Reducing meat consumption and following plant-based diets:
Current evidence and future directions to inform integrated transitions

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Reference:
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 and Technology*, *91*, 380-390. https://doi.org/10.1016/j.tifs.2019.07.046

Highlights

Evidence on transitions to more plant-based diets is increasing but still fragmented.

This limits concerted efforts to successfully shape and sustain these transitions.

We present a systematic review of relevant variables, framed as barriers and enablers.

These were mapped into a coherent overarching framework of behavior change.

Studies that integrate capability, opportunity and motivation variables are needed.

Abstract

Background

There is increasing consensus that transitioning towards reduced meat consumption and more plant-based diets is a key feature to address important health and sustainability challenges. However, relevant evidence that may inform these transitions remains fragmented with no overarching rationale or theoretical framework, which limits the ability to design and deliver coordinated efforts to address these challenges.

Scope and approach

Eleven databases were systematically searched using sets of keywords referring meat curtailment, meat substitution and plant-based diets, as well as consumer choice, appraisal or behavior (2602 articles selected for title and abstract screening; 161 full-texts assessed for eligibility; 110 articles selected for extraction and coding). Barriers and enablers were identified and integrated into an overarching framework (i.e., COM-B system), which conceptualizes behavior as being influenced by three broad components: capability, opportunity and motivation.

Key findings and conclusions

This review mapped potential barriers and enablers in terms of capability, opportunity, and motivation to reduce meat consumption and follow more plant-based diets. These included lack of information for consumers and difficulty to acquire new cooking skills (barrier, capability), changes in service provision in collective meal contexts (enabler, opportunity), and positive taste expectations for plant-based meals (enabler, motivation). Evidence on variables referring to the motivation domain is clearly increasing, but there is a striking need for studies that include capability and opportunity variables as well. The results of this review are relevant to a variety of fields and audiences interested in promoting sustainable living and health improvements through dietary choice.

Keywords: Plant-based diets; Meat substitution; Meat consumption; Sustainability; Health.

1 INTRODUCTION

Within the context of global environmental change, the thriving of human individuals and societies depends on ensuring food production and distribution systems that make food available, abundant and accessible. However, while ostensibly sustaining life, such systems may also contribute to depleting the natural resources (e.g., land; water; energy), sharp declines in biodiversity, violation of environmental thresholds which support life on Earth (e.g., nitrogen and carbon cycles), and push towards eating habits that are not optimal for human health (Aiking, 2014; Campbell et al., 2017; Ritchie et al., 2018). These impacts are ongoing and will likely increase globally over the next decades due to a growing population, as well as dietary-relevant socioeconomic changes that are expected to occur throughout the world (Alexandratos & Bruinsma, 2012; Clark & Tilman, 2017; Tilman et al., 2011).

Against this backdrop, there is increasing consensus that efforts to improve the sustainability of food systems will benefit from a transition towards an increased reliance on plant-based foods, and a decreased consumption of meat and other animal-based products (Aiking & de Boer, 2018; Clark & Tilman, 2017; Godfray et al., 2018; Poore & Nemecek, 2018; Röös et al., 2017; Shepon et al., 2018; Springmann et al., 2016; Tilman & Clark, 2014; Willet et al., 2019). The cumulative evidence suggests that large-scale shifts in consumers' dietary patterns can help deliver health and environmental benefits on a scale and reach not achievable by production-based improvements alone (Clark & Tilman, 2017; Poore & Nemecek, 2018; Willet et al., 2019).

Undertaking substantial changes from meat-based to increasingly plant-based diets will nevertheless require a profound societal transition (de Boer & Aiking, 2017; Dagevos & Voordouw, 2013). An outline and review of meat consumption from its roots to current trends, drivers and consequences suggest that it has become invested with a fundamental role in social representations of food and meals, particularly in western societies (Fiddes, 1991; Graça, 2016; Hartman & Siegrist, 2017). This reinforces concerns that shaping consumer demand towards reduced meat consumption and increasingly plant-based diets will likely be a strenuous challenge. Food practices are complex and influenced by numerous interacting factors. Features such as the social context, the food provisioning system and its organizational and logistical structure, taste, familiarity and preference for particular foods and distaste for others, play a fundamental role in what and how we eat (Köster, 2009; Warde, 2016). Thus, a transition towards healthier and more sustainable food systems should be strengthened by the coordinated

efforts of civil society, governmental bodies, health and environmental organizations, and also market actors – which need to be informed by a coherent research program and integrated body of knowledge on how to reduce meat consumption and follow more plant-based diets (Godfray et al., 2018; Stoll-Kleemann & O'Riordan, 2015).

1.1 Towards an integrated body of knowledge on transitions to more plant-based diets

In recent years, research interest on topics relevant for a shift from meat-based to increasingly plant-based diets has been spreading and rapidly increasing. This has given rise to several recent and relevant reviews on the topic. For instance, Corrin & Papadopoulos (2017) reviewed public perceptions and attitudes towards vegetarian and plant-based diets, and Rosenfeld (2018) reviewed evidence on the psychology of vegetarianism. Both these reviews have advanced useful information for promoting reduced meat consumption and increased plant-based eating. Similarly, Bianchi and colleagues conducted two reviews of studies evaluating the effectiveness of interventions to reduce the demand for meat, focused either on restructuring physical micro-environments (Bianchi, Garnett, Dorsel, Aveyard, & Jebb, 2018), or on targeting conscious determinants of behavior (Bianchi, Dorsel, Garnett, Aveyard, & Jebb, 2018).

Several additional relevant reviews also provide invaluable resources for audiences interested in promoting healthier and more sustainable eating (e.g., de Boer & Aiking, 2017; Hartman & Siegrist, 2017; Stoll-Kleemann & Schmidt, 2017; van der Weele et al., 2019). Nevertheless, food-related practices are a multi-determined issue that challenges disciplinary borders and requires integrated approaches to be properly studied and understood (Atkins & Michie, 2013; Köster, 2009). As will become apparent in the present review, most of the literature on reduced meat consumption and increased plant-based eating remains atheoretical and conceptually fragmented or narrowed, with no overarching integrative framework.

This fragmentation is in sharp disconnection with fundamental insights from more systematic and integrative approaches for understanding food practices and behaviors, together with their change in context (e.g., Atkins & Michie, 2013; Michie & West, 2013). Specifically, it limits the ability to inform coordinated efforts to shift to more plant-based diets in at least three critical ways. The first is that a parsimonious conceptual map is necessary for advancing and testing mechanisms of change that disentangle the web of influences that can be causally (vs incidentally) connected to the target behavior. The second is that an overarching framework

is necessary to map a coherent set of potential moderators and mediators that help clarify which endeavors and approaches work best for whom, when, where, and why. The third is that integrating evidence from the distinct but complementary disciplines that address transitions in food and eating (e.g., psychology; sociology; history; economics; marketing; political science; agricultural and food science) requires developing and using a common framework achieved out of disciplinary compromises, which are temporarily settled and always open to conceptual attunement.

To offer a step forward in the ability to shape an integrated body of knowledge on how to change to increasingly plant-based diets, we propose drawing on a comprehensive but parsimonious overarching model of behavior developed in the field of psychology that has shown to be applicable across contexts and domains. This model conceptualizes behavior as influencing and being influenced by three broad components: capability, opportunity and motivation (i.e., COM-B system of behavior; Michie et al., 2011, 2014). According to the COM-B model (Figure 1), for sustained change of practice and behavior to take place, a set of variables under these three components have to be aligned: (1) capability, which includes psychological (e.g., knowledge) and physical (e.g., dexterity) features in being able to perform a given behavior; (2) opportunity, which includes social (e.g., social norms) and physical (e.g., availability) features that foster/support or hinder/compromise the behavior; and (3) motivation, which entails reflective (e.g., deliberate thinking) and automatic (e.g., habits) psychological processes that energize the behavior.

The COM-B model is linked to the 14 domains of the Theoretical Domains Framework (Atkins et al., 2017), which has been obtained from a synthesis of 33 theories of behavior and behavior change (Cane, O'Conner & Michie, 2012). The model has a high heuristic value and can be illustrated using examples from food consumption (van der Vliet et al., 2018). Capability refers to being psychologically and physically able to perform the focal behavior, and encompasses the domains of knowledge, cognitive and interpersonal skills, memory, attention and decision processes, and behavioral regulation. This includes, for example, knowing what constitutes a healthy and sustainable diet in practice, and having the skills to prepare appetizing meals that are also healthy and environmentally-friendly. Opportunity refers to having a social and physical context that makes it affordable, appropriate and easy to perform the behavior, including the domains of environmental context and resources (e.g., living in an area with plenty of available, affordable and healthy/sustainable food options), as well as social

influences (e.g., having a conducive family environment). Finally, motivation refers to the inner reflective and automatic processes that drive the behavior, including the domains of beliefs about consequences, beliefs about capabilities, goals, intentions, social/ professional role and identity, optimism, reinforcement and emotions. Examples of motivational drivers of the focal behavior would be to have a positive attitude towards engaging in healthy and sustainable eating, or having pleasure in eating plant-based meals.

Importantly, each target behavior may have a specific set of barriers (i.e., variables pushing people away from the behavior) and enablers (i.e., variables pulling people closer to the behavior) in each component (capability, opportunity, motivation), which should be properly identified and assessed to map the respective system of behavior (Michie et al., 2014). Furthermore, the COM-B system proposes that the three components may interact to influence (and be influenced by) behavior (Michie et al., 2011; van der Vliet et al., 2018). For instance, having a very positive taste experience when trying out a plant-based meal that is also shared with close others, may arguably help shape positive attitudes toward such meals (i.e., thus strengthening motivation) and create a proximal social context that is also favorable to increased plant-based eating (i.e., thus strengthening opportunity). Increased capability and opportunity to perform a behavior may arguably also help reinforce motivation (Figure 1; Michie et al., 2011, 2014).

[FIGURE 1]

1.2 The present work: aim and objectives

There is increasing consensus that a transition from meat-based to more plant-based diets is a key feature to address important health and sustainability challenges in the food systems. However, research that may help shape this transition remains theoretically and empirically fragmented. This fragmentation limits the ability to design and deliver coordinated efforts of stakeholders and decision-makers in addressing these pressing challenges. The present review aims to address this limitation and has two specific objectives: (1) to map the variables (i.e., actual or potential barriers and enablers) known to be associated with meat curtailment, meat substitution and adherence to plant-based diets; (2) to integrate the current body of knowledge into a coherent overarching theoretical framework of behavior change (COM-B system). The results of this review will be relevant to a variety of fields and audiences interested in promoting sustainable living and health improvements through dietary choice.

Furthermore, they will inform future research and interventions on how to reduce meat consumption and promote more plant-based diets.

2 METHODS

2.1 Literature search and selection of relevant studies

Eleven databases (Web of Science, ScienceDirect, Academic Search Complete, MEDLINE, Business Source Complete, Social Sciences Citation Index, Psychology and Behavioral Sciences Collection, Scopus, AGRIS, PsycARTICLES, ERIC) were systematically searched in January 2018 using sets of keywords referring to our focal topic (i.e., meat curtailment, meat reduc*, reduc* meat, meat substitut*, substitut* meat, plant-based diet, veg* diet) as well as consumer choice, appraisal or behavior (i.e., behavio*, willingness, intention, food choice; adherence, predictor*, determinant*, barrier*, facilitator*). The search was limited to studies published in peer reviewed journals in the English language. As inclusion criteria, we selected articles that reported empirical (quantitative or qualitative) studies on variables (i.e. facilitators and barriers) associated with meat curtailment, meat substitution, and/or plant-based diets. The exclusion criteria were: (1) review articles, opinion/commentary and conference papers; (2) studies not focused on food practices and consumer choice or behavior (e.g., life cycle analyses modelling, health/environmental impact of meat production/consumption); (3) studies focused only on physiological and/or clinical aspects of consumption; and (4) studies on entomophagy.

Figure 2 presents a flow diagram summarizing the literature search and selection process. We managed the searches in Endnote version X8 and, after removing duplicate entries, exported the records into the online reference management platform Rayyan.QCRI.org to proceed with the title and abstract screening. Six articles that were published and identified during the screening phase were manually included in the review database as well, yielding a total of 2602 articles for title and abstract screening. The lead author screened all the records and an independent reviewer screened 262 randomly selected records (~10%) in order to assess reliability in inclusion/exclusion decisions (Cohen's kappa = .94). Afterwards, 161 full-texts were assessed for eligibility by the lead author based on the inclusion and exclusion criteria, of which 51 were excluded, resulting in a final set of 110 articles to be subjected to data extraction and qualitative synthesis.

[FIGURE 2]

2.2 Data extraction, synthesis and integration

Data were extracted into a standardized synthesis table (Table S1 in Supplementary Materials) by the lead author and checked with the other two authors. The extraction considered a set of study general characteristics (e.g., authors; date of publication; country), design (e.g., quantitative; qualitative; mixed), sample (e.g., sample size; gender distribution; sampling procedures), and main theoretical framework (if any). The focal topics to which the variables of each study referred to were also identified (i.e., meat reduction/curtailment; plant-based diets; plant-based meals). Additionally, the data were sorted into primary and secondary outcomes and integrated into a coherent overarching framework: (i) the primary outcomes referred to a short and focused synthesis of variables (i.e. barriers and facilitators) associated with meat curtailment, meat substitution, and adherence to a plant-based diet; (ii) the secondary outcomes referred to a classification of these variables into the broad components of the COM-B model (i.e., capability, opportunity, motivation), according to the guidelines proposed by Michie et al. (2014). The process of assortment and classification of data into primary/secondary outcomes was conducted by the lead author and checked with the other two authors. Afterwards, an independent reviewer classified the data from 22 randomly selected records (20%) into the COM-B components (i.e., secondary outcomes), in order to assess reliability in the classification process (Cohen's kappa = .90).

3 RESULTS

3.1 Studies characteristics

The literature search revealed 110 articles meeting the inclusion criteria, published between 1989 and 2018. A small proportion of the articles (5.4%) were published before the year 2000, 10% were published between 2001-2006, 16.4% were published between 2007-2012, and the majority of the studies included in the review (68.2%) were published between 2013-2018, which shows the increasing research interest on this topic.

Most of the articles (81%) reported studies with a uniquely quantitative design, 73% of which used cross-sectional surveys and 21.3% of which were experiments or randomized control trials. A smaller proportion (15.5%) reported studies with a uniquely qualitative design, 41.2% of which used focus groups and 58.8% used individual interviews as a means for

collecting data. Only 3.6% reported studies with a mixed design using qualitative and quantitative methodological triangulation.

The studies reported data from countries in the European (61%), North American (35.5%), Asian (9%) and/or Australasian (5.5%) regions. Samples ranged from eight to 63808 participants (M = 2011; SD = 7481; Q_1 = 112, Q_2 = 293, Q_3 = 1017), 57.3% were relatively balanced in terms of gender (~50/50), 37.1% were markedly biased towards female participants (>60/40) and 5.6% were markedly biased towards male participants (>60/40).

The large majority of studies (70%) did not specify a main theoretical framework. As for the focal topics, the studies reported findings for variables referring to meat reduction (61%), plant-based diets (38.2%), and/or plant-based meals and food products (22.7%). As for the COM-B theoretical framework, the very large majority of studies addressed variables that were framed in the motivation domain (93.6%), and a smaller proportion addressed opportunity (20%) and/or capability variables (6.4%). Additionally, most studies addressed capability, opportunity or motivation variables in isolation (83.6%), and only 16.4% addressed variables from two or the three domains simultaneously.

3.2 Sociodemographic variables

Gender, age and education were identified as key variables in many studies in the review. The male gender was consistently associated with increased meat consumption and unwillingness to eat more plant-based diets, whereas the female gender was usually associated with lower meat consumption and with being more open to eat plant-based meals and follow plant-based diets (Chan et al., 2017; Costacou et al., 2003; de Boer & Aiking, 2011; de Groeve & Bleys, 2017; Graça, Calheiros, et al., 2015; Graça, Oliveira, et al., 2015; Hayley et al., 2015; Herzog & Golden, 2009; Hoek et al., 2004; Kalof et al., 1999; Lea et al., 2006a; O'Keefe et al., 2016; Pfeiler & Egloff, 2018; Rothgerber, 2013; Schösler et al., 2015; Siegrist et al., 2015; Tobler et al., 2011; Verain et al., 2015; Neff et al., 2018). With regard to age, the picture was less consistent than for gender. Whereas some studies found that younger participants tended to be more positive towards plant-based meals and plant-based diets (de Boer & Aiking, 2011; Elzerman et al., 2015; Jallinoja et al., 2016; Pfeiler & Egloff, 2018), other studies found the opposite (Chan et al., 2017; Chatard-Pannetier et al., 2004; Costacou et al., 2003; Graça, Oliveira, et al., 2015). As for education and other SES variables, the studies were overall consistent in showing higher education and higher SES as enablers for following more plant-

based diets (Cai et al., 2012; Costacou et al., 2003; de Boer & Aiking, 2011; Hoek et al., 2004; Jallinoja et al., 2016; Link & Jacobson, 2008; Pfeiler & Egloff, 2018; Siegrist et al., 2015; Smith et al., 2011). Consumers who reported following plant-based diets were also more likely from urban areas (de Boer & Aiking, 2011; Hoek et al., 2004).

3.3 Capability variables

The review identified a small set of barriers and enablers referring to psychological and physical capability that may be relevant for reducing meat consumption and eating more plant-based diets (see Table 1 for an overview and Table S1 in Supplementary Materials for details). As for psychological capability, one study with consumers who followed a plant-based diet highlighted the process of getting new information and building capacity (e.g., learning how to cook new meals) as critical (but challenging) to their successful transition (Kleine, 1993). Another study found that the most used sources of information were the internet, books, magazines or newspapers, and health food stores (Cramer, Kessler, et al., 2017). However, one study with former meat avoiders identified the difficulty in preparing new foods as an important barrier while they were following a plant-based diet (Haverstock & Forgays, 2012). Similarly, studies with consumers who regularly ate meat identified both lack of information and lack of cooking skills as barriers to following plant-based diets (Hoek et al., 2017; Lea et al., 2006a, 2006b; Mullee et al., 2017; O'Keefe et al., 2016). As for barriers referring to physical capability, one study showed that higher sensitivity to bitter tastes was associated with less positive attitudes towards plant-based dishes that were rich in vegetables, and more positive attitudes towards dishes that were rich in animal products (Cliceri et al., 2018).

[TABLE 1]

3.4 Opportunity variables

Several barriers and enablers referring to social and physical/material opportunity are also highlighted as potentially relevant for reducing meat consumption and eating more plant-based diets (see Table 1 for an overview and Table S1 in Supplementary Materials for details). With regard to social opportunity, perceiving that meat is socially construed as central in food practices was identified as an important barrier to reduce meat consumption in several studies (Bohm et al., 2015; Hoek et al., 2017; Macdiarmid et al., 2016). Perceived norm with regard to eating meat was identified in some studies as an overall relatively poor predictor of willingness

and intentions to change meat consumption (Graça, Calheiros, et al., 2015; Povey et al., 2011; Wyker & Davidson, 2010). However, one study found that simple manipulations of dynamic norms about meat consumption (i.e., drawing attention to the collective reduction of meat eating over time) increased consumer interest in eating less meat, and increased the percentage of clients who ordered a meatless lunch at a cafeteria (Sparkman & Walton, 2017).

Further studies also reinforced the relevance of social opportunity variables in our focal topic. Participants who followed a plant-based diet reported having experienced prejudiced encounters and violations of expected normal or ideal interaction patterns for avoiding eating animal products (Hirschler, 2011), and highlighted that other people were important in supporting (or hindering) their transition and learning processes (Kleine, 1993; Link & Jacobson, 2008). In fact, the current meat-eating habits and unwillingness to change of other household members were consistently identified as a barrier to change individual meat consumption (Hoek et al., 2017; Lea et al., 2006a, 2006b; Lea & Worsley, 2003; Link & Jacobson, 2008; Mullee et al., 2017; O'Keefe et al., 2016; Šedová et al., 2016). Additionally, in one study, having family history of NCDs (e.g., cancer), which could be seen as a proxy for exposure to a set of risk factors and unhealthy behaviors in the family context, was associated with eating a less plant-based diet (Cai et al., 2012). Former meat avoiders also identified lack of social support as a barrier while they were following a plant-based diet (Haverstock & Forgays, 2012; Hodson & Earle, 2018), and mixed findings were also reported for current meat eaters in which significant others could be identified both as enablers and as barriers to following a plant-based diet (Wyker & Davidson, 2010). Two additional studies found that individuals who reduced meat consumption or followed a plant-based diet were encouraged to do so by their friends and family members, medical doctors, co-workers, or exposure to media contents (Cramer et al., 2017; McIntosh et al., 1995).

As for variables referring to the domain of physical opportunity, higher prices of meat were identified as triggers to reducing or avoiding meat consumption (Charlebois et al., 2016), and beef E.coli recalls were found to significantly reduce consumer demand for beef products (Shang & Tonsor, 2017). One large study involving 27 countries observed that protein supplies (i.e. plant protein and meat protein) differed across countries based on geographical location and GDP (de Boer & Aiking, 2018), and another study found that although meat consumption was found to increase with income at the national level, the overall pattern was that from a

certain point onwards higher levels of income in more developed countries were associated with lower levels of meat consumption (Vranken et al., 2014).

Two further studies – one with school meals and one with retailers – hinted into potentially interesting interactions between physical and social opportunity variables. A study with schools who implemented a mandatory vegetarian day in their canteens produced mixed short and medium-term effects (Lombardini & Lankoski, 2013): in the short term, there were signs of non-compliance manifested as a decrease in student participation in school lunches and the amount of food served, as well as increased food waste; but in the medium term, the only sign of non-compliance was a decrease in the amount of food served, and there were indications of positive spillovers in some schools (i.e., increase in the share of the vegetarian hot dish on days in which non-vegetarian food was also served). A study with food retailers identified several barriers to promoting and supporting consumer transitions towards reduced meat consumption (Tjärnemo & Södahl, 2015), which included a reluctance to change food product range (e.g., offering and promoting more plant-based meat substitutes), perceiving meat as an important and strategic product category, and a priority on adjusting product line in accordance with consumer demand (i.e., meeting rather than shaping consumer demand for meat). Similarly, other studies found that the strong taxonomic categories of meat products (based on the type of animal source) could overshadow the role of meat substitutes as appealing sources of protein, and reinforce social constructions of conventional meat as center of the plate protein (Hoek et al., 2011; O'Keefe et al., 2016).

3.5 Motivation variables

The review identified a set of variables referring to reflective and automatic motivational processes that may be relevant for reducing meat consumption and eating more plant-based diets (see Table 1 for an overview and Table S1 in Supplementary Materials for details). Reflective motivations for reducing meat consumption and eating more plant-based diets usually included beliefs regarding the consequences of eating more planted-based diets, namely improved health and well-being (Baker, Thompson, & Palmer-Barnes, 2022; Cramer, Kessler, et al., 2017; Chatard-Pannetier et al., 2004; Fox & Ward, 2008; Jabs et al., 1998; Link & Jacobson, 2008; McIntosh et al., 1995;), having more sustainable eating habits (de Boer et al., 2016; de Boer et al., 2013; Hoek et al., 2011; Hunter & Röös, 2016; Kalof et al., 1999; Truelove & Parks, 2012; Verain et al., 2012), concerns with animal suffering (Bobić et al.,

2012; de Backer & Hudders, 2015; de Boer & Aiking, 2011; de Boer et al., 2017; Ensaff et al., 2015; Heiss & Hormes, 2017; Hirschler, 2011; Jabs et al., 1998), or often a mix between health, sustainability, and/or animal ethics motivations (Apostolidis & McLeay, 2016; Arbit et al., 2017; Charlebois et al., 2016; Cliceri et al., 2018; Fox & Ward, 2008; Graça, Oliveira, et al., 2015; Haverstock & Forgays, 2012; Lea et al., 2006a; Lea & Worsley, 2003a; Mohr & Schlich, 2016; Mullee et al., 2017; Neff et al., 2018; Ruby et al., 2013; Schösler et al., 2014; Tobler et al., 2011; Viainio et al., 2016; Van Loo et al., 2017; Wyker & Davison, 2010). However, these were often seen as not self-standing enablers; positive taste experiences and expectations, perceived convenience, familiarity and perceived easiness to replace meat were also consistently identified as key features for using meat substitutes, reducing meat consumption and following more plant-based diets (Apostolidis & McLeay, 2016; de Boer et al., 2014; Elzerman et al., 2015; Ensaff et al., 2015; Frenko et al., 2015; Haverstock & Forgays, 2012; Hoek et al., 2004; Hoek et al., 2011; Lea et al., 2006a, 2006b; Mullee et al., 2017; Richardson et al., 1994; Schösler et al., 2014; Sniehotta et al., 2005; Tucker, 2014; Wyker & Davison, 2010).

Attitudes and perceived behavioral control were also identified as predictors of willingness and intentions to reduce meat consumption and follow plant-based diets (Carfora et al., 2017; de Boer & Aiking, 2011; Graça, Calheiros, et al., 2015; Povey et al., 2011; Wyker & Davison, 2010). Other studies also found that perceived self-efficacy in reducing meat consumption and eating plant-based diets predicted intentions to change (Hunter & Röös, 2016; Sniehotta et al., 2005) as well as actual behavior (Link & Jacobson, 2008). Moreover, some studies found that increased familiarity and repeated exposure to meals with meat substitutes could increase positive appraisals by consumers over time, particularly for more neophobic consumers (Hoek et al., 2013; Hoek et al., 2011). Participants who were already more frequent consumers of meat substitutes were also found to be more willing to increase their consumption of these products (Jallinoja et al., 2016; Schösler et al., 2015).

Perceived lack of responsibility to change, perceived lack of effectiveness of meat avoidance as mitigating climate change, licensing arguments and feelings of personal entitlement to eating meat, were identified as barriers to reducing meat consumption (Bohm et al., 2015; de Boer et al., 2016; Dowsett et al., 2018; Graça, Calheiros, et al., 2015; Macdiarmid et al., 2016; Mullee et al., 2017; Truelove & Parks, 2012; Viainio et al., 2016). Individuals who were skeptical about climate change and mentioned not caring for environmental protection

were also reluctant to eat more plant-based diets (de Boer et al., 2013). In contrast, being less prone to endorse blatant justifications and rationalizations of meat consumption was associated with higher meat avoidance (Piazza et al., 2015; Rothgerber, 2013). Some of these variables referring to processes of cognitive reconstruction and motivated reasoning were framed under the lens of moral disengagement (i.e., selective deactivation of moral self-regulatory processes when considering the impact of meat consumption), which in turn was associated with unwillingness to reduce meat consumption (Graça et al., 2014, 2016; Graça, Oliveira et al., 2015). Several studies also identified lack of familiarity and general negative appraisal of meat substitutes, consumer health concerns with reduced meat consumption, and food neophobia, as barriers to change (Ensaff et al., 2015; Fenko et al., 2015; Hoek et al., 2011; Hoek et al., 2017; Lea et al., 2006a; Mullee et al., 2017; Šedová et al., 2016; Tucker, 2014; Wyker & Davison, 2010; Vanhonacker et al., 2013). In turn, other studies found that being interested in trying out new foods and meals was associated with eating meat substitutes and following more plant-based diets (Hoek et al., 2004; Hoek et al., 2011; Lea & Worsley, 2003a; Mullee et al., 2017).

A set of variables referring to affective/emotional features were identified as relevant barriers or enablers for a transition in several studies. Disliking the taste of meat, holding general negative or ambivalent representations, as well as negative feelings such as worry, fear and guilt towards eating meat, was associated with reduced meat consumption and willingness to follow more plant-based diets (Berndsen & van der Pligt, 2004, 2005; de Boer & Aiking, 2011; de Boer et al., 2017; Graça, Oliveira, et al., 2015; Haverstock & Forgays, 2012; Rothgerber, 2014, 2015a, 2015b; Zur & Klockner, 2014). In contrast, individuals who ate meat more often, derived more pleasure and identified more strongly as meat eaters, held positive attitudes towards meat consumption, or perceived plant-based meals as incomplete and unsatisfactory, were less willing to change their eating habits (Bohm et al., 2014; Carfora et al., 2017; de Boer et al., 2016; Dowsett et al., 2018; Ensaff et al., 2015; Graça, Calheiros et al., 2015; Graça et al., 2016; Graça, Oliveira et al., 2015; Kildal & Syse, 2017; Lea et al., 2006a; Leah & Worsley, 2003a; Macdiarmid et al., 2016; Mullee et al., 2017; O'Keefe et al., 2016; Vainio et al., 2018; Zur & Klockner, 2014). Meat attachment (i.e., a positive bond towards meat consumption comprised of hedonism, affinity, entitlement, and dependence) also showed negative associations with willingness and intentions to reduce meat consumption and to follow more plant-based diets (Dowsett et al., 2018; Graça, Calheiros et al., 2015; Graça et al., 2016; Graça, Oliveira et al., 2015).

Some values and personality traits were consistently observed to be associated with meat avoidance and reduced meat consumption. Participants who endorsed values such as benevolence, altruism and universalism, as well as moral traits and general moral concern, were more likely to follow more plant-based diets (Apostolidis & McLeay, 2016; Arbit et al., 2017; Bobić et al., 2012; de Backer & Hudders, 2015; de Boer et al., 2007; Hailey et al., 2015; Hoek et al., 2011; Kalof et al., 1999; Ruby et al., 2013). In contrast, participants who endorsed more traditional and conservative values were less likely to follow plant-based diets (de Backer & Hudders, 2015, Hodson & Earle, 2018; Kalof et al., 1999; Pfeiler & Egloff, 2018; Ruby et al., 2013; Tan et al., 2016). Nevertheless, the influence of variables such as conservativeness and deference to tradition and authorities was less pronounced or even reversed in some non-western countries, in which religious and spiritual motivations for eating plant-based diets were also identified (e.g., India, Malaysia; Ruby et al., 2013; Tan et al., 2016).

Several studies consistently pointed towards spillover effects of being generally more conscious about health, the environment or animals, and willingness to eat more plant-based. Having unhealthy habits such as smoking and drinking alcohol, as well as more sedentary lifestyles, was associated with following less plant-based diets, whereas individuals with regular physical activity, lower BMI, lower waist-to-hip ratio, and who were more health conscious as a whole were more likely to have tried plant-based foods and to follow plant-based diets (Carfora et al., 2017; Costacou et al., 2003; Cramer, Kessler, et al., 2017; Cramer, Sibbritt, et al., 2017; Fenko et al., 2015; Heiss et al., 2017; Hoek et al., 2004; Pfeiler & Egloff, 2018; Santaliestra-Pasías et al., 2014; Shickle et al., 1989; Spencer et al., 2007; Torjusen et al., 2012). Apparent spillover effects were also observed with individuals who already followed more environmentally-friendly lifestyles and behaviors, as they also tended to be more willing to reduce meat consumption and to follow more plant-based diets (de Boer & Aiking, 2011; de Boer et al., 2016; Hoek et al., 2004). In addition, some studies found that individuals who grew up with a greater variety of pets (e.g., dogs, cats, birds, hamsters), or reported having closer attachments to their childhood pets, were also more likely to engage in greater meat avoidance in adulthood (Heiss & Hormes, 2017; Rothgerber & Mican, 2014).

There was evidence on how variables referring to motivational processes in reducing meat consumption and eating more plant-based diets can be successfully manipulated. For instance, using labels to increase salience of the environmental impact of meals at a university restaurant did not cause a shift in consumption patterns from meat to plant-based meals, but

meat dishes slightly decreased sales when labeled red (i.e., assigned with low environmental score; Brunner et al., 2018). One study found that replacing portions of meat with plant-based analogues did not affect consumer appraisal of some meals (e.g., taco blend) but reduced positive appraisals in others (e.g., carne asada; Guinard et al., 2016). Nevertheless, presenting meat analogues as vegan yielded positive sensory appraisals from meat eaters in one study (Adise et al., 2015), whereas in another study, associating meat products with factory farm descriptions induced negative sensory appraisals and reduced the intake of those products (Anderson & Barrett, 2016). Similarly, promoting meat-animal association (e.g., by presenting a picture of a roasted pork with head) decreased willingness to eat the meat and increased willingness to eat a vegetarian alternative (via increased empathy towards the animal and disgust towards the meat; Kunst & Hohle, 2016), particularly with participants who were less culturally exposed to unprocessed meat (Kunst & Haugestad, 2018). Emphasizing the slaughtering of an animal (vs. being presented with a diagram of the animal as meat) and emphasizing the animal origin of meat (vs being presented with a recipe) also led to lower hedonic ratings and/or lower willingness to eat the meat (Tian et al., 2016). Furthermore, increased perceived cuteness of animals resulted in less willingness to eat their meat (via increased empathy towards the animal; Zickfield et al., 2018). Taken together, these findings experimentally reinforce the importance of consumer perceptions and reactions towards the animals that are used for meat production.

There was also experimental evidence from studies addressing more deliberate and reflective motivational processes for reducing meat consumption and eating more plant-based diets. Communicating the risks of meat consumption with affective and moral concerns decreased the acceptability of these risks, and increased intentions to reduce meat consumption (Berndsen & van der Pligt, 2005). A study with children who were exposed to an episode of a popular TV show in which vegetarianism was the central theme (i.e., “Lisa the Vegetarian” from The Simpsons) showed increased familiarity and positive intentions towards vegetarian diets on a follow-up measurement, comparing to a group of children who were not exposed to the episode (Byrd-Bredbenner et al., 2010). A study with older-aged consumers found that exposure to messages to reduce meat consumption with health and well-being appeals influenced attitudes and intentions to reduce meat consumption (Bertolotti et al., 2016), and a study with university students showed that sending self-monitoring reminders with SMS messages reduced red meat consumption (via changes in healthy-eating and meat-eating

identities, and intentions to reduce meat consumption; Carfora et al., 2017). However, one study with university students found that providing information about the climate impact of meat had no positive effects on the appraisal of a set of initiatives for reducing meat consumption (de Groeve & Bleys, 2017). Another study with participants from university settings and the general population found that providing information about the climate impact of meat had no effects on attitudes towards meat consumption, but led to lower intentions to eat meat when meat consumption and environmental concern were controlled for (Graham & Abrahamse, 2017). Similarly, reading a message on the environmental, health, or combined health and environment impacts of meat consumption yielded increased intentions to reduce meat consumption for consumers who already had more negative attitudes towards meat consumption, but not for consumers who believed that eating meat was healthy, climate-friendly, and necessary (Vainio et al., 2018). Another study found that perceiving materials that advocated for plant-based diets as more autonomy-supportive (vs. controlling) was associated with increased intentions to reduce meat consumption and eat more plant-based meals (Duchene & Jackson, 2017).

4 DISCUSSION

Research that may inform transitions from meat-based to increasingly plant-based diets has been rapidly increasing in recent years, but the literature on this topic remains scattered with no overarching rationale or theoretical framework. This fragmentation is in contrast with recent and important insights from research on behavior change (Michie et al., 2014; Michie & West, 2013), and limits our ability to respond to important health and environmental challenges related to our current food system (Godfray et al., 2018; Poore & Nemecek, 2018; Springmann et al., 2016; Willet et al., 2019). The present work adds two main contributions to help address this problem. The first is that it mapped a set of relevant barriers and facilitators that can be systematically addressed in future research and interventions on dietary transitions to more plant-based diets. The second is that it integrated these variables into an overarching framework, offering a step forward to the forthcoming process of building and testing a coherent body of knowledge - which may ultimately inform coordinated efforts to promote large-scale shifts to more plant-based diets. Accordingly, this discussion presents: (1) an integrative overview of current capability, opportunity and motivation variables potentially relevant to our focal topic; and (2) a highlight of priorities for future research and intervention.

4.1 Capability, opportunity and motivation to follow more plant-based diets

The review identified a set of variables referring to capability, opportunity and motivational processes that may be relevant for reducing meat consumption and eating more plant-based diets. Potential barriers for a transition that were framed in the capability domain were difficulty to get practical reliable information, difficulty to acquire new skills and competencies, and high sensitivity to bitter tastes. Clearly, the evidence on this domain is still insufficient, but that are broad intervention functions that may be useful to address barriers and enablers/facilitators in terms of capability (cf. Behavior Change Wheel, BCW; Michie et al., 2014). These include building knowledge (e.g., informing about how to follow increasingly plant-based diets and reducing meat consumption) and skill (e.g., training cooking skills required to prepare balanced and appetizing plant-based meals that are tailored to personal preferences). Preferably, these two features should be embedded in practice, as learning by doing and acquiring skills by doing.

In the opportunity domain, potential barriers identified were social representations of meat as center of the plate protein, social prejudice towards consumers following plant-based diets, unwillingness and reactance from close others (e.g., family; friends), and lack of social support for a transition. Nevertheless, potential enablers/facilitators also in the opportunity domain were willingness and supportiveness from close others (e.g., family; friends), meat recalls and increased prices of meat products, perceived dynamic norms (i.e., emphasizing collective meat reduction as increasing over time), and changes in service provision in collective meal contexts (e.g.; canteens; cafeterias). Again, evidence on this domain is also clearly scarce, but several intervention functions may be useful to address barriers and enablers/facilitators in terms of opportunity (cf. BCW; Michie et al., 2014). These include for instance sociotechnical restructuring focusing on changing physical/material contexts (e.g., increase offer and change display of plant-based foods and meals) and/or focusing on social contexts (e.g., reconfigure perceived norms on reduced meat consumption and plant-based eating).

As for the motivation domain, the body of evidence is also still developing but somewhat more established, which allows for beginning to identify general trends rather than isolated findings. Taken as a whole, the findings reviewed reinforce the notion that eating meat frequently, as well as holding positive entrenched attitudes and beliefs with regard to meat

consumption, are important motivational barriers to change. These habits, attitudes and beliefs seem to feed a pattern of attachment to meat consumption that may arguably activate a loss frame and trigger defensive reactions (e.g., reactance; motivated reasoning) when considering a change of habits. The overall evidence framed in the motivation domain also reinforced the role of health, sustainability and/or animal ethics motivations in reducing meat consumption and following plant-based diets, but suggested that these are often not self-standing enablers/facilitators. Indeed, other motivational features were identified as key enablers/facilitators as well, such as perceived convenience, familiarity, and positive taste experiences and expectations with regard to plant-based meals. Intervention functions to address barriers on this domain, and enhance known enablers/facilitators, may include for instance persuasion (e.g., using communication techniques to induce positive affect towards plant-based meals and diets, and stimulate action) or incentivisation (e.g., create feelings of reward and positive outcome expectations with regard to plant-based meals and diets) (cf. BCW; Michie et al., 2014).

As more evidence on capability, opportunity and motivation variables relevant to following more plant-based diets becomes available, it will be possible to identify the specific barriers and enablers/facilitators that different intervention functions should address in each domain. A set of policy options that are sensitive to the material/physical and social contexts can be selected accordingly to deliver these intervention functions (e.g., guidelines; regulation; service provision; marketing and communication), which will inform specific activities and modes of delivery for effectively shaping and sustaining these dietary transitions (Michie et al., 2014). The COM-B system is indeed being successfully used to inform interventions in several contexts and behaviors (e.g., Barker et al., 2016; Cassidy et al., 2018; Goud et al., 2017; Mangurian et al., 2017; Murthag, 2018), but not yet in our focal topic. Note, however, that the large majority of the findings captured in this review were from observation or cross-sectional studies (see Table 1 for an overview and Table S1 in Supplementary Materials for detailed information). Thus, at this stage, targeting a given set of barriers/facilitators in each domain, and matching them with the respective intervention functions, policy options, activities and modes of delivery, will still be driven mostly by hypothesized relationships rather than empirically established mechanisms of change. This reinforces the need for establishing priorities for future research and intervention.

4.2 Additional priorities for future research and intervention

Besides highlighting what is known, one of the main contributions of this review is highlighting what we do not know yet. Using an overarching model of behavior change allowed for identifying and highlighting a clear need for further research that addresses capability and opportunity variables. Table 1 illustrates how evidence on these two domains is severely under-represented comparing to the motivation domain, and this means that we are likely missing critical information for improving our ability to inform concerted efforts for a dietary transition. Similarly, it is necessary to understand how capability, opportunity and motivation variables relate and interact with each other in triggering and sustaining behavior change. The COM-B system proposes a process of change in which: (i) relevant variables in the capability, motivation and opportunity domains can influence and sustain a given behavior; (ii) the behavior itself can influence variables in all three of these domains; and (iii) capability and opportunity both can influence motivation (cf. Michie & West, 2013; see Figure 1 as well, in which the arrows represent potential for causal inference). One priority for the near future is thus to gather evidence on the process of changing to more plant-based diets considering variables from the three domains, preferably with studies that use experimental and/or longitudinal designs.

It is also noteworthy that many studies included in the review found relevant differences between groups of consumers. The review showed that sociodemographic variables such as gender, age and education were clearly relevant to our focal topic. This reinforces previous calls for developing conceptual, methodological and delivery tools that consider the context in which food habits take place, while at the same time identifying and engaging with different groups of consumers (Graça, 2016). It is important for future research to acknowledge and account for individual and group differences (e.g., via clustering and segmentation techniques), apart from studies which simply average over subjects and thus blur such differences. Additionally, this has potential implications for interventions as well, as it may be unreasonable to expect similar results in settings and consumers with sharply different characteristics.

Although we used a combination of search terms that allowed for retrieving and screening a considerable number of articles, this review did not cover all the available research on topics relevant for a shift from meat-based to increasingly plant-based diets. Similarly, the focus was not on performing an in-depth analysis of all the articles that were included in the qualitative synthesis, but rather to apply an integrative framework that can act as a hub to link

existing evidence with future directions for research and intervention. This means that the framework will need to be continuously updated and improved in the near future, to ensure it expands in terms of range while narrowing in terms of the specific paths that inform different policy options and intervention functions. Nevertheless, we emphasize that research on shifting from meat-based to increasingly plant-based diets should not necessarily disregard other theoretical frameworks in favor of the COM-B model. Rather, the COM-B offers a highly flexible and parsimonious overarching framework that can be used as a tool to encompass relevant constructs that are proposed by other theories, with a focused view on how to foster behavior change. Thus, inter-theoretical dialogue and integration should be highly encouraged. Additionally, despite not fully capturing all relevant research on the topic, the current systematic review was comprehensive regarding the databases used for the search and allowed to build an integrative framework of factors relevant for understanding transitions towards more plant-based diets, which represents a step forward for future intervention efforts in this matter.

To conclude, plant-based diets are attracting more attention from consumers, researchers and policy-makers for their potential to improve health, better the environment and avoid animal suffering. They are also opening promising opportunities for expansion and development for market actors and civil society organizations. Dietary changes represent notwithstanding a challenge, and hence specific motivation, capability and opportunity factors such as those identified in this review should be tackled to successfully shape and sustain these transitions.

Acknowledgements

The authors would like to thank two anonymous reviewers for their inputs that helped improve this article. This work was supported by Programa Lisboa 2020, Portugal 2020 and the European Union through the European Regional Development Fund (LISBOA-01-0145-FEDER-029348), by the state budget through the Portuguese Foundation for Science and Technology (PTDC/PSI-GER/29348/2017), and by a grant from the Portuguese Foundation for Science and Technology (SFRH/BPD/115110/2016) awarded to the first author.

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Figure 1. The COM-B system for understanding behavior change.

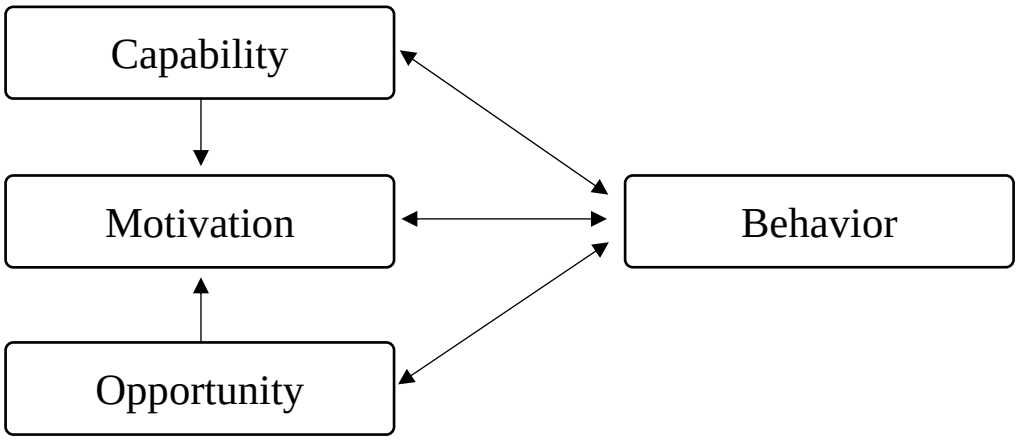

Figure 2. Flow diagram of the literature search.

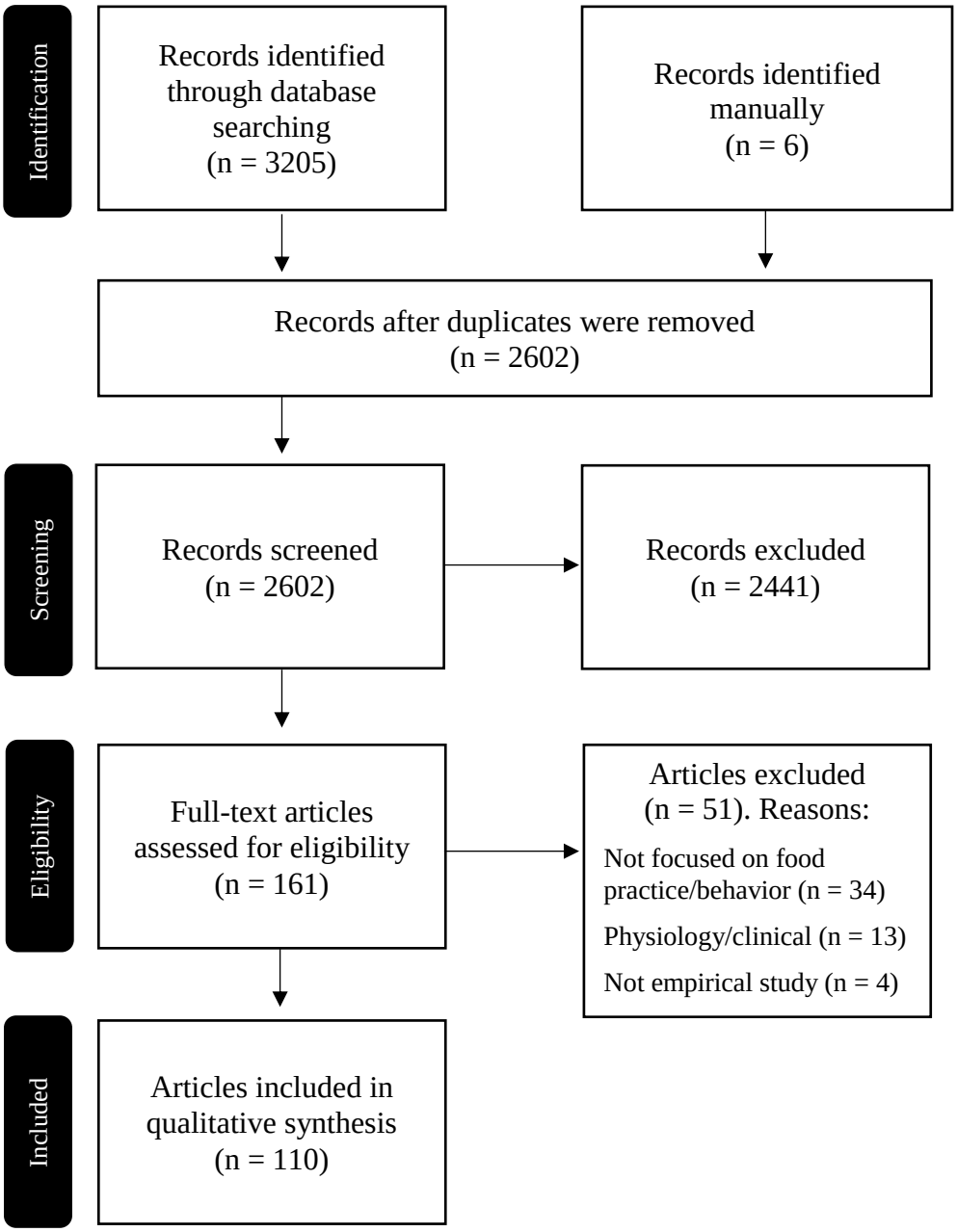

Table 1. Summary of relevant barriers and enablers/facilitators for reducing meat consumption and following more plant-based diets.

	CAPABILITY		**OPPORTUNITY**		**MOTIVATION**	
	👎 Barriers	👍 Facilitators	👎 Barriers	👍 Facilitators	👎 Barriers	👍 Facilitators
Observation/ Cross-sectional evidence	- Difficulty to get reliable information; - Difficulty to acquire new skills and competencies; - High sensitivity to bitter tastes.	NE	- Social representations of meat as center of the plate protein; - Social prejudice towards consumers following plant-based diets; - Unwillingness and reactance from close others (e.g., family; friends); - Lack of social support.	- Willingness and supportiveness from close others (e.g., family; friends); - Meat recalls (i.e., perceived food insecurity) and increased prices of meat products.	- Perceived lack of responsibility to change; - Licensing arguments; - Lack of environmental concern; - Moral disengagement; - Meat attachment; -Lack of familiarity and negative appraisal of meat substitutes/plant-based meals; - Food neophobia; - Health concerns with meat reduced diets; - Frequent meat eating habits; - Hedonic feelings towards meat consumption; - Endorsement of traditional and conservative values; - Following unhealthy lifestyles.	- Interest in healthier and/or sustainable eating habits; - Reducing/avoiding animal suffering; - General health and environmental consciousness; - Close relationships with companion animals; - Familiarity and favorable attitudes towards meat substitutes; - Positive outcome expectancies (e.g., taste); - Perceived easiness and convenience; - Perceived self-efficacy and behavioral control; - Lower tendency to endorse meat eating justifications and rationalizations; - Interest in trying new foods; - Worry and guilt towards meat consumption; - Disliking the taste of meat; - Altruistic, moral, and universalistic traits and values.
Intervention/ Experimental evidence	NE	NE	NE	- Dynamic norms (emphasizing collective meat reduction as increasing over time); - Changes in service provision in collective meal contexts (e.g.; canteens; cafeterias).	- Holding strong beliefs that eating meat is healthy, climate-friendly, and necessary (i.e., may generate resistance to efforts and materials that encourage dietary shifts).	- Emphasizing meat's environmental impact, animal origin and factory farm origin; - Broadcasting positive and appealing representations of plant-based diets and lifestyles; - Framing appetizing meat analogues as vegan/plant-based; - Using reminders to reduce meat consumption; - Using health, environmental, and autonomy-supportive frames in materials that encourage dietary shifts.

NE: No Evidence available from the studies included in the review

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