facilitate a vegan dietary approach [49]. In general, the focus should be on providing broad SHD recommendations to individuals while accounting for context-specific factors (e.g., population-specific nutrient requirements). The adoption of such diets could improve nutrient intakes, reduce NCD-related morbidity and mortality, and reduce diet-related environmental impacts.

3. The university setting and living lab approach

Before presenting our review of the literature, we first introduce the rationale for our focus on targeting the university setting in the promotion of an SHD. Many university students are experiencing "emerging adulthood"—a life stage characterized by behavior change and increased levels of independence and autonomy over their dietary choices—which represents an opportune time for dietary behavior change intervention [50]. In addition, the university can be seen as a model setting for dietary behavior change, in which factors at all levels can be targeted in a variety of complementary ways (Fig. 2). At the individual level, the university enables a "small changes" approach to dietary behavior change through the delivery of dietary behavioral interventions. Such an incremental approach is assumed to be more palatable and effective for producing lasting behavior change [36] and is why many researchers modeling SHDs explicitly built the constraint of dietary "acceptability" into their models [12,15,51–53]. However, incremental improvements in individual dietary behaviors may not be sufficient to curb the disproportionate impact of typical diets on NCDs and environmental degradation; thus, at the food system level, transformational change is required [5]. Crucially, the university setting can also enable transformative action through shifts in food procurement policy, thus reconciling any tensions between incremental and transformational approaches to dietary behavior change.

Within the campus environment, the potential to shift toward sustainable and healthy food procurement holds promise for promoting SHD consumption. Controlling food availability on campus, this process can thus influence what students (and staff) can purchase and would be in line with the overarching FAO/WHO recommendation to create an enabling environment for SHD consumption [7]. Within such an enabling environment, other efforts to shift dietary behaviors

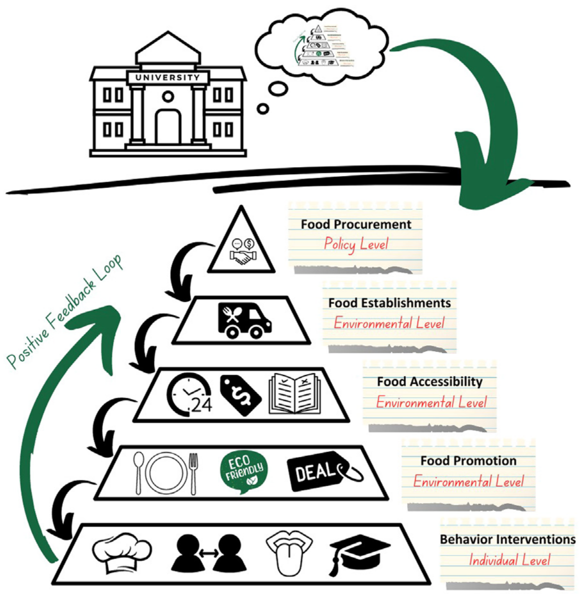

Fig. 2 – The university, presented as an ideal setting for dietary behavior change. Black arrows show interrelations between strategies employed at all levels of influence. Policy-level strategies (e.g., food procurement policy) influence what is served in food establishments, which in turn affects campus food availability/accessibility and is the setting where environmental interventions can take place (e.g., food promotion), which is the ideal setting within which individual-level interventions can take place (e.g., dietary behavioral interventions). The green arrow indicates a positive feedback loop between levels, where a shift toward sustainable and healthy dietary behaviors at the individual level feeds back to further encourage action at preceding levels.

in a sustainable and healthy direction (e.g., behavioral interventions) are more likely to be successful, owing to the improved availability of sustainable and healthy food on campus. In this scenario, achieving SHD consumption on campus is conceivable and could help to address the poor dietary habits and weight gain often observed in university students [54–56]. However, such a shift in food procurement policy may have economic consequences for the university itself, as well as its students. Of particular concern, low-income students may struggle to afford to eat a more SHD [57,58]. Therefore, it is important that university policies are sensitive to this reality and ensure that sustainable and healthy food options are affordable for all of their students.

As the most populous stakeholder on campus, the student voice must be centered when developing interventions. Encouragingly, this cohort has shown an appetite for leading the sustainable and healthy dietary transition. For example, the student-led Plant-Based Universities campaign has garnered support within some universities in the United Kingdom and Germany, where 10 university student unions have recently voted in favor of plant-based food procurement on campus as a result of campaign efforts [59]. Any similar proposals to shift campus food procurement policy should likewise incorporate the student perspective. However, student support is only 1 step in a much larger process, and support from university management will be needed to realize such an ambition (and ultimately determine its success). With that said, there is evidence to suggest that collaboration between staff and students can provide many benefits for institutions, including enhanced engagement, motivation, and learning [60].

The living lab (LL) concept, in which a diverse array of stakeholders cocreate solutions for societal problems in a real-world setting and in a collaborative, iterative, and innovative manner, and then evaluate the impact of such changes [61,62], is a means to facilitate student–staff collaboration on campus (Fig. 3). Moreover, this methodological approach has shown promise in the improvement of health behaviors, helping to reduce smoking by ~80% on an Irish university campus [63] while becoming more prevalent across Europe since the inception of the European Network of LLs in 2006 [62]. Of particular relevance to the topic being considered, an LL has been implemented in a UK university to promote sustainable dietary behaviors [64]. This approach also fits with the ethos of the Okanagan Charter and the Higher Education Healthy Campus Charter & Framework for Ireland 2020–2025, which call for a participatory, innovative, and whole-campus approach to health promotion [65,66]. With all of this considered, the LL concept forms the basis of our strategy in the University College Dublin PLAN'EAT LL [67].

4. What factors influence sustainable (and unsustainable) dietary behaviors?

While sustainable (and unsustainable) dietary behaviors are the focus of this review, it is worth noting that the existing dietary behavior literature has often focused on behavioral outcomes compatible with SHDs (e.g., increasing fruit and vegetable or fiber intakes). Thus, we included studies investigating factors related to general healthy dietary behaviors insofar as they approximate SHD behaviors (Supplemental Table S1). Regarding types of dietary behaviors, we included actual consumption and purchase behaviors, as well as intentions to consume or purchase foods (Supplemental Table S2). Factors were mainly identified through a series of iterative and largely unstructured literature searches in the PubMed and Scopus databases from September 2022 through December 2023 (Supplemental Table S3). Factors were then classified into stem and leaf categories, according to the DONE framework (Supplemental Table S4) [17]. We included individual, interpersonal, and environmental factors, but excluded policy factors, because factors at the policy level are unlikely to be easily incorporated into behavioral interventions and are thus less likely to inform researcher-led interventions (Supplemental Table S1). For a detailed description of our methodology, see Supplemental File S1.

Table 1 lists factors that may influence sustainable (and unsustainable) dietary behaviors, including the study design(s) from which the evidence is derived, whether the factor has been identified within the university population or not, whether the factor is likely to be a barrier to, or enabler of, SHD consumption, or if it is likely fixed or modifiable, as well as the specific type(s) of dietary behavior that factor may in-

Table 1 – Factors that may influence sustainable and healthy diet consumption.

Factors	Study design(s)	University population	Barrier or enabler	Fixed or modifiable	Type of dietary behavior
Individual level					
Cooking skills	Cross-sectional	No	Enabler	Modifiable	Greater SHD adherence [104] Lack of cooking skills a perceived barrier to PBD consumption [99]
Concern for environment	RCT + cross-sectional + cohort	Yes	Enabler	Modifiable	Choosing sustainable fish [87] Greater intentions to purchase PBMAs [81] Greater legume consumption [80] Greater plant protein consumption [87] Lower carbon meal purchase in virtual environment [129] Lower meat consumption [80,87,92,115,116,143] MD consumption [96] PBD consumption [99] PBMA consumption [128]
Conscious habitual eating[a]	MA of RCTs + cross-sectional	Yes	Either	Modifiable	Greater FV and healthy snack consumption [78,130] Greater meat consumption [143] Greater unhealthy food consumption (e.g., SSBs, candies) [130]
Cost as perceived barrier	Cross-sectional + qualitative	Yes	Barrier	Modifiable	Healthy/sustainable food consumption [136] Healthy diet consumption [86] Intentions to consume PBMAs [77]
Extraversion	Cross-sectional	Yes	Either	Fixed	Greater FV consumption [91,134] Greater meat consumption [134,135] Greater SSB consumption [135] Healthier diet consumption [133]
Female sex	Cross-sectional	Yes	Enabler	Fixed	Greater FV consumption [91] Greater intentions to avoid meat/fish [85] Greater intentions to eat plant proteins [87] Greater MD adherence [84,89] Greater motivation to replace meat/fish with legumes [90] Greater SHD adherence [93] Healthy diet consumption [86,88] Lower meat consumption [92] Meat avoidance [88] PBD consumption [74,75,99]
Food enjoyment[a]	Cross-sectional	No	Enabler	Modifiable	Greater intentions to purchase PBMAs [81] Greater legume consumption [80]
Food neophobia	Cross-sectional	Yes	Barrier	Modifiable	Greater levels associated with meat consumption [143] Lower levels associated with PBD consumption [132]
Health consciousness	Cross-sectional + cohort	Yes	Enabler	Modifiable	Greater legume consumption [80] Greater SHD adherence [117] Lower meat consumption [87,92,116,115] PBD consumption [98,114,116]

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Table 1 (*continued*)

Factors	Study design(s)	University population	Barrier or enabler	Fixed or modifiable	Type of dietary behavior
Healthy eating intentions	Cohort	No	Enabler	Modifiable	Lower meat consumption [80,115]
Higher education level	Cross-sectional	N/A	Enabler	Fixed	Choosing sustainable fish [87] Greater intentions to avoid meat/fish [85] Greater MD adherence [84,89] Greater PBD adherence [70] Greater SHD adherence [71,93,103,104] Greater FV consumption [102] Greater fiber consumption [102] Greater motivation to replace meat/fish with legumes [90] Lower beef consumption [95] PBD consumption [75,98]
Higher income[a]	Cross-sectional	No	Enabler	Fixed	Greater fiber consumption [102] Greater FV consumption [102] Greater MD adherence [89] Greater PBD adherence [70] Greater SHD adherence [93,103]
Knowledge of animal ethics/welfare[a]	MA of RCTs + cross-sectional	Yes	Enabler	Modifiable	PBD consumption [99,114,116,132] Reduction in/lower meat consumption [80,92,116,131]
Lower body weight or BMI	Cross-sectional + cohort	Yes	Enabler	Fixed	Greater PBD adherence [69,70,72,73] Greater SHD adherence [71] PBD consumption [74,75]
Nutrition knowledge	RCTs + cross-sectional	Yes	Enabler	Modifiable	Greater FV consumption [107,120–122] Greater MD adherence [96] Lower carbon diet consumption [126] Lower meat consumption [112,120,124,125]
Nutrition self-efficacy	RCT + cross-sectional	Yes	Enabler	Modifiable	Greater FV consumption [94,107,108] Greater intentions to purchase PBMAs [81] Greater PBD adherence [114] Greater SHD adherence [104]
Older age	Cross-sectional	No	Enabler	Fixed	Choosing sustainable fish [87] Greater MD adherence [84,96] Greater motivation to replace meat/fish with legumes [90] Greater SHD adherence [103] Higher fiber intakes [88] Lower beef consumption [95] Lower PBD consumption [75] Lower PBMA consumption [97]
Openness[a]	Cross-sectional	Yes	Enabler	Fixed	Greater FV consumption [91,134,135] Greater intentions to avoid meat/fish [85] Healthier diet consumption [133] Lower meat consumption [135] PBD consumption [98,132]

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Table 1 (*continued*)

Factors	Study design(s)	University population	Barrier or enabler	Fixed or modifiable	Type of dietary behavior
Physical activity	Cross-sectional	No	Enabler	Fixed	PBD consumption [75] Greater PBD adherence [70] Greater SHD adherence [104]
Race/ethnicity[a]	Cross-sectional	No	Either	Fixed	Greater dairy food consumption (Whites) [105,106] Greater fish consumption (Asians/Pacific Islanders) [106] Greater meat consumption (UK Blacks/Latinos/Whites) [105,106] Greater SHD adherence (Whites/Asians/Multiracial) [93] Greater "unhealthy" food consumption (Blacks) [106] Higher quality diet (Asians) [106] Lower dairy food consumption at breakfast/snacking (Blacks) [106] Lower FV consumption (Blacks/African Americans) [106] Lower meat consumption (Asians/Blacks) [95,105,106] Lower SHD adherence (Blacks/Hispanics) [93] PBD consumption (Asians) [75]
Sedentary behavior[a]	Cross-sectional	No	Barrier	Fixed	Greater unhealthy food consumption [137,138] Lower FV consumption [94,137,138] Lower fiber consumption [137] Lower SHD adherence [104]
Self-regulation skills	MAs of RCTs + RCTs	Yes	Enabler	Modifiable	Greater FV consumption [109–111,113] Greater PBD adherence [114] Lower fat intake [109–111] Lower meat consumption [112] Lower SFA intake [109,110] Lower SSB intake [111]
Taste[a]	Cross-sectional	No	Either	Modifiable	Enabler of meat reduction [82] Enabler of plant-source food consumption [82] Predictor of FV consumption [78,79] Perceived barrier to PBMA consumption [77] Perceived barrier to plant-source food consumption [76,83]
Time constraints[a]	Cross-sectional	Yes	Barrier	Fixed	Healthy diet consumption [86] More perceived time predictive of FV consumption [79]
Urban residence	Cross-sectional	No	Enabler	Fixed	Greater FV consumption [101] Greater PBD adherence [69] Lower SHD adherence [100]
Younger age	Cross-sectional	Yes	Either	Fixed	Greater FV consumption [91] Greater PBD adherence [70] Lower beef consumption [95] PBD consumption [98]

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Table 1 (*continued*)

Factors	Study design(s)	University population	Barrier or enabler	Fixed or modifiable	Type of dietary behavior
Interpersonal level					
Acculturation	Cross-sectional	No	Barrier	Fixed	Greater snack and fast food consumption [144] Lower FV consumption [144] Lower legume consumption [144]
Eating norms[a]	MA of RCTs + RCT	Yes	Either	Modifiable	Eating more or less food [142] Lower meat consumption [141] Making healthier or less healthy food choices [142]
Male gender norms[a]	RCT + cross-sectional	No	Barrier	Modifiable	Greater meat consumption [139,140]
Peer pressure	Cross-sectional	Yes	Either	Fixed	Barrier to PBD consumption [99] Enabler of legume consumption [80] Enabler of meat reduction [141]
Social support	Cross-sectional	No	Enabler	Modifiable	Greater FV consumption [107] Greater intentions to avoid meat/fish [85] Lower meat consumption [143]
Environmental level					
Food promotion[a]	RCTs	Yes	Enabler	Modifiable	Greater fiber content of shopping basket in virtual setting [159] Increased FV purchasing [113,158] Lower carbon meal purchase in virtual environment [129] Mixed effects on meat purchasing [145] Mixed effects on PBMA purchasing [145]
Food availability/accessibility[a]	RCTs + cross-sectional	Yes	Enabler	Modifiable	Greater FV consumption [79,151–155] Greater PBMA consumption [145,156] Greater SHD adherence [104] Lower meat consumption [145,156] Lower meat purchase/selection [145]
FOP food labels	RCTs	Yes	Enabler	Modifiable	Sustainable/healthy food choices in real-life setting [147–149] Sustainable/healthy food choices in virtual setting [129,146]
Increased product visibility	RCTs	Yes	Enabler	Modifiable	Greater purchase of healthier breakfast and snack foods [148] Greater fiber content of shopping basket in virtual setting [159]

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Table 1 (*continued*)

Factors	Study design(s)	University population	Barrier or enabler	Fixed or modifiable	Type of dietary behavior
Lower product price	RCTs	Yes	Enabler	Modifiable	Greater FV consumption [113,150] Greater "healthy foods" purchase [150] Greater high-fiber grains/cereals purchase [150] Lower %SFA foods purchase [150] Lower high-fat dairy purchase [150] Lower SSB purchase [150] Mixed effects on reducing meat purchase/consumption [145,150]
Meal environment	Cross-sectional	Yes	Barrier	Modifiable	Lower adherence to MD [84] Lower adherence to a healthy diet [86]
Modified portion sizes	RCTs	No	Enabler	Modifiable	Greater FV consumption [113,145] Lower meat consumption [113,145]
Product convenience	RCTs	Yes	Enabler	Modifiable	Greater consumption of PBMAs [145,156] Lower meat consumption [145,156]
Sensory appealing meals	RCTs + cross-sectional	Yes	Enabler	Modifiable	Greater intentions to purchase PBMAs [81] Greater purchase of meat-free meals [145]

Abbreviations: BMI, body mass index; FOP, front-of-pack; FV, fruit and/or vegetable; MA, meta-analysis, MD: Mediterranean diet; PBD, plant-based diet; PBMA, plant-based meat alternative; RCT, randomized controlled trial; SFA, saturated fatty acid; SHD, sustainable and healthy diet; SSB, sugar-sweetened beverage.
Factor levels are taken from the Determinants of Nutrition and Eating (DONE) framework [17]. In this context, an "enabler" is a factor that has been associated with sustainable dietary behaviors, a "barrier" is one that has been associated with unsustainable dietary behaviors (and factors classed as "either" could be both an enabler or barrier), a "fixed" factor is one that is deemed unlikely to directly change sustainable dietary behaviors when manipulated in a dietary intervention, or is unable to be modified, and a "modifiable" factor is one that is deemed likely to change sustainable dietary behaviors when changed in a dietary intervention (based on the literature as well as factor modifiability ratings from the DONE framework). Here, PBD consumption refers to the consumption of vegan or vegetarian diets, PBD adherence refers to adherence to plant-based dietary patterns measured by *a priori* or *a posteriori* methodologies, and SHD adherence refers to adherence to dietary patterns measured by SHD diet indices. Data from meta-analyses of interventions communicating genetic cardiometabolic risk, which could affect an individual's perceived physical health (a health cognition), were not included in the table as there was no significant effect of such interventions on changing dietary behaviors in the studies included in this review [118,119].

[a] The following factors were not explicitly rated by the DONE framework, so were rated as similar factors that had ratings: conscious habitual eating is rated as "habitual eating"; extraversion and openness are rated as "personality traits"; food enjoyment and taste are rated as "food preferences"; higher income is rated as "low income"; knowledge of animal ethics/welfare is rated as "food ethics"; race/ethnicity is rated as "ethnicity"; sedentary behavior incorporated physical inactivity and is rated as "physical activity level"; time constraints is rated as "daily rhythm/structure"; eating norms and male gender norms are rated as "social norms"; food promotion is rated as "food adverts"; and food availability/accessibility is rated as the average of "food accessibility" and "food availability."

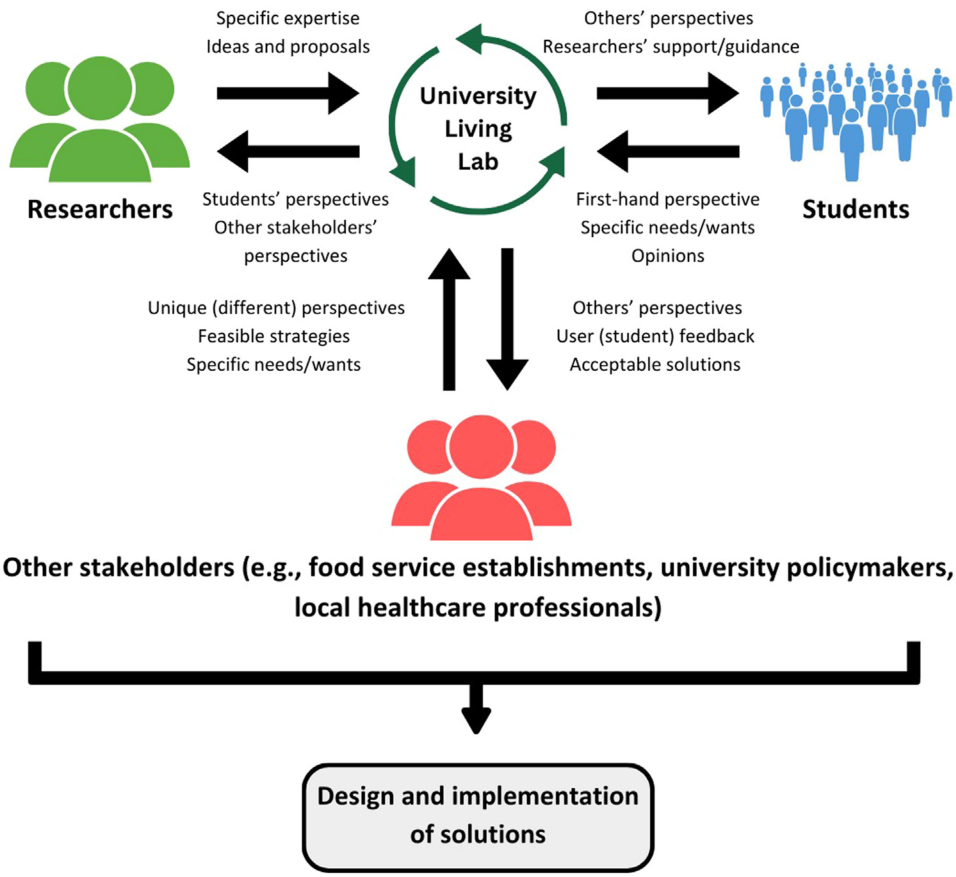

Fig. 3 – The university living lab process, adapted from Yasuoka et al. [174]. Arrows from stakeholders toward the university living lab indicate inputs from that stakeholder. Arrows from the university living lab toward stakeholders indicate learnings from the other stakeholders involved in the university living lab. Learnings from this iterative, cocreation approach ultimately feed into the design and implementation of solutions for a given challenge (e.g., interventions aimed at promoting sustainable and healthy diets).

fluence. Table 2 lists factor stem and leaf categories, modifiability ratings, relationship strength, population-level effect, and overall priority for research, all as per the DONE framework [17]. Both tables thus provide the necessary information to rank factors by priority (presented in Section 5). The following subsections are organized first by factor level (i.e., individual, interpersonal, environmental per the DONE framework) [17]. Within levels, factors are then organized into further subsections according to their stem category (also per the DONE framework) [17]. Where possible, we focus on studies conducted in the university population to highlight factors that may be specific to this cohort.

4.1. *Individual factors*

Thus far, the literature has focused mainly on individual factors [50,68]. Specifically, we identified relationships between biological (e.g., body weight), demographic (e.g., sex), psychological (e.g., self-efficacy), and situational (e.g., sedentary behavior) factors and sustainable (and unsustainable) dietary behaviors (listed in Tables 1 and 2 and reviewed in the following subsections).

4.1.1. *Biological factors*

Lower levels of body weight or body mass index are consistently associated with the consumption of plant-based dietary patterns derived using either *a priori* or *a posteriori* methodologies [69–75]. Taste has also been associated with sustainable dietary behaviors: acting as a perceived barrier to plant-source food consumption [76,77], as well as a predictor of fruit and vegetable intake [78,79]. Enjoyment and sensory appeal, which likely incorporate taste, have likewise been associated with legume consumption and intentions to eat plant-based meat alternatives in French adults and young Taiwanese adults, respectively [80,81]. In their review, Graça et al. [82] identified positive taste expectations of plant-based meals, and a dislike of the taste of meat, to enable meat reduction and plant-source food consumption, whereas Cliceri et al. [83] reported a higher sensitivity to bitterness as a barrier to eating plant-source foods.

4.1.2. *Demographic factors*

The female sex is consistently associated with sustainable dietary behaviors [74,75,84–93,98,99], while males were reported as more likely to be "disproportionate" beef eaters (i.e., consumers of greater than 4 oz–equivalents [or four ~28

Table 2 – Classification of factors and heat map of factor ratings with respect to specific criteria, according to the DONE framework [17].

Factors	Stem category	Leaf category	MR	RS	PLE	OPR
Individual level						
Cooking skills	Psychological	Food knowledge, skills, abilities	2.54	1.31	1.92	**2.14**
Concern for environment	Psychological	Food beliefs	2.17	1.42	1.67	**1.99**
Cost as perceived barrier	Psychological	Food beliefs	2.31	1.67	2.08	**2.29**
Conscious habitual eating[a]	Psychological	Food habits	2.00	1.70	2.80	**2.45**
Extraversion[a]	Psychological	Personality	1.83	1.64	1.64	**1.97**
Female sex	Demographic	Biological demographics	1.30	1.55	2.00	**1.87**
Food enjoyment[a]	Biological	Sensory perception	1.91	1.73	2.36	**2.29**
Food neophobia	Psychological	Eating regulation	1.82	1.64	1.55	**1.94**
Health consciousness	Psychological	Health cognitions	2.27	1.82	2.45	**2.48**
Healthy eating intentions	Psychological	Health cognitions	2.18	1.70	1.80	**2.18**
Higher education level	Demographic	Personal socioeconomic status	1.92	1.54	2.69	**2.31**
Higher income[a]	Demographic	Personal socioeconomic status	1.55	1.55	2.70	**2.19**
Knowledge of animal ethics/welfare[a]	Psychological	Food Beliefs	2.00	1.70	1.80	**2.12**
Lower body weight or BMI	Biological	Anthropometrics	2.00	1.29	2.07	**2.00**
Nutrition knowledge	Psychological	Food knowledge, skills, abilities	2.42	1.58	1.67	**2.15**
Nutrition self-efficacy	Psychological	Food knowledge, skills, abilities	2.40	1.70	2.20	**2.38**
Older age	Demographic	Biological demographics	1.57	1.50	2.29	**2.04**
Openness[a]	Psychological	Personality	1.83	1.64	1.64	**1.97**
Physical activity	Situational	Related health behaviors	2.25	1.50	2.17	**2.22**
Race/ethnicity[a]	Demographic	Cultural characteristics	1.67	1.55	1.75	**1.91**
Sedentary behavior[a]	Situational	Related health behaviors	2.25	1.50	2.17	**2.22**
Self-regulation skills	Psychological	Self-regulation	1.92	1.83	2.17	**2.28**
Taste[a]	Biological	Sensory perception	1.91	1.73	2.36	**2.29**
Time constraints[a]	Situational	Situational and time constraints	2.15	1.23	1.69	**1.90**
Urban residence	Demographic	Situational demographics	1.56	1.33	1.67	**1.74**
Younger age	Demographic	Biological demographics	1.57	1.50	2.29	**2.04**
Interpersonal level						
Acculturation	Cultural	Cultural behaviors	2.11	1.11	1.67	**1.81**
Eating norms[a]	Social	Social influence	1.92	1.42	2.67	**2.24**
Male gender norms[a]	Social	Social influence	1.92	1.42	2.67	**2.24**
Peer judgment	Social	Social influence	2.25	1.42	2.25	**2.21**
Social support	Social	Social support	2.00	1.50	2.67	**2.31**
Environmental level						
Food promotion[a]	Meso/macro	Exposure to food promotion	2.33	1.33	2.50	**2.28**
Food availability/accessibility[a]	Micro	Home food availability and accessibility	2.08	1.75	2.46	**2.39**
FOP food labels	Product	Extrinsic product attributes	2.23	1.38	2.08	**2.13**
Increased product visibility	Meso/Macro	Home food availability and accessibility	2.15	1.31	2.00	**2.04**
Meal environment	Micro	Eating environment	2.09	1.36	2.27	**2.14**
Modified portion sizes	Micro	Portion size	2.45	1.82	2.45	**2.55**
Lower product price	Product	Extrinsic product attributes	2.31	1.69	2.67	**2.50**
Product convenience	Product	Extrinsic product attributes	2.15	1.54	2.50	**2.32**
Sensory appealing meals	Product	Intrinsic product attributes	2.38	1.85	2.69	**2.62**

Abbreviations: BMI, body mass index; DONE, Determinants of Nutrition and Eating; FOP, front-of-pack; MR, modifiability rating; RS, relationship strength; PLE, population-level effect; OPR, overall priority for research.

Factor levels and ratings are taken from the DONE framework [17]. Modifiability refers to the extent to which it is possible to change the influence of the specific factor in a healthful direction and was scored as low (1.00–1.49), moderate (1.50–1.99), substantial (2.00–2.49), and high (2.50–3.00). Relationship strength refers to the strength of the relation between the factor and the outcome (i.e., correlational (1.00) or causal (2.00) and was scored as low (1.00–1.24), moderate (1.25–1.49), substantial (1.50–1.74), and high (1.75–2.00). Population-level effect refers to the expected impact of the factor on eating behavior at the population-level, taking into account the strength of the association as well as the prevalence of the exposure to the factor in the general population, and was scored as low (1.00–1.49), moderate (1.50–1.99), substantial (2.00–2.49), and high (2.50–3.00). Overall priority for research is a weighted score of the 3 prior scores, based on the following formula: modifiability rating/3 + relationship strength rating/2 + population-level effect rating/3.

[a] The following factors were not explicitly rated by the DONE framework [17], so were rated based on similar factors that had ratings: conscious habitual eating is rated as "habitual eating"; extraversion and openness are rated as "personality traits"; food enjoyment and taste are rated as "food preferences"; higher income is rated as "low income"; knowledge of animal ethics/welfare is rated as "food ethics"; race/ethnicity is rated as "ethnicity"; sedentary behavior is rated as "physical activity level"; time constraints is rated as "daily rhythm/structure"; eating norms and male gender norms are rated as "social norms"; food promotion is rated as "food adverts"; and food availability/accessibility is rated as the average of "food accessibility" and "food availability."

g–equivalents] per 2200 kcal) in a nationally representative sample of US adults [95]. Older age is likewise associated with more sustainable dietary behaviors overall [84,88,90,94–96,103], but not for all types of sustainable dietary behaviors (i.e., consumption of vegetarian diets or plant-based meat alternatives) [75,97], while younger age is also often associated with sustainable dietary behaviors [70,91,95,98]. Urban residence has been associated with consumption of a "vegetable-focused" dietary pattern in a nationally representative sample of Irish adults [69], lower adherence to an SHD in Mexican adults [100], and greater fruit and vegetable consumption in African American adults [101]. Other markers of socioeconomic status (e.g., higher education, higher income) are positively associated with sustainable dietary behaviors (e.g., fruit and vegetable consumption, greater adherence to SHDs) [70,71,75,84,85,87,89,90,93,95,98,102–104].

Cultural demographic characteristics may also influence sustainable (and unsustainable) dietary behaviors. In nationally representative data from the United Kingdom and United States, Asian groups reported lower meat consumption but greater vegetable consumption than other racial groups at lunch and dinner, whereas White groups consumed more dairy foods than other racial groups, Black groups consumed less dairy foods at breakfast and when snacking, and Black groups from the United Kingdom consumed more meat than other racial groups at lunch [105]. Somewhat echoing these findings, in their systematic review, Bennett et al. [106] found that studies assessing dietary intakes of ethnic groups tended to report higher quality diets among Asian groups, including lower meat consumption and greater fish consumption relative to other ethnic groups. Bennett et al. [106] also reported White groups to be highest dairy consumers, whereas Black/African American groups more often reported lower consumption of fruits and vegetables and dairy foods, but higher consumption of "unhealthy" foods (e.g., desserts, snacks, fast food). In other nationally representative data from the United States, Whites, Asians, and Multiracial individuals were more likely to be in the highest quintile of PHD adherence, whereas Blacks and Hispanics were more likely to be in the lowest quintile of PHD adherence [93], and Blacks and Asians were less likely to be "disproportionate" beef consumers [95]. Asians were also more likely to eat a plant-based diet in nationally representative data from New Zealand [75].

4.1.3. *Psychological factors*

Of the many psychological factors studied [50,68], self-efficacy is associated with healthier dietary behaviors and greater fruit and vegetable consumption in the vast majority of observational studies investigating this relationship [94,104,107]. Moreover, greater levels of perceived behavioral control, a related concept to self-efficacy, was associated with intentions to purchase plant-based meat alternatives in young Taiwanese adults [81], and a 1-month-long self-efficacy intervention led to lasting improvements in fruit and vegetable consumption in a randomized controlled trial (RCT) of mostly young adults [108]. Another important psychological determinant of dietary behaviors is self-regulation. Implementation intention interventions, which involve setting strategic action plans to enhance self-regulation capacity, have been reported to be effective at improving dietary behavior in multiple systematic reviews and/or meta-analyses [109–111]. Furthermore, Loy et al. [112] found an implementation intention intervention to be more effective than an informational intervention for reducing meat consumption in university students (i.e., –50 g/d vs. –27 g/d from baseline, respectively, at 4-week follow-up). In their systematic review, Taufik et al. [113] also reported that more than half of their included studies targeting self-regulation as a factor were effective at improving dietary behavior, and greater levels of planning—a form of self-regulation—have been associated with successful maintenance of a plant-based diet in US university students [114]. Health cognitions may also influence sustainable dietary behaviors, with greater health motives associated with greater legume consumption in 1 study [80], greater consumption of plant-based diets in 2 studies [98,114], and lower meat consumption in 4 studies [80,87,92,115]. In a study of university students from 11 countries across Europe and Asia, health motives were likewise associated with the consumption of vegetarian and vegan diets [116], whereas lower health motives predicted poor adherence to an SHD in a study of young Australian adults [117]. Curiously, disclosing one's genetic risk of developing a condition, which could affect an individual's health cognitions (a psychological factor), may not be effective for dietary behavior change [118,119]. However, some examples of impact are reported when the provision of genetic risk-based advice is compared with generic healthy eating advice, as well as when the study population has higher initial levels of motivation and/or genetic literacy [118,119].

Another well-researched psychological factor is nutrition knowledge. Although greater nutrition knowledge has been associated with greater adherence to the Mediterranean diet and greater fruit and vegetable consumption [96,120], and improvements in knowledge improve fruit and vegetable intakes in interventions [107,121,122], interventions that aim to increase nutrition knowledge have been found to be less effective at reducing meat intake [123]. However, there are examples of such interventions that have led to reductions in meat intake and diet-related carbon footprint in the university setting [124–126], and lower levels of nutrition knowledge have been associated with greater red and processed meat consumption in university students [120]. Greater cooking skills, a related factor to nutrition knowledge, have been associated with greater SHD adherence in young adults [104], whereas a lack of cooking skills was cited as a perceived barrier to the consumption of a vegan diet in a sample of predominantly female US adults [99].

Food beliefs, including environmental concern, may also impact sustainable dietary behaviors [74,80,87,81,92,96,99,115,127–129], as might self-reported food habits [78], which can promote both healthful and unhealthful dietary behaviors and may moderate the intention–behavior relationship [130]. A greater concern for animal ethics and welfare is another (psychological) factor cited as an enabler of plant-based diet consumption [99,114,116,132]. In fact, a recent meta-analysis reported significant reductions in meat consumption (in the short-term) after exposure to interventions appealing to animal welfare [131]. Lower levels of food neophobia [132] and higher levels of openness [85,91,98,132–135] have also been associated with sustainable dietary behaviors, whereas associations between extraversion and dietary behaviors are mixed [91,133–135]. Cost was cited as a perceived barrier to healthier diet consumption in Australian university students [86,136] and to plant-based meat alternative consumption in European adults [77].

4.1.4. *Situational factors*

Situational factors such as sedentary behavior and physical inactivity are known to be associated with unhealthful dietary behaviors (e.g., greater fast food consumption, lower fruit and vegetable consumption) [94,104,137,138]. On the other hand, greater physical activity levels are associated with greater adherence to SHDs [70,75,104]. A perceived lack of time was associated with lower adherence to a healthy diet in Australian university students [86], whereas a perception of having time was predictive of fruit and vegetable intakes in young US adults [79].

4.2. *Interpersonal factors*

Few studies have investigated the influence of interpersonal factors on dietary behaviors [50,68]. That said, we identified relationships between social (e.g., peer pressure) and cultural (i.e., acculturation) factors and sustainable (and unsustainable) dietary behaviors (listed in Tables 1 and 2 and reviewed in the following subsections).

4.2.1. *Social factors*

Various social norms may influence sustainable (and unsustainable) dietary behaviors. Pressure from relatives and doctors was cited as a driver of legume consumption in a study of French adults [80], whereas social judgment was cited as a barrier to eating a vegan diet in US adults [99]. Masculinity, a social (or gender) norm, has been associated with meat consumption in US and Australian adults [139,140]. In a unique study that communicated a dynamic eating norm that people are reducing their meat consumption, a greater interest in reducing meat consumption as well as reductions in meat purchasing behaviors were reported for those exposed to this norm [141]. In addition, a meta-analysis of 15 interventions that manipulated informational eating norms also reported significant changes in dietary behaviors directly after exposure (i.e., eating more or less food, or making healthier or unhealthier choices, depending on the norm) [142].

Social support may also impact sustainable dietary behaviors. Shaikh et al. [107] identified social support as a predictor of fruit and vegetable consumption in 5 of 6 studies investigating this relationship. Three of these studies also reported social support as a mediator of fruit and vegetable consumption [107]. Having a social network of meat reducers and avoiders was associated with intentions to reduce meat consumption in a nationally representative sample of Danish adults, which also suggests social support as an influence [143].

4.2.2. *Cultural factors*

Greater acculturation has been associated with lower diet quality and micronutrient intakes, including a lower consumption of fruits, vegetables, and legumes among US Latinos [144]. No other cultural factors were identified at the interpersonal level; however, cultural factors were identified at the individual level (i.e., race/ethnicity) and were discussed in Section 4.1.2.

4.3. *Environmental factors*

Environmental factors have been studied less often than individual factors, but more so than interpersonal factors [50,68]. We identified relationships between product (e.g., sensory appeal), microenvironment (e.g., modified portion sizes), and meso-/macroenvironment (e.g., increased food availability/accessibility) factors and sustainable (and unsustainable) dietary behaviors (listed in Tables 1 and 2 and reviewed in the following subsections).

4.3.1. *Product factors*

In their systematic review, Bianchi et al. [145] reported that manipulating the sensory appeal of meat or vegetarian dishes reduced meat demand in RCTs of virtual shopping environments. On a similar note, Chen et al. [81] reported greater ratings of sensory appeal to predict intentions to purchase plant-based meat alternatives in young Taiwanese adults. The addition of an environmental front-of-pack label to food products has been shown to reduce the environmental footprint of a virtual basket in a recent RCT [146], and information at the point-of-purchase (including color coding) has proved effective in improving dietary behaviors in the university and virtual settings [129,147,148]. Indeed, Nutri-Score, a traffic-light label, has been demonstrated to improve dietary choices in a large RCT while outperforming other labels [149]. Price incentives have also been shown to promote a range of healthy dietary behaviors but were not always effective at decreasing meat consumption or purchase [113,145,150].

4.3.2. *Microenvironment factors*

Modifying portion sizes (i.e., increasing vegetables and/or decreasing meat) has been shown to increase vegetable consumption, increase the sale of smaller compared with larger portion meat products, and decrease meat consumption, in a total of 5 RCTs identified from 2 systematic reviews [113,145]. The eating environment may also influence dietary behaviors: in a study of young Australian university students, 10% cited social events as a barrier to eating healthily because of temptation to eat unhealthy foods or a lack of availability of healthier foods [86]. In addition, eating out of the home was associated with a lower likelihood of adhering to the Mediterranean diet in an Italian cohort [84].

4.3.3. *Meso-/macroenvironment factors*

A recent multisite US study provided strong evidence for the effectiveness of “produce prescriptions” in the improvement of fruit and vegetable intake, leading to a roughly 1-cup-per-day increase in their consumption after a median of 6 months of follow-up [151]. Likewise, the provision of free fruits and/or vegetables has been shown to increase their consumption in the university setting [152–155]. The provision of plant-based meat alternatives in place of meat in the trial from Bianchi et al. alsolikely contributed to the success of the intervention, in which meat consumption was reduced by 63 g/d after 4 weeks [156]. These studies highlight the important role of increasing food availability and accessibility in the promotion of sustainable dietary behaviors, both within and beyond the university setting.

Nudges—which are interventions that use subtle cues to influence behavior in a noncoercive manner (e.g., choice architecture interventions) [157]—have shown some promise for encouraging sustainable dietary behaviors. Specifically, "priming" nudges that alter subconscious cues (e.g., increased visibility) have been shown to positively influence dietary behavior [148]. In addition, a nudge that incorporated a reflective component (i.e., "nudge+") lowered GHGe from meal purchases by a further 40% compared with a default nudge, which was itself effective at lowering meal purchase–related GHGe, in a recent virtual RCT of more than 3000 UK adults [129]. Interventions targeting other aspects of food promotion are somewhat mixed in their efficacy. Some studies report increased vegetable consumption subsequent to food promotion (e.g., prompts) [113], whereas other studies that manipulated descriptions of meat and plant-based meat alternatives had little effect on purchasing [145], and those that positively manipulated the appeal of vegetarian dish descriptions were largely effective in promoting their consumption in place of meat-based dishes [145]. It is possible that effects may differ depending on the particular description advertised. For example, a study conducted across 5 US universities found that taste-focused labels increased vegetable consumption by 14% compared with basic labels and 29% more than health-focused labels [158]. Manipulating the order of default items has also been shown to improve the fiber content of online shopping baskets [159].

4.4. *Key findings for synthesis*

Although not exhaustive, the evidence presented here offers insight into the factors associated with sustainable (and unsustainable) dietary behaviors that may be important to characterize in a given adult population and could be used to inform the development of interventions aimed at promoting SHDs. Furthermore, we have identified factors that could potentially influence SHD consumption both within and beyond the university population. To synthesize our findings into a more actionable format that can guide the development of future interventions, we present a novel scoring system to rank factors by priority for future research in the following section.

5. High-priority factors to target in future research

To develop a hierarchy of factors that could be important to consider in the development of interventions aimed at promoting SHDs, we took inspiration from the approach of Gardner et al. [160] and crudely ranked the modifiable (Supplemental Table S5) and fixed (Supplemental Table S6) factors listed in Table 1 according to subjective quality criteria. These are: (1) strength of evidence; (2) population; (3) type of dietary behavior; (4) modifiability [17] (for modifiable factors only); (5) relationship strength [17]; and (6) population-level effect [17]. Each component was scored from 0.00 to 1.00 and then added to compute a total score that could range from 0.00 to 6.00 for modifiable factors and 0.00 to 5.00 for fixed factors. We also calculated a score (range, 0.00 to 5.00 for modifiable factors and 0.00 to 4.00 for fixed factors) for each factor without taking the population into account to not penalize factors that were supported by strong evidence but were not conducted in the university population (e.g., self-regulation) and to allow for a broader application of our findings beyond the university setting. For detailed information on the specifics of the scoring criteria, and to see the full list of factors and their respective rankings, see Supplemental File S1 and Supplemental File S2. For modifiable factors, our scoring system identified conscious habitual eating (5.50/6.00), product price (5.25/6.00), food availability/accessibility (5.25/6.00), product convenience (5.25/6.00), self-regulation skills (5.25/6.00), knowledge of animal ethics/welfare (5.00/6.00), food promotion (5.00/6.00), and eating norms (5.00/6.00) as the highest ranked factors and thus potentially important to target in interventions aimed at promoting SHDs in university students (Fig. 4). When scored without consideration for population, modified portion sizes also scored highly (4.25/5.00) (Fig. 4). For fixed factors, younger age (4.25/5.00), female sex (4.25/5.00), and lower body weight or body mass index (4.00/5.00) scored highly both within the university population and without consideration for population, as did higher income (3.50/4.00) and older age (3.25/4.00) for the latter. In addition, higher education levels scored highly both with (4.00/5.00) and without (3.50/4.00) consideration for the population. However, this is not a very relevant factor within the university setting, as university students are all enrolled in third-level education.

6. Implications for future research

Our review of the literature identified factors that are likely to be barriers to, or enablers of, SHD consumption, as well as those that may be modifiable or fixed (Table 1). In addition, our synthesis of this information has allowed for the identification of a priority list of modifiable factors to consider in the intervention development process both within and beyond the university setting (Fig. 4). These factors span different levels of influence (i.e., individual, interpersonal, environmental) and, as such, each could influence sustainable (and unsustainable) dietary behaviors through a variety of mechanisms. Therefore, it would be advisable to integrate these factors alongside a sound model of behavior change when developing interventions to ensure that any proposed interventions are theoretically grounded and are targeted toward the appropriate group of individuals for the appropriate target dietary behavior. Doing so would improve the likelihood of intervention success, which must be determined through a thorough evaluation of the intervention and is especially important considering most dietary interventions conducted in the university setting lack a theoretical basis [147]. The Capability, Opportunity, and Motivation Behavior model, which specifies the 3 necessary conditions to perform a behavior (i.e., capability, opportunity, motivation), can be used in this regard because it can uncover which components of behavior need to be addressed to achieve a given dietary behavior, especially if the specific factors (e.g., cost, taste) influencing that behavior are understood [161].

	Top 10 modifiable factors that may influence sustainable and healthy diet consumption									
	1	2	3	4	5	6	7	8	9	10**
Scoring Criteria	Conscious habitual eating*	Product price	Food availability/ accessibility*	Product convenience	Self-regulation skills	Knowledge of animal ethics/ welfare*	Food promotion*	Eating norms*	Modified portion sizes	Nutrition knowledge
Strength of Evidence	1.00/1.00	0.75/1.00	0.75/1.00	0.75/1.00	1.00/1.00	1.00/1.00	0.75/1.00	1.00/1.00	0.75/1.00	0.75/1.00
Population	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	0.50/1.00	1.00/1.00
Type of Dietary Behavior	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00	1.00/1.00
Modifiability	0.75/1.00	0.75/1.00	0.75/1.00	0.75/1.00	0.50/1.00	0.75/1.00	0.75/1.00	0.50/1.00	0.75/1.00	0.75/1.00
Relationship Strength	0.75/1.00	0.75/1.00	1.00/1.00	0.75/1.00	1.00/1.00	0.75/1.00	0.50/1.00	0.50/1.00	1.00/1.00	0.75/1.00
Population-Level Effect	1.00/1.00	1.00/1.00	0.75/1.00	1.00/1.00	0.75/1.00	0.50/1.00	1.00/1.00	1.00/1.00	0.75/1.00	0.50/1.00
Total Score	5.50/6.00	5.25/6.00	5.25/6.00	5.25/6.00	5.25/6.00	5.00/6.00	5.00/6.00	5.00/6.00	4.75/6.00	4.75/6.00
Total Score (Without Population)	4.50/5.00	4.25/5.00	4.25/5.00	4.25/5.00	4.25/5.00	4.00/5.00	4.00/5.00	4.00/5.00	4.25/5.00	3.75/5.00

Fig. 4 – Heat map of the top 10 modifiable factors that may influence sustainable and healthy diet consumption within the university and beyond. Each of the 6 components of the total score were scored from 0.00 to 1.00, where dark green indicated a perfect score (i.e., 1.00/1.00), light green indicated a score of 0.75/1.00, and light red indicated a score of 0.50/1.00. Strength of evidence was rated as: 1.00 = derived from a single meta-analysis of randomized controlled trials (RCTs) or multiple meta-analyses of RCTs; 0.75 = derived from multiple RCTs; 0.50 = derived from a single RCT and multiple observational studies; 0.25 = derived from multiple observational studies; and 0.00 = derived from a single observational study or qualitative studies. The population was rated as: 1.00 = including studies conducted in an exclusively university population; 0.50 = including studies conducted in an exclusively young adult population (i.e., with a mean or median age of 18–30 years); and 0.00 = neither (i.e., including studies conducted in other adult populations). Type of dietary behavior was rated as: 1.00 = consumption or purchase (multiple studies); 0.75 = consumption or purchase (single study); 0.50 = intentions to eat (multiple studies); and 0.25 = intentions to eat (single study). Modifiability was rated as: 1.00 = "high"; 0.75 = "substantial"; 0.50 = "moderate"; and 0.25 = "low," as specified by the Determinants of Nutrition and Eating (DONE) framework [17]. Relationship strength was rated as: 1.00 = "high"; 0.75 = "substantial"; 0.50 = "moderate"; and 0.25 = "low," as specified by the DONE framework [17]. Population-level effect was rated as: 1.00 = "high"; 0.75 = "substantial"; 0.50 = "moderate"; and 0.25 = "low," as specified by the DONE framework [17]. Scores from each component were added together to compute a total score that could range from 0.00 to 6.00. Scores were also totaled without the "population" component (i.e., 0.00 to 5.00) to not penalize factors that were supported by strong evidence but were not conducted in the university population (e.g., self-regulation) and to allow for a broader application of our findings beyond the university setting. Total scores range from dark green (for higher scores) to light green (for lower scores). *The following factors were not explicitly rated by the DONE framework, so were rated as similar factors that had ratings: conscious habitual eating is rated as "habitual eating"; food availability/accessibility is rated as the average of "food accessibility" and "food availability"; knowledge of animal ethics/welfare is rated as "food ethics"; food promotion is rated as "food adverts"; and eating norms is rated as "social norms." **Other factors (i.e., health consciousness, nutrition self-efficacy, front-of-pack labels, increased product visibility, sensory appealing meals) had an equivalent rating to nutrition knowledge, so could also have been ranked in the top 10. Nutrition knowledge was selected for presentation in the heat map as it is likely a necessary (but not sufficient) component of dietary behavior change.

The specific dietary targets proposed in any SHD intervention should ideally be guided by an understanding of the current dietary patterns of the population in question as well as other context-specific factors inherent to the population and/or setting. Indeed, establishing a representative baseline of diet is an FAO/WHO-recommended action for promoting SHDs [7]. Hypothetical interventions could target the whole dietary pattern, promote or discourage specific food groups inherent to SHDs or unsustainable and unhealthy diets, or target other outcomes (e.g., reducing food waste). To evaluate intervention success, researchers could calculate adherence to a reference SHD (e.g., the PHD) using validated diet indices pre- and postintervention [37,39,42,43,162], with differences in score reflecting changes in the overall sustainability (and healthfulness) of the diet after the intervention. Or, if the intervention is focused on the promotion (or discouragement) of certain food groups (e.g., increasing legume intake, decreasing meat intake), and not an overall dietary pattern, measuring consumption of such food groups pre- and postintervention, or changes in a biomarker of a specific food group intake (e.g., carotenoids for fruits and vegetables), are ways to measure adherence to this aspect of SHD consumption and evaluate intervention success. Beyond these examples, researchers may measure SHD adherence using different indicators (e.g., body weight, food waste, nutrient intake, cost) based on their conceptions of a SHD and the impacts they deem most appropriate to target in interventions (e.g., health, environmental, nutritional, economic).

Our insights into the factors that may influence sustainable (and unsustainable) dietary behaviors allow for the development of more personalized interventions. This is especially the case if paired with an understanding of the target population and desired dietary behaviors. Using university students as an example, certain high-priority factors identified in our review and synthesis of the literature may be more (or less) applicable to their context. For instance, interventions aimed at improving nutrition knowledge may be impactful in this population, as they are actively engaged in third-level education and thus may value knowledge more than other populations. In addition, product price could be a barrier to SHD consumption for university students given the financial pressures of tuition and living expenses at a time when students cannot work full-time jobs. Personalized nutrition interventions that account for context-specific behavioral factors such as these could be an effective way to promote SHDs in the university population. This is especially the case because most university students are entering a life stage associated with increased dietary independence [50], where such interventions would be particularly timely. Although conceptions of personalized nutrition often center differences in biological traits as inputs to generate personalized advice [163], using insights from our review and synthesis would center differences in external (e.g., product price) and behavioral (e.g., self-regulation skills) factors as inputs. Such an approach represents a potential means to improve the appropriateness and effectiveness of interventions relative to a 1-size-fits-all strategy. Indeed, there is some evidence to suggest that personalized interventions may be more effective for changing dietary behaviors than generic healthy eating advice [164,165] and, relevant to our paper, a personalized decision tree approach was tested to promote SHD adherence in the MyPlanetDiet RCT, with results imminent [166,167].

Aided by our novel scoring system, researchers could select whichever high-priority factors they deem most appropriate to target in interventions. In addition, researchers could adapt our scoring system to be more specific to their needs and, from there, target high-priority factors relevant to their context. Continuing with the university setting as an example, price incentives in university food establishments would represent a more appropriate intervention for those whose dietary behaviors are largely driven by the price of foods (including those of lower income) and could be delivered as part of a more personalized intervention. On the other hand, implementation intention interventions would be more appropriate for those with poor dietary self-regulation skill, and could also be delivered as part of a personalized intervention. In addition, stratifying individuals based on fixed factors (e.g., age) could be useful for directing interventions to individuals. Because dietary behaviors may be guided by many interacting factors, clustering individuals based on multiple factors associated with similar dietary behaviors could represent another way to funnel individuals to personalized interventions. A similar approach, where individuals are clustered based on cardiometabolic biomarkers [168], was more effective at improving diet quality than generic healthy eating advice in a recent RCT [164].

All told, there are many reasons why researchers should understand which factors are of highest priority to measure in a given population. Combining an understanding of the specific factors likely to guide dietary behavior in a given population with a sound model of human behavior can further guide effective intervention development [161], and any interventions should be matched to the appropriate dietary target(s) for the individuals being targeted (ideally determined from current dietary intakes as well as other context-specific factors [e.g., feasibility]). Following implementation, it is then crucial to evaluate intervention success with respect to the specific outcomes being targeted (e.g., food group intake, food waste). Given that policies are effective insofar as their interventions are effective [161], our findings could thus indirectly influence SHD policy via the development of more effective dietary behavioral interventions.

7. Summary and conclusions

Because there are ~235 million university students worldwide [169], encouraging SHDs in the university setting could be very impactful on a global scale. Furthermore, because the university setting can facilitate the targeting of factors at all levels of influence, it represents a hub for effective intervention development. We hope this review and synthesis of evidence can help guide the development of effective interventions aimed at promoting SHDs.

We acknowledge some limitations: our review is a narrative evaluation of the literature; we only identified factors that may influence sustainable (and unsustainable) dietary behaviors, not those that may not; the literature itself has gaps, to date largely focused on a limited selection of foods (e.g., fruits and vegetables) [113]; the observational nature of many included studies limited the ability to infer causality regarding the effect(s) of factors on dietary behaviors; our scoring system was crude and subjective in nature; and factors not quantified by the DONE framework were scored as closely related factors, which may not fully represent their effect(s) on dietary behaviors (e.g., conscious habitual eating was scored as "habitual eating") [17,170]. However, our approach allowed us to integrate research from many study designs, disciplines, and populations, which permitted the inclusion of a range of recently published systematic reviews [74,82,106,111,113,119,123,145,147,150]. Furthermore, our scoring system included ratings from 188 experts in dietary behavior-related fields, and we considered experimental evidence more important than observational evidence when scoring modifiable factors.

To conclude, our review of the literature identified ~40 factors that may influence sustainable (and unsustainable) dietary behaviors. Of these, environmental factors (e.g., product price, food availability/accessibility) appear to be most important to target in future interventions, alongside certain individual (e.g., conscious habitual eating, self-regulation skills) and interpersonal (i.e., eating norms) factors. Faced with the possibility that global food consumption alone could contribute nearly 1 °C to global warming by 2100 [171], and the current widespread prevalence of diet-related NCD [3], we underscore the urgency for action and encourage universities to create sustainable and healthy campus food environments. This would complement researcher-led approaches to promote SHDs, such as any putative interventions that incorporate insights from our review and synthesis of the literature.

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Author Contributions

Patrick S. Elliott: Writing – review & editing, Writing – original draft, Conceptualization. Lauren D. Devine: Writing – review & editing. Eileen R. Gibney: Writing – review & editing. Aifric M. O'Sullivan: Writing - review & editing, Writing - original draft, Supervision, Conceptualization. All authors have read and agreed to the published version of the manuscript.

Declaration of competing interest

The authors declare no conflicts of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.nutres.2024.03.004.

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