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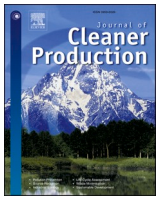

Double nudges can accelerate the transition towards more climate-friendly diets – experiment involving default meals and carbon footprint information

Sigrid Denver [a], Jonas Nordström [b,c], Tove Christensen [a,*]

[a] Department of Food and Resource Economics, University of Copenhagen, Rolighedsvej 23, 1958 Frederiksberg C, Denmark
[b] School of Economics and Management, Agrifood Economics Centre, Lund University, Box 7080, SE-220 07, Lund, Sweden
[c] Department of Economics, Swedish University of Agricultural Sciences, Box 7080, SE-220 07, Lund, Sweden

HIGHLIGHTS

- Changing the default or providing information reduced the carbon footprint of food choice.
- Applying two nudges in combination reduced the carbon footprint substantially.
- Changing the default induced more diverse substitution than information provision.
- NAM variables helped to elucidate the effect of carbon footprint information.
- One third of the respondents were not willing to forgo beef.

ABSTRACT

There is an increasing focus on the importance of reducing red meat consumption for environmental as well as health reasons. In this study, we have assessed how consumers' choice of protein source in a meal could be affected by two nudging tools. The first nudge consisted of serving a plant-based steak as the default option instead of beef, alongside placing the plant-based steak at the top of the list of possible protein sources. The second nudge was to provide information about the food's carbon footprint. Based on a representative survey among 2000 Danish respondents, we found a significant effect of both nudges, with substantially fewer respondents choosing ground beef for their meal. An interesting twist in the substitution pattern was found when beef was the default option, as carbon information made respondents shift from beef to chicken, pork, or fish, whereas when a plant-based steak was served as default, carbon information resulted in more diverse consumption – including also substitution to the plant-based option. We also found that respondents with a personal norm of feeling a moral obligation to reduce their contribution to climate change, who were sensitive to other's opinions, stated a high awareness of challenges related to climate change, or bought a lot of organic food were more likely to avoid beef and/or be affected by the carbon footprint information. Finally, one third of the sampled consumers were not willing to forgo beef.

1. Introduction

1.1. Background

Food systems are estimated to be responsible for 34 % of global anthropogenic greenhouse gas (GHG) emissions (Crippa et al., 2021), of which agricultural production and land use change make up 71 %. Xu et al. (2021) estimated that the production of animal-based food accounted for 57 % of food-production-related emissions. In addition, they estimated that the food category with the single largest contribution to GHG emissions is beef, accounting for 25 % of GHG emissions from food production. Looking at consumption, Hallström et al. (2021) estimated that animal-based food was responsible for 71 % of diet-related climate impact among a sample of Swedish consumers.

Based on these observations, it is not surprising that there has been an increasing focus on reducing the consumption of red meat in recent years (Poore and Nemecek, 2018). An excessive intake of red meat has also been seen to have a negative impact on human health (Godfray et al., 2018; Ritchie et al. (2018); Willett, 2019). For example, Ritchie et al. (2018) showed that increased consumption of meat-substitute products in a "flexitarian" diet (i.e., a diet primarily consisting of vegetarian meals but occasionally including meat and fish) would have

* Corresponding author.
E-mail address: tove@ifro.ku.dk (T. Christensen).

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significant potential for reducing GHG emissions and at the same time improve public health, as measured by avoided premature deaths. However, they also concluded that this change in diet would be strongly dependent on a combination of price reductions and improved social acceptability of changing one's diet. Denver and Christensen (2015), Christensen et al. (2020), and Denver et al. (2022) took an organic angle and found that Danish consumers with high organic consumption often had a diet consisting of more vegetables and less meat than consumers who were less likely to buy organic food. Specifically, the latter study found that around half of the sampled Danish consumers said they were willing to reduce their consumption of red meat, compared to two thirds of the most loyal organic consumers. Compared with other European countries, Fagt (2023) found that Danish consumers were the slowest in Europe to reduce their consumption of meat and pointed towards several barriers to changing diets. These included a generally conservative food culture in Denmark (where a combination of meat, gravy, and potato is often the preferred meal), a general lack of familiarity with the proposed 'golden' alternative to meat proteins (e.g., legumes), and a need to change the social norm by normalising plant-based food. Along similar lines, the Danish Council on Climate Change (2021) suggested four food-related instruments to support Denmark in reaching its national climate goals of carbon neutrality by 2050: 1) food with low climate impact must be accessible and identifiable; 2) easy availability of information about the carbon footprint of food choices (possibly by introducing a carbon footprint label); 3) economic incentives to choose food with a lower carbon footprint; 4) a change in the social norm so that the default option in the public and private sphere would be a diet that has few animal-based products while being rich in plant-based ingredients.

In a review article, Godfray et al. (2018) suggested a dual-process approach when aiming to change the behaviour of whole populations to reduce their demand for meat. The dual approach suggests activating both conscious and nonconscious processes to influence food choice. Conscious processes work through interventions such as education, information provision, labelling, and taxes, whereas nonconscious choice processes work through changes in the food environment (choice architecture, marketing, etc.). A study by Campbell-Arvai (2015) was mentioned as an example of testing a nonconscious intervention, where they showed that repositioning beef to appear after vegetarian dishes on menus or in buffets reduced meat consumption. This change in norm nudge was characterised in Godfray et al. (2018) as a change in default. They concluded by acknowledging that changing dietary behaviours in response to interventions can be slow but that social norms can and do change. Furthermore, they highlighted the need for more evidence about the effect of different ways conscious and nonconscious food choices can be influenced.

In the remaining part of the introduction, we dig into the existing literature on instruments proposed by the Danish Council on Climate Change (2021) to reduce meat consumption, with an emphasis on beef. To limit the scope of the paper, we focus on the non-monetary instruments. We first present studies on changing the default as a nudge to reduce meat consumption (section 1.2). In the terminology of Godfray et al. (2021), this nudge targets a nonconscious change in behaviour. We then review studies that test the effects of carbon footprint information or labelling, which according to Godfray et al. (2021) aim to activate a conscious process of behavioural change (section 1.3). Finally, experiences of using double nudges are presented in section 1.4. For both nudges, we investigated the potential for using the norm activating model (NAM) to understand the drivers of (and barriers to) a behavioural change towards reduced beef consumption in order to reduce the carbon footprint of food (section 1.5). We conclude the section by formulating three research questions (section 1.6).

1.2. The effect of the default on food choice

Meier et al. (2022) suggested that the default option in a food-related context differs from many other default applications. Firstly, food choice is not a one-time decision with potential long-term commitments and/or consequences, unlike decisions about pension savings programmes or whether to invest in solar panels. Instead, food choices are made several times a day and a person may not aim to make the same choice each time. Secondly, in the reviewed studies of how default options affect food choices, the individuals did not always automatically receive the default option in the absence of choice. More specifically, Meier et al. (2022) distinguished between 'default rules', where individuals automatically receive the established default if they do not make an active choice, as opposed to 'default options', where individuals are required to make an active decision or at least confirm the default choice (this distinction between default rules and default options was originally formulated by Altmann et al., 2019). Meier et al. (2022) found that most of the reviewed studies investigated default options, so that most interventions still required effort to choose or confirm. Although the default option can be seen as the promoted option in these interventions, the individual must actively confirm their choice (Meier et al., 2022). This is also the approach that we took in this study.

Jachimowicz et al. (2019) identified three main mechanisms related to the potential effect of default options: endorsement, endowment, and effort. The endorsement mechanism suggests that individuals implicitly or explicitly assume that the default option is a recommendation and that it is the socially accepted choice, also denoted as the social norm. The endowment mechanism suggests that consumers use the default option (e.g., red meat or plant-based meat) as the reference point (or 'anchor') for further considerations. This anchoring effect is also related to the human bias of loss aversion (Kahneman and Tversky, 1979), where individuals assess opting out of the default as a loss compared to keeping the default option. Finally, the effort mechanism is related to a general human preference for the easy option, which suggests that individuals take the default option because this is the easiest for them, as they do not have to spend time and effort evaluating other options.

Münscher et al. (2016) defined defaults as 'pre-selected options that leave decision makers the freedom to actively select a different option'. They proposed a taxonomy of choice architecture techniques covering three overall categories of intervention: decision information (A), decision structure (B) and decision assistance (C). The decision structure category (B) is divided into sub-categories where B1 captures 'changing choice default' techniques and B3 'change range or composition of options'.

The importance of changing the default food choice (category B1 nudges in Münscher et al. (2016)) as suggested by the Danish Council on Climate Change (2021) has been studied by Hansen et al. (2019) and Taufik et al. (2022), among others, as well as in a systematic review on food choices by Meier et al. (2022). In a Danish context, Hansen et al. (2019) found that using a vegetarian meal as the default option at three conference dinners increased the number of vegetarian meals by 86 % on average. As the study used a non-representative sample of highly educated people interested in public health, the generalisability of their results is not known. In a Dutch context, Taufik et al. (2022) investigated the effect of changing the pre-selected option on a menu both in a hypothetical online survey and in a field experiment. Their online survey showed that 34 % of the respondents chose the bean burger when it was the pre-selected option, compared to 24 % when a beef burger was the pre-selected option. In the field experiment, the authors found that the bean wrap was chosen by 80 % of visitors when it was the pre-selected option, compared to 9 % when the chicken wrap was the pre-selected alternative. The results from both the field experiments and hypothetical choice situation thus indicate rather large effects from B1-type default-based interventions. In their systematic review, Meier et al. (2022) focused on meat consumption with green default options and found that manipulating the defaults can be a promising tool in reducing the climate impact related to food choices, mainly due to the endorsement effect. Meier and colleagues suggested that future research should focus on verifying and quantifying the causal impact of mechanisms and

moderators. As most studies in the review were field experiments, Meier et al. (2022) highlighted that lab experiments could complement existing studies.

In a hypothetical choice situation involving undergraduate students at a university in the United States, Campbell-Arvai et al. (2014) conducted a field experiment with various interventions. One of these interventions is of specific interest here, in that the students were shown a menu with meat-free meals. If the respondents wished to select food options that were different from those on the default menu, they could consult a second menu that included meat-based dishes placed approximately 3.5 m away from their table. Showing the meat-free menu reduced the share of ordered meat dishes by 83 % (from 60 % to 10 %) compared to a situation where both meat-based and meat-free meals were listed on the same menu. Using the taxonomy suggested by Münscher et al. (2016), this nudge would be categorised under B3 ('change range or composition'). Another example of this type of nudge can be found in Gravert and Kurz (2021), with a field experiment carried out in a restaurant in Sweden. The guests were mainly white-collar employees, so the results may not represent the wider Swedish population. Their experimental design used two menus, with either a meat or a vegetarian option placed first on the menu and followed by a fish dish. The menu with meat as the first option also indicated that a vegetarian dish was available on request. In a similar way, the menu with the vegetarian meal as the first option informed guests that a meat dish was available on request. The authors found that showing the vegetarian dish as the first option reduced the share of meat-based meals by 54 % (from 46 % to 21 %) compared to the menu with meat shown first. The share of fish meals sold also increased (from 51 % to 64 %).

Other examples of B3 nudges involve changing the position of the different dishes on the same menu. For example, Dayan and Bar-Hillel (2011), Thunström and Nordström (2011, 2013), Wyse et al. (2019), and Bianchi et al. (2023) used this technique to study healthy food choices. Based primarily on data from students in Israel, Dayan and Bar-Hillel (2011) found that items placed at the beginning or end of the menu were more likely to be sold. The authors could not offer a satisfactory explanation of the advantage of being listed either first or last on the menu. Based on a student sample in Australia, Wyse et al. (2019) found no significant effect on the selection of fruit and vegetable snacks of placing the items first or last on an online canteen menu. Thunström and Nordström (2011, 2013) carried out a field experiment at a canteen in Sweden that was mainly visited by blue-collar workers, where the order of healthy-labelled dishes varied on the menu. Thunström and Nordström (2013) found that displaying the healthy-labelled dish at the top of the menu did not impact the sales of these dishes, whereas Thunström and Nordström (2011) found that sales of non-labelled conventional dishes benefited from a 'nudge' in terms of displaying the dish at the top of the menu. They also found that sales of both non-labelled conventional and healthy-labelled dishes substantially increased when popular ingredients such as poultry and red meat were included at the top of the menu. Bianchi et al. (2023) used a simulated food delivery platform and a sample of UK participants over the age of 18. In the intervention, the food options were listed in ascending order of energy content. The results revealed that the intervention reduced the energy content of the participants' food baskets. In a systematic review by Bucher et al. (2016), the authors concluded that a nudge that manipulates the food product order or proximity is likely to influence food choice.

Our experimental design was inspired by the designs used in Hansen et al. (2019), Taufik et al. (2022), Campbell-Arvai et al. (2014), Gravert and Kurz (2021), and Thunström and Nordström (2013), and the results in Bucher et al. (2016) and Bianchi et al. (2023), in that we tested the effectiveness of a 'change in default option' nudge in an online hypothetical setting. To increase the expected impact of changing the pre-selected dish, we displayed the pre-selected dish at the top of the menu. We varied the order of the other dishes on the menu.

Using the taxonomy suggested by Münscher et al. (2016), our setting for this first nudge can be categorised as an alteration of B ('the decision structure'). The default nudge that we propose is somewhere in between two examples suggested by Münscher et al. (2016): 'setting a no-action default' (no action required) and 'a prompted choice', where a question is asked but no default suggested. In our experiment, we offered a default choice, but the respondents still had to make an active choice. Furthermore, the default option was also placed at the top of the menu or choice list. Thereby, our first nudge falls under both sub-categories B1 ('changing choice default') and B3 ('change range or composition').

1.3. The effect of carbon footprint information on food choice

According to Camilleri et al. (2019) and Hartmann et al. (2021), consumers generally have poor knowledge about the carbon footprint of their food. Information about the carbon footprint of different products in addition to labelling schemes might therefore help consumers make a more 'informed' choice. Several studies have examined the effect of labels showing the product's carbon footprint (e.g., Apostolidis and McLeay, 2016; Peschel et al., 2016; Lombardi et al., 2017; Canavari and Coderoni, 2020; Edenbrandt et al., 2021; Carlsson et al., 2022; Edenbrandt and Lagerkvist, 2022; Lohmann et al., 2022; Edenbrandt and Nordström, 2023).

For example, the study by Edenbrandt et al. (2021) used 800 Swedish respondents to investigate the effect of introducing a label with carbon footprint information on different types of mince, including minced beef (with the highest carbon footprint) and plant-based mince (with the lowest carbon footprint). The study found that, in a hypothetical setting, a label with carbon footprint information led to a 25 % reduction in emissions from the respondents' choice of mince. Edenbrandt and Lagerkvist (2022) found that Swedish consumers with little interest in climate labels had on average a higher carbon footprint from their food consumption than consumers who also indicated an interest in a climate label. They also found that consumers who were interested in reducing their meat consumption or avoiding meat altogether were the ones most interested in the climate label. Lohmann et al. (2022) conducted a large-scale field experiment to explore the effects of carbon footprint labels on meal choices in five cafeterias at the University of Cambridge, UK. They found that introducing a carbon footprint label decreased the probability of selecting a high-carbon meal by less than 3 percentage points.

Peeters and Czapinski (1990) found that greater emphasis was attached to negative information than to positive information, and that negative information is therefore likely to trigger a stronger response. The framing of messages was also investigated by Dolgopolova et al. (2022), who carried out a meta-analysis on how attribute framing affects consumers' choice of food. Attribute framing means that product attributes can be described by either emphasising positive characteristics (e.g., dietary fibre and vitamins) or by focusing on the absence of negative characteristics (e.g., sugar and fat). Dolgopolova et al. (2022) found that in terms of food products, gain frames tended to induce stronger responses from consumers than loss frames, while loss-framed messages tended to be more effective in decisions involving significant risk.

Although the results from field studies tend to reveal a smaller effect of carbon footprint labels compared to stated preference studies, the results suggest that a climate label would have some effect on the aggregate carbon footprint from food consumption. This inspired us to choose carbon footprint information as the second nudge to reduce beef consumption. Additionally, we were inspired by findings on the importance of attribute framing and thus included different versions of carbon footprint information in the nudge. By doing so, we hope to contribute to the literature on how information provision affects beef consumption.

However, not all consumers are interested in labelling schemes, and we therefore see a need to combine labels with other nudges or interventions to induce significant behavioural changes.

1.4. Double nudges

Combining two nudges has previously been used to study energy demand (Brandon et al., 2019; Fang et al., 2023), farm behaviour (Howley and Ocean, 2022), and consumers' choice of delivery method (Nijssen et al., 2023), among others. Furthermore, Lorenz-Walther et al. (2019) investigated the potential for reducing food waste in canteens using reduced portion sizes and information posters as tools. They found that reducing portion sizes reduced the amount of leftovers on a plate, whereas the effect of information was mixed, with both increases and decreases in leftovers. Faccioli et al. (2022) investigated the effect of combining two regulatory tools in a hypothetical setting where carbon footprint information on food products was combined with a carbon tax based on CO_2 emissions. Based on data from 6000 UK citizens, they found that the effect of carbon footprint information almost doubled with the addition of a carbon tax, which was based on short-term, non-traded carbon prices in 2020.

Wongprawmas et al. (2023) conducted a food choice experiment among 1312 Italian students using an online pre-order system for university canteens. They investigated two nudges – a 'Healthy and Sustainable Logo' nudge and a 'Dish Placement' nudge (where the order of dishes displayed on the menu was changed), as well as a combination of both nudges. They found that on average, dish placement led to a significant increase in the selection of healthy and sustainable dishes. However, when dividing students into two groups according to their stated healthy and sustainable eating habits, they found that the group of students who already had strong sustainable and healthy eating behaviours were affected by both the placement and the combination of nudges, whereas the other group of students were not affected. A similar study was conducted among US students by Andreani et al. (2024). Overall, they found no effect of either the Healthy and Sustainable Logo or the Dish Placement, but when grouping students according to their health and sustainability behaviour, they found that the logo and logo-plus-placement led to a significant increase in the selection of healthy and sustainable dishes among students who already had strong healthy and sustainable eating behaviours. Wongprawmas et al. (2023) and Andreani et al. (2024) both found that population characteristics such as age, gender, being on a low-calorie diet, living with parents, intention to consume healthy and sustainable food, and eating habits also affected the effectiveness of the nudges and should be considered when identifying a successful nudging strategy. A slightly different outcome was observed in the study by Erhard et al. (2023). They assessed the effectiveness of online defaults within menus in the context of meal delivery services—both with and without framing the choice as more sustainable or tasty. They found that changing the default to a plant-based menu did not increase the likelihood of choosing that option. However, a combination of using a plant-based default and framing the plant-based default as the more sustainable or tasty option was effective in increasing the number of plant-based choices. Hence, the double nudge proved effective.

Combining nudges has thus been found to increase effectiveness, but the strength of the nudges tends to depend on the context. Consequently, we tested the effect of a label with carbon footprint information as a single nudge and as part of a double nudge. As Meier et al. (2022) called for future studies on the quantitative effects of nudges, we were inspired not only to combine two nudges but also to quantify the effects on the carbon footprints of food.

1.5. An extended norm activation model

To gain insights into the impact of moderators on consumers' choice of a low-carbon diet, we took our departure from the Norm Activation Model (NAM; Schwartz, 1977), where awareness, responsibility, and personal norms were found to be drivers of pro-environmental behaviour. According to the NAM theory, problem awareness and ascription of responsibility will activate the personal norm that guides whether the individual undertakes a specific action that prevents a detrimental outcome (De Groot and Steg, 2009; Steg and De Groot, 2010). Han (2014) suggested incorporating attitude and social norm as antecedents of behavioural intention. In the context of food choices, Onwezen et al. (2022) found that social norms were indeed important for understanding Dutch consumers' acceptance of alternative protein sources. In line with Han (2014), we therefore extend the NAM and include not only awareness, responsibility, and personal norms, but also social norms as moderators of pro-environmental behaviour. This extension is also in line with the theory of planned behaviour suggested by Ajzen (1991), who proposed that the subjective norm reflects an individual's perception of social pressure to act in a specific manner.

Following Edenbrandt et al. (2021), we considered the variables representing awareness, responsibility, and personal and social norms to be moderating variables and not mediating variables.

1.6. Our study

In the present study, we assessed how food choices can be affected by changing the choice architecture, involving a change of default option from beef —which tends to be the social norm today—to plant-based food. To reinforce the default option nudge, we placed the default option at the top of the list of possible sources of protein. We also assessed the extent to which information about the carbon footprint affected choices. We therefore considered the following research questions:

RQ1. How is the consumers' preferred choice of protein source in meals affected by a change of default option, provision of carbon footprint information, or implementation of both nudges?
RQ2. How is the average carbon footprint of meals affected by a change of default option, provision of carbon footprint information, or implementation of both nudges?
RQ3. Can the Norm Activation Model (NAM) explain differences in consumers' intention to purchase beef after exposure to carbon footprint information?

In a hypothetical experimental setting, the respondents were offered meals with five different kinds of protein sources, including ground beef, a fish fillet, chicken breast, a cut of pork, or a plant-based steak (hereinafter referred to as beef, fish, chicken, pork, and plant-based steak, respectively). The study provides new insight in a number of ways. For RQ1, we examined the effect of changing the default option from beef to a plant-based protein source combined with changing the option at the top of the list and the effect of providing information about the food's carbon footprint. While the combined effect of multiple nudges has previously been analysed, this has not been studied in a sample of Danish consumers. For RQ2, where we quantified the reduced carbon footprint from the two interventions, we included differences in substitution patterns, which we have not seen in other studies. Finally for RQ3, we analysed heterogeneity in the sample population by including variables related to awareness, responsibility, and not only personal norms but also including a social norm variable (thereby using an extended NAM), as well as variables capturing the frequency of organic consumption. By improving our understanding of these moderating mechanisms, our results can assist in speeding up the transition to a more plant-based diet in Danish society. RQ1–RQ3 were all investigated in a large representative sample of Danish consumers.

2. Materials and methods

In this section, we first introduce the data collection method and document how the carbon footprint information was retrieved from a database and presented to the respondents. We then present the experimental design involving two rounds of choice tasks before describing the analytical and statistical approach used to address each research question in turn.

2.1. Materials

The data were collected by the company Norstat, which hosts and maintains a panel of consumers in Denmark. The study was approved by the Research Ethics Committee of Science and Health at the University of Copenhagen. The questionnaire was tested in a pilot study involving 100 respondents and the results from the pilot study were used to improve the questionnaire's comprehensibility and to reduce its length. The main survey was carried out in September 2022 and included 2000 respondents. We refer to supplementary information for the precise formulations of the questions (S1) and descriptive statistics for all variables (S2). Recruitment of the respondents aimed to achieve representativeness of the adult population in terms of gender, age, and geographical location. Informed consent was obtained and handled by Norstat in accordance with national requirements and the data were received in pseudonymised form. The response rate was 26 % after the initial invitation and one reminder.

Information about the carbon footprint of the various protein sources was obtained from Concito (2021) using their database with carbon footprints for around 500 food items. Carbon footprints can vary widely according to e.g. the cut of meat or type of fish. For example, the carbon footprint of beef sirloin is 4–5 times larger than that of ground beef. According to Concito (2021), the carbon footprint measured in CO_2e per kg of the product group was in the range 37–186 kg for beef, 1.9–5.6 kg for poultry, 2.1–7.7 kg for pork, and 2.1–7.5 kg for fish such as salmon or herring. The carbon footprint of a vegetable patty was 0.2–2.7 kg CO_2e, and thereby substantially lower than that of the other products. All carbon footprints were measured at the supermarket and thereby included emissions from primary production, land use change, processing, packaging, transportation, and handling in the retail shop. In the experiment, we used a carbon footprint for beef of 37 kg CO_2e, which was at the lower end of the range for beef, because ground beef was the product described in the experiment. For the other protein sources, no specific products were indicated to the respondents and we therefore used carbon footprints approximately in the middle of the ranges.

Based on their carbon footprints, fish, pork, and chicken were placed in a category with a medium carbon footprint, beef in a category with a higher carbon footprint, and plant-based steak in a category with a lower carbon footprint. In order to simplify presentation and reduce the respondents' cognitive burden, the relative carbon footprints of the three product categories were presented in round numbers as 20:2:1 (i.e., the carbon footprint of beef is 10 times higher than that of pork, chicken and fish, which is twice as high as the carbon footprint of a plant-based steak). This is roughly in accordance with the climate impact database as described.

2.2. Experimental design

The experiment involved two rounds of choice tasks where the respondents were asked to state their preferred protein sources. The setting was an ordinary weekday and the respondents were asked to choose a hypothetical meal consisting of vegetables, carbohydrates, and a protein source.

2.2.1. The default nudge

In the first round, the respondents were randomly allocated into two splits with either ground beef or a plant-based steak presented as the pre-selected choice of protein source in the dish. The respondents were asked to rank five different protein sources with the pre-selected choice being shown at the top of the list and the other four protein sources shown below in a random order. Thereby, the respondents in the two splits were not only presented with different pre-selected protein sources, but they were also offered different 'first options on the list'. More specifically, the hypothetical settings in Split Beef versus Split Plant differed in two ways:

1. The text specifying which protein source the two splits were initially offered as part of a meal differed – the protein source was either ground beef (Split Beef) or a plant-based steak made of vegetables (Split Plant) – and after being presented with this initial option, they had to choose which (out of the five) protein sources they would choose. This experimental technique can be grouped as a B1 category 'Changing choice defaults' using the taxonomy suggested by Münscher et al. (2016).
2. The two splits also differed in terms of which type of protein source was placed at the top of the list from which the respondents were asked to rank the protein sources. Ground beef was placed at the top of the list for Split Beef, while the plant-based steak was placed at the top of the list for Split Plant. The other four protein sources were allocated randomly. This experimental technique can be grouped as a B3 category 'Change range or composition of options' using the taxonomy suggested by Münscher et al. (2016).

More specifically, the respondents were given the following information in round 1 (note that the text in [] was provided to Split Plant):

Imagine that on an ordinary weekday you must purchase a meal. The meal includes ground beef [a plant-based steak made of vegetables] and side dishes with as many vegetables, pasta, and potatoes as you like. Imagine that you can replace the ground beef [plant-based steak] with another 'steak' of the same quality and size. When we refer to 'plant-based steak' below, we mean a steak made from vegetables. (Note that only Split Beef received the last piece of information as Split Plant had already received this specification of the plant-based steak.)

We would like to ask you to rank the alternatives according to what you want most to what you want least. Choose 1 for the alternative you want most, 2 for what you want second most, and so on. If there are one or more alternatives you don't want to eat at all, you can choose 'No'.

2.2.2. The informational nudge

In the second round, the effect of adding information about the carbon footprint of dishes was studied using a within-subject design where respondents in both splits were given the same information. All respondents received the following information in round 2:

You will now receive information about the climate footprint of the different types of 'steaks'. The carbon footprint of the side dishes (vegetables, potatoes, and pasta) makes up a small part of the meal's carbon footprint – and it is the same for all meals. Differences in the carbon footprint of the 'steaks' are both described in text and shown as labels. Information about the carbon footprint is based on Concito's climate database. Again, we ask you to rank the alternatives from what you want most to what you want least. Choose 1 for the alternative you want most, 2 for what you want second most, and so on. If there are one or more alternatives you don't want to eat at all, you can choose 'No'.

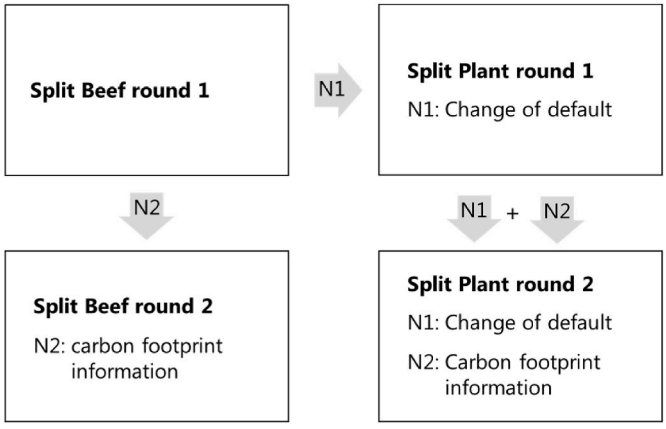

Fig. 1. Overview of the experimental design.

Fig. 1 provides an overview of the experimental design and flow of actions, while Table 1 shows the information provided to respondents in round 2.

2.3. Analytical approach

To address the first research question (RQ1) regarding the effect of the nudges on the consumers' preferred choice of protein source, we investigated how the shares of respondents who chose a protein source with high emissions (beef), medium emissions (chicken, fish or pork), or low emissions (a plant-based steak) as their first choice were affected by the two nudges used either individually or in combination. Differences across the two splits in round 1 revealed the effect of a change in the default alternative (N1), differences before and after carbon footprint information in Split Beef revealed the effect of providing information as an individual nudge (N2), while differences before and after carbon footprint information in Split Plant revealed the effect of providing carbon footprint information as the second nudge (N1+N2). Differences within splits were examined using McNemar's test and differences across splits were examined using X^2 tests.

The second research question (RQ2), focusing on the effect of applying single or double nudges on the carbon footprint, required quantification of the nudges' impact. We therefore quantified the impact of the shifts in preferred protein source identified in RQ1. By taking this approach, we were able to capture differences in substitution patterns across consumers when subjected to the nudges, e.g. some consumers were not affected by the nudges, some shifted from beef to chicken, others from a plant-based steak to pork, etc. In other words, we measured the average carbon footprint in the sample for each nudge. The carbon footprint calculations were based on the 20:2:1 relationship between the carbon footprint of beef versus chicken, fish, or pork, versus a plant-based steak. The average carbon footprint in the sample related to the choices made by respondents and was reported as a change in CO_2e, together with 95 % confidence intervals, and as percentage changes. We quantified the effect of N1 (change of default) by comparing the total CO_2e in round 1 for Split Beef with Split Plant. The effect of N2 (carbon footprint information) was quantified by comparing the total CO_2e in round 1 and round 2 for each split. Finally, the effect of the two nudges combined (N1+N2) was quantified by comparing round 1 for Split Beef with round 2 for Split Plant.

To address the third research question (RQ3), we used the extended NAM to gain a deeper understanding of the types of respondents who were likely to choose beef regardless of the default option and to understand which groups were likely to be affected by carbon footprint information. Eight statements from the questionnaire were used to construct six NAM-inspired variables related to responsibility, personal norm, social norms, and problem awareness that were included in the statistical models. Four single-item variables and two constructs with two items were used in the analysis. Specifically, the average of two individual items was used to construct the variables Responsibility (Cronbach's alpha 0.67; Pearson Correlation Coefficients 0.50) and Personal Norm (Cronbach's alpha 0.61; Pearson Correlation Coefficients 0.43). If the alpha value for a construct is less than 0.6, the association between the variables is poor, while an alpha value between 0.6 and 0.7 is characterised as moderate and values above 0.7 are characterised as good (Hair et al., 2003). Our constructs are thereby at the lower end of acceptable. The statements from the questionnaire used to construct the variables are shown in Table 2 and the summarised statistics for the NAM variables can be found in the supplementary information (S3).

To address RQ3, we used a two-step approach that allowed us to identify characteristics of respondents who preferred beef as a starting point (Model I), as well as characteristics of the respondents who were affected in different ways by carbon footprint information (Model II). Thereby, Model I was used to identify the group of consumers who needed to be nudged (the Beef eaters) and Model II identified the extent to which the informational nudge was effective. For Model I, only data from round 1 were used. We thus focused on identifying the characteristics of respondents who had beef as their first choice, with either beef or a plant-based steak as their default option – without having received specific information about its carbon footprint. The characteristics that were included as explanatory variables included NAM variables, as well as socio-demographic variables and organic purchase frequency as control variables. Model II was used to understand the characteristics of respondents who were (or were not) affected by carbon footprint information in their choice of protein sources. Accordingly, we distinguished between four groups of respondents:

Table 1
The table shown to respondents in round 2 of the experiments.

Protein source	Shown to Split Beef	Shown to Split Plant	Label used for both splits	Your ranking:
Ground beef	The starting point	20 times larger		
A plant-based steak	20 times smaller	The starting point		
Chicken	10 times smaller	2 times larger		
Pork	10 times smaller	2 times larger		
Fish	10 times smaller	2 times larger		

Note: In the description given to respondents in Split Plant, the protein source 'a plant-based steak' was shown in the first row of the table, i.e., for both splits the other four alternatives were randomised.

Table 2
Explanatory variables from the norm activation model (NAM).

Variable	Statements used to create variable	Inspired by
Responsibility	I feel co-responsible for climate change because I contribute with carbon emissions through my consumption [a] My personal contribution is very small, so I do not feel responsible for climate change [b]	Kaiser et al. (1999)
Personal Norm	I feel a moral obligation to reduce my contribution to climate change [a] I do not have a (moral) responsibility to reduce my contribution to climate change if other consumers do not [b]	Han (2014) & Onwezen et al. (2013)
Social Norm	Most people who are important to me would want me to have a climate-friendly diet [a]	Han (2014)
Problem Awareness1	The production of red meat has a large impact on greenhouse gas emissions [a]	Edenbrandt et al. (2021)
Problem Awareness2	In general, do you think that climate change, which is sometimes called the greenhouse effect, will be a very serious problem, somewhat of a problem, or won't really be a problem for you and your family? [c]	Stern et al. (1999)
Problem Awareness3	Do you think that climate change will be a very serious problem, somewhat of a problem, or will not really be a problem for our planet?	Stern et al. (1999)

Note: Coding of response categories was based on the logic that higher scores would be associated with a greater willingness to change behaviour: [a] Totally disagree (1), Partly disagree (2), Neither agree nor disagree (3), Partly agree (4), Totally agree (5), Don't know (0). [b] Totally agree (1), Partly agree (2), Neither agree nor disagree (3), Partly disagree (4), Totally disagree (5), Don't know (0). [c] Won't really be a problem (1), Will be somewhat of a problem (2), Will be a very serious problem (3), Don't know (0).

- Beef eaters (respondents who chose beef in both rounds)
- Positively affected (respondents who chose beef in round 1 but not round 2)
- Negatively affected (respondents who did not choose beef in round 1 but did so in round 2)
- Beef avoiders (respondents who did not choose beef in either round).

While Model I only included data from round 1, Model II included data from both round 1 and round 2. The same set of explanatory variables were used in Model I and Model II. Both models are logistic regression models inspired by the statistical analysis used in Hosmer et al. (2013). Equations I and II below describe Model I and Model II, respectively.

$$Model\ I: \log \frac{P(y_I = 1|x)}{1 - P(y_I = 1|x)} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 \quad (I)$$

$$Model\ II: \log \frac{P(y_{II} = j|x)}{P(y_{II} = 4|x)} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5,\ j = 1, 2, 3. \quad (II)$$

In Model I, the dependent variable was a binary variable, y_I, which took the value 1 if the respondent ranked beef as their first choice and 0 otherwise. Model II is a multinomial logistic regression model in which the dependent variable y_{II} was a four-dimensional vector representing the four different groups. For both models, we carried out a likelihood ratio test for the global hypothesis that there are no systematic differences related to the explanatory variables across the groups (H_0: $\beta = 0$).

We assumed a linear relationship between the explanatory variables and the log odds of the event that a respondent belonged to a group. In particular, β_0 is a constant and $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ are parameters to be estimated linked to the explanatory variables x_1, x_2, x_3, x_4, x_5. The first vector of explanatory variables, x_1, represents the six NAM variables. Hence, we investigated the relationship between attitudes expressed by the NAM variables and preferring meat in Model I and the relationship with the NAM variables and the influence of information in Model II. Moreover, the models included a number of control variables. The vector x_2 consisted of six dummy variables and controlled for respondents who answered 'don't know' to each of these six NAM statements. As the respondents were randomly assigned to either Split Plant or Split Beef, the dummy variable x_3 was used to control for potential differences in the choices linked to the default alternative. The organic user groups were represented by the vector x_4. We grouped the respondents according to their stated organic consumption following the approach used in Christensen et al. (2020), i.e., the respondents were grouped into five user groups based on their average stated organic purchase frequency: light users (organic purchase frequency of up to 10 %), medium users (organic purchase frequency of 11–40 % inclusive), heavy users (organic purchase frequency of 41–60 % inclusive), super users (organic purchase frequency of above 60 %), and organic not reported (organic purchase frequency not reported). Another vector of dummy variables, x_5, was used to identify potential systematic socio-demographic differences related to the respondents' gender (female versus other), region (living in the Capital Region versus living elsewhere), education (having a higher education of 5 years or more versus other education), and age (18–34, 35–49, 50–64, 65–74), where the younger age groups were compared to the oldest age group.

The group of Beef eaters was used as reference group and the log-ratios for the other groups were all estimated relative to this group. Furthermore, the reference respondent used in the estimations was a light user who had another gender identity than female, lived outside the Capital Region, did not have a higher education of 5 years or more, was in the age group 65–74 years, and was in Split Beef.

Note that an odds ratio above 1 (or below 1) for an explanatory continuous variable indicates that respondents who provided an answer at the higher end of the scale had a higher (or lower) likelihood of belonging to the group specified by the dependent variable (Positively affected, Negatively affected, or Beef avoider) rather than being a Beef eater. An odds ratio above 1 (or below 1) for a dummy variable indicates that respondents who belonged to the group specified by the dummy variable had a higher (or lower) likelihood of belonging to the specified group rather than being a Beef eater, compared to respondents in the reference group for the dummy variable.

Of the 2000 respondents, 36 stated that they did not consume meat and were removed from the sample as it was not meaningful to group them according to their propensity to choose beef. Moreover, 35 respondents said 'No' to all alternatives before and/or after information was provided. These respondents were removed from the sample as it was assumed that they were unwilling to participate in the experiment. Finally, we removed 51 respondents who answered 'don't know' to all statements shown in Table 2. Thus, the final sample included 1878 respondents. The estimations were performed using the software SAS 9.4.

3. Results

This section presents the socio-demographic characteristics of the sampled consumers (section 3.1) followed by the analyses for each research question in turn (section 3.2–3.4).

3.1. Socio-demographic characteristics of the sample

Socio-demographic characteristics of the respondents in the sample are compared with national quotas in Table 3. The numbers suggest that the sample reflects the Danish population to a satisfactory level with regard to these characteristics.

3.2. How did a change in the default option, provision of carbon footprint information, or implementation of both nudges affect consumers' preferred choice of protein source in meals? (RQ1)

The results suggest that the vast majority of the respondents chose beef, chicken, fish, or pork, while few preferred a plant-based steak (see Table 4). Changing the default from beef to a plant-based steak significantly decreased the share of respondents who chose beef and increased the share who had chicken, fish, pork, or a plant-based steak as their preferred alternative. More specifically, changing the default reduced the share of respondents who chose beef by 26 % (from 46 % to 34 % of the sample). Providing carbon footprint information reduced the share of respondents who chose beef by 17 % in Split Beef and by 29 % in Split Plant. In both splits, carbon footprint information induced more respondents to choose chicken, fish, or pork, and fewer to choose beef. However, the effect differed across the two splits: while information about the carbon footprint in Split Beef resulted in beef being substituted

Table 3
Descriptive statistics of the sample compared with national quotas from Statistics Denmark.

	Sample (1878 respondents)	Statistics Denmark
Female	53 %	51 %
18–34 years old	27 %	28 %
35–49 years old	22 %	23 %
50–64 years old	27 %	25 %
65+ years old	25 %	25 %
Living in the Capital Region	29 %	32 %
Higher education of 5 years or more	15 %	14 %[a]

Note: [a] Numbers extracted from Statistics Denmark (https://www.statistikbanken.dk), valid for September 2022 for inhabitants 18 years old and above.
[a] Valid for inhabitants between 20 and 69 years old.

Table 4
The share of respondents in Split Beef and Split Plant who prioritised different protein sources.

Split	Split Beef (%)		Split Plant (%)		Test 1	Test 2	Test 3
Round	Round 1	Round 2	Round 1	Round 2	*p*-values		
Intervention	None	Information	Default	Default and information			
Beef	46 %	38 %	34 %	24 %	<0.0001	<0.0001	<0.0001
A plant-based steak	7 %	7 %	10 %	13 %	0.8840	0.0121	0.0019
Chicken, pork, fish	48 %	55 %	57 %	63 %	<0.0001	<0.0001	<0.0001

Note: Based on 941 respondents in Split Beef and 937 respondents in Split Plant. Test 1: *p*-values for McNemar's test for round 2 in Split Beef versus round 1 in Split Beef. Test 2: *p*-values for χ^2 tests for round 1 in Split Plant versus round 1 in Split Beef. Test 3: *p*-values for McNemar's test for round 2 in Split Plant versus round 1 in Split Plant.

with chicken, fish, or pork, the substitution in Split Plant was not only from beef to chicken, fish, or pork, but also to the plant-based steak. Taken together, the double nudges reduced the share of respondents choosing beef by 48 % (from 46 % of the respondents to 24 % of the respondents). The McNemar's and χ^2 test values are shown in Table 4.

3.3. How was the average carbon footprint of chosen meals affected by a change of default option, provision of carbon footprint information, or implementation of both nudges? (RQ2)

The carbon footprint of an average meal chosen by respondents in the two splits is shown in Table 5. The results from round 1 suggest that having a plant-based steak instead of beef as the default meal reduced the average carbon footprint from the meals in the sample by 22 %. Moreover, providing respondents with information about the carbon footprint reduced the carbon footprint from the meals by 14 % in Split Beef and 21 % in Split Plant. The total reduction in emissions from having a plant-based steak instead of ground beef as the default meal and providing information about the carbon footprint was 39 %. All the differences mentioned here are statistically significant at the 5 % level.

3.4. Can the Norm Activation Model (NAM) explain changes in consumers' intention to purchase beef after exposure to carbon footprint information? (RQ3)

The results from the logistic regression models are shown in Table 6. The typical characteristics of respondents who chose beef in round 1 are shown to the left in Table 6. We found that respondents with higher scores for three of the NAM-related variables (Responsibility, Personal Norm, and Problem Awareness1) were less likely to prefer beef than respondents with lower scores for these variables. We also found that super users of organic food were less likely than light users to prefer beef. Furthermore, female respondents, respondents living in Copenhagen, and respondents with a higher level of education were found to be less likely to prefer beef. The variables used to measure the Social Norm and Problem Awareness2 and Problem Awareness3 are not statistically significant at a 5 % significance level. Moreover, the group of respondents with beef as their default choice were significantly more likely to choose beef than respondents with a plant-based steak as default. In particular, the results suggest that the odds of choosing beef were reduced by almost 50 % ($1.86^{-1} = 0.54$) when a respondent received a plant-based steak as the default option instead of beef.

Note that Table 6 is a short version of the original Models I and II. The original models that include all the dummy variables (also the non-significant ones) can be seen in the supplementary information (S4), which also reports the 95 % confidence intervals for the odds ratio point estimates for all variables. Furthermore, the maximum likelihood

Table 5
Average carbon footprint per respondent based on their preferred protein source.

	Kg CO_2e in round 1	Kg CO_2e in round 2	Round 2 compared to round 1
Split Beef	2.54 (CI: 2.40; 2.69)	2.19 (CI: 2.04; 2.33)	−0.35 (−14 %)
Split Plant	1.98 (CI: 1.85; 2.12)	1.56 (CI: 1.44; 1.69)	−0.42 (−21 %)
Split Plant compared to Split Beef	−0.56 (−22 %)	−0.63 (−29 %)	−0.98 (−39 %)[1]

Note: Based on 941 respondents in Split Beef and 937 respondents in Split Plant. CI: 95 % confidence intervals. All the differences are statistically significant at the 5 % level. [1]These numbers represent a comparison of emissions in Split Plant from round 2 with emissions in Split Beef from round 1.

Table 6
Results regarding the characteristics of respondents who chose ground beef (Model I) and characteristics of respondents affected by carbon footprint information (Model II).

Variable	Model I	Model II		
	Chose beef in round 1	Positively affected	Negatively affected	Beef avoiders
Responsibility	0.84**	1.23*	1.47**	1.24**
Personal Norm	0.84**	1.09	0.89	1.27**
Social Norm	1.06	1.21**	1.10	1.00
Problem Awareness1	0.86**	1.27**	1.27*	1.25**
Problem Awareness2	0.90	1.21	1.05	1.22*
Problem Awareness3	1.08	1.07	0.67*	1.000
Split Beef vs. Split Plant	1.86**	0.48**	0.64*	0.38**
Medium users vs. light users	0.93	1.47	1.04	1.20
Heavy users vs. light users	0.78	1.99**	1.29	1.65**
Super users vs. light users	0.50**	1.75*	1.67	2.46**
Organic not reported vs. light users	1.22	4.35**	2.44	1.35
Female vs. other respondents	0.39**	1.84**	1.22	3.58**
18–34 years vs. 65+ years	1.08	1.60**	0.80	1.18
35–49 years vs. 65+ years	1.85**	1.48*	0.41**	0.67**
50–64 years vs. 65+ years	1.17	0.68	0.72	0.77
Living in the Capital Region vs. living in another region	0.76**	1.36*	0.83	1.57**
Education (higher education vs. another education)	0.66**	1.10	1.86*	1.57**
−2 Log Likelihood	2228.51	3610.75		
Likelihood ratio test for global H_0: $\beta = 0$.	χ^2:294.20	χ^2: 492.59		
	p-value <0.0001	*p-value*: <0.0001		

Note: Model I is a binary and Model II is a multinomial logistic regression model. The results are shown as odds ratio point estimates. The results are based on 941 respondents in Split Beef and 937 respondents in Split Plant. *The odds ratio point estimates are significant at the 10 % level. ** The odds ratio point estimates are significant at the 5 % level.

estimates and associated test statistics are shown in the supplementary information (S5).

Before diving into detail about the characteristics of respondents who were affected in different ways by carbon footprint information, we provide an overview of the size of the four groups in Fig. 2. The majority of respondents in the two splits were either Beef avoiders or Beef eaters. We identified that more respondents in Split Plant were Beef avoiders than in Split Beef. In both splits, 13 % chose beef in the first round and shifted to another alternative in the second round (Positively affected), whereas 5 % did not choose beef in round 1 but chose beef in round 2 (Negatively affected).

We now turn to a description of the characteristics of respondents who were affected in different ways (either positively, negatively, or not affected) by carbon footprint information. These are the results of Model II, shown to the right in Table 6. There was a clear effect of the default protein source as respondents in Split Beef were more likely than respondents in Split Plant to belong to the group of Beef eaters than to any of the other three groups. Regarding the effect of carbon footprint information, respondents with higher scores for the NAM-related variables Responsibility and Problem Awareness1 were more likely to be Positively affected or Beef avoiders than Beef eaters. Respondents with high scores for Social Norm were more likely to be Positively affected than Beef eaters, whereas respondents with high scores for the Personal Norm variable were more likely to be Beef avoiders than Beef eaters. Organic Heavy and Super users were more likely than Light users to be Positively affected or Beef avoiders. Finally, Beef avoiders were often female, living in Copenhagen, or with a higher education, while females and young people were often Positively affected.

4. Discussion

The discussion is structured such that the results regarding the effect of the nudges on food choice (RQ1) are discussed in sections 4.1–4.3 and the accompanying reductions in carbon footprints (RQ2) are discussed in section 4.4. The explanatory power of the NAM variables regarding understanding how information affected the different groups of consumers (RQ3) is discussed in 4.5 and 4.6, while we consider the main limitations of our study in 4.7.

4.1. The effect of changing the default (part of RQ1)

Our results suggest that promising behavioural changes can be achieved by changing the default option. As presented in section 1.2, the default nudge in our study consisted of both a change in whether the offered dish included beef or a plant-based steak and positioning the offered dish at the top of the menu or choice list. Using a hypothetical lab experiment, we found that the share of respondents who chose beef decreased by 26 % when we changed the default. This is comparable but slightly lower than the field experiment results found in Campbell-Arvai et al. (2014), where the choice of meat dishes decreased by 83 % when participants were given a meat-free default and had to stand up to collect the meat dish from another table. Furthermore, Hansen et al. (2019) found that a vegetarian default reduced the choice of meat-based meals by 86 %, and Gravert and Kurz (2021) found that placing a vegetarian meal rather than a meat-based meal at the top of the menu in a restaurant reduced the choice of meat-based dishes by 54 %. Regarding the latter, Wongprawmas et al. (2023) and Andreani et al. (2024) found different results in their hypothetical experiment of changing defaults in an online meal-ordering setting. They found that changing the default mainly affected the choice of meat dishes among respondents who already had an interest in healthy and sustainable eating. Taufik et al. (2022) investigated the effect of changing the default both in a hypothetical online survey and in a field experiment and found a significant effect of changing the default in both types of experiment, with the largest effect in the field experiment.

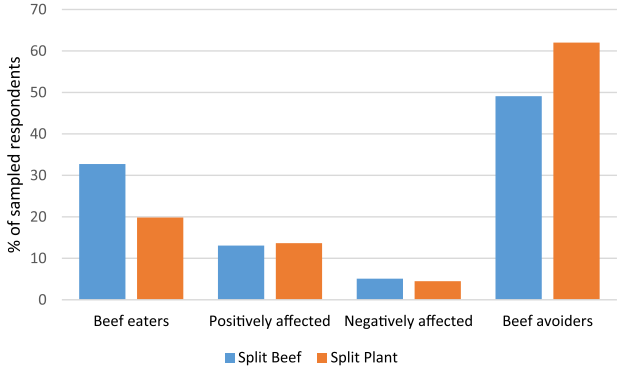

Fig. 2. Share of respondents according to whether they chose beef in round 1 and/or round 2. *Note*: Based on 941 respondents in Split Beef and 937 respondents in Split Plant.

These findings place our results in between the hypothetical studies by Wongprawmas et al. (2023) and Andreani et al. (2024) and the field studies carried out by Gravert and Kurz (2021) and Hansen et al. (2019). Overall, the effect found in our lab experiment was slightly lower than the effect found in the aforementioned field studies, which can to some extent be explained by the lower effort involved in changing from a default in a hypothetical setting than in a real-world setting. Due to the differences in results between lab and field experiments, we suggest more studies involving parallel testing of hypotheses in both types of experiments in the future.

The investigated default nudge in our study consisted of both a change in whether beef or a plant-based steak was presented as part of an offered meal and a change in the option at the top of the list, where the first option was the same as the offered protein source (beef or plant). In this set-up, we could not distinguish the effect of the offered protein source from the effect of placing the offered protein source at the top of the list. This is a limitation that future studies can address by digging into the relative importance of these two nudges (e.g. changing the pre-selected option that needs to be confirmed or changed versus changing the option placed at the top of the list).

4.2. The effect of carbon footprint information (part of RQ1)

Providing carbon footprint information reduced the share of respondents who chose beef by 17 % in Split Beef and 29 % in Split Plant. We propose two explanations for the differences in how information affected the respondents' choices. Firstly, we propose that the carbon footprint information encouraged fewer consumers with beef as the default option to shift away from beef because the loss associated with a shift away from a popular default option (i.e., the beef) is larger than that associated with a shift from a less popular default option (i.e., the plant-based steak), thus the shift in reference point (through the endowment mechanism) may have had an impact on the effect of information. This explanation is in line with Tversky and Kahneman's (1991) interpretation of the status quo bias as loss aversion (Kahneman et al., 1991; Kahneman and Tversky, 1979) and could explain why the information had a larger effect when a plant-based steak was the default option. The second explanation relates to the presentation of the information. More specifically, when beef was the default option, the alternatives (a plant-based steak, chicken, pork, and fish) were all described as having a *lower* carbon footprint than the reference point. When a plant-based steak was the default option, the alternatives (beef, chicken, pork, and fish) were all described as having *higher* carbon footprints than the reference point. This difference in the formulation of the carbon footprint could have affected the choices. Presenting the carbon footprint of beef as being higher than a plant-based steak (split Plant) can be considered negative information about beef compared to the default (a plant-based steak), while the lower carbon footprint of the plant-based

steak compared to the beef (split Beef) can be considered positive information about alternatives to the default. Our results thereby indicated that using negative information about the beef was more effective in nudging respondents away from choosing beef than using positive information about the choice of a plant-based steak. This follows the behavioural effect suggested in Peeters and Czapinski (1990), where negative information was found to be most effective.

We propose that the robustness of our findings concerning the effectiveness of different types of framing for the carbon footprint information would be an interesting topic for future studies. In particular, in-depth interviews where arguments and reasoning can be elicited may provide important insights regarding our two explanations for the larger impact of carbon footprint information when a plant-based steak was offered as the default option. The extent to which our results are transferable to online food shops or to food choices in a cafeteria or restaurant in real-life settings would also be interesting topics for future research.

On one hand, previous research indicates that customers choosing food in a real-life situation (e.g., in a restaurant or cafeteria) might pay less attention to informational nudges compared to the online survey setting that our study used. For example, Eves et al. (2026) and Babakhani et al. (2020) found that sensory stimuli were important drivers of food choice that could overrule the effects of informational nudges. On the other hand, Lohmann et al. (2022) and Brunner et al. (2018) found positive effects from carbon labelling and a reduction in carbon emissions in their restaurant-based field experiments. Less clear results were found in Slapø and Karevold (2019), where carbon labelling significantly reduced sales of meat dishes in the short term but not in the long term. These diverse results highlight some of the challenges related to transferring results from lab to field experiments and should be taken into account when considering actual implementation – and future combined lab and field experiments would be valuable to test the external validity of lab experimental results.

4.3. The effect of double nudges (part of RQ1)

Together, the two nudges of changing the default from beef to a plant-based steak and providing carbon footprint information reduced the share of respondents who chose beef by 48 %. Our results therefore suggest that using two nudges simultaneously can create an effect that is substantially larger than the effect obtained by using only one of the nudges. Our results are thereby in line with the study by Faccioli et al. (2022), which found a substantial effect of using carbon footprint information alongside taxes in a double nudge. Our results also complement those of Erhard et al. (2023), who found that changing the default as a single nudge did not affect behaviour but combining this with information about sustainability and taste in a double nudge increased the number of plant-based choices. We therefore suggest that the effect of combining nudges still needs further investigation. The extent to which our results are transferable to online food shops or to food choices in a cafeteria or restaurant in real-life settings would be an interesting topic for future research.

4.4. The effect of the individual and double nudges on the average carbon footprint (RQ2)

We estimated that having a plant-based steak instead of beef as the default meal reduced average carbon footprints from the meals in the sample by 22 %. We also estimated that carbon footprint information induced behavioural changes that led to an average per-meal emission reduction of 14 % in Split Beef and 21 % in Split Plant. Together, the two nudges of changing the default to a plant-based steak and providing carbon footprint information reduced the average emissions per meal by 39 %. These results are similar to the findings of Edenbrandt et al. (2021), who estimated that in a hypothetical setting, a label with carbon footprint information led to a 25 % reduction in emissions from the respondents' choice of mince. These are promising results but may not be directly generalisable to a real-world setting, as other sensory and visual stimuli have been shown to be important drivers of food choice behaviour (Eves et al., 2026; Babakhani et al., 2020).

4.5. Characteristics of consumers who chose beef (part of RQ3)

We identified that around one third of the sampled consumers were not willing to forgo beef when one or both nudges were used. The group of respondents with a strong preference for beef often had low scores for the NAM variables compared to other respondents. Furthermore, the results suggest a negative relationship between the consumption of organic food and eating beef. This is in line with several previous studies in which consumers with a high consumption of organic produce were found to eat less meat than other consumers (Christensen et al., 2020; Denver and Christensen, 2015). In addition, men, residents outside the Capital Region, and people without a higher education were over-represented among respondents with strong preferences for beef. These findings are in line with Hielkema and Lund (2021), who found that within Denmark, men and residents living in the countryside or in a small town were less likely to have the intention to reduce their meat consumption.

To reduce beef consumption within this group of consumers, stronger motivators such as taxes will be needed, as suggested by Thøgersen (2021). Several other studies have examined the effect of carbon taxes and suggest that a carbon tax can be effective in reducing emissions associated with the food sector (e.g. Gren et al. (2021); Gren et al. (2019); Tiboldo et al. (2022); Huang (2022)).

4.6. Characteristics of consumers who reacted to information (part of RQ3)

We found that feeling a moral obligation to reduce one's climate impact (i.e., having a high score for the variable related to personal norm) increased the likelihood of not eating beef but it did not alter the effect of carbon footprint information. Results from Edenbrandt et al. (2021) support our first finding, but their results indicate that individuals with greater feelings of responsibility and personal norms were also more affected by carbon footprint information than individuals with lower levels.

In our study, being sensitive to other people's opinions (i.e., having a high score for the variable related to social norms) increased the likelihood of carbon footprint information inducing one to shift away from beef, but it did not increase the likelihood of having already made the decision to avoid beef, which is currently not a widespread social norm in Denmark. Regarding the effect of awareness, we found that people with a stated awareness of the climate impact of beef production were more inclined to avoid beef or shift away from beef when carbon footprint information was provided. These findings are in line with findings by Wongprawmas et al. (2023) and Andreani et al. (2024) – that the strongest effect of nudges towards more sustainable and healthy food were found among the groups who had already stated an interest in these topics. However, a general concern about climate change, which could also be interpreted as an awareness indicator, did not affect food choice in our study.

The results suggest a positive relationship between the consumption of organic food and an eagerness to shift away from beef after receiving information about its carbon footprint. To our knowledge, this has not previously been investigated. Several studies have, however, found that consumers with a high organic consumption are often more concerned about the environment (Ahmed et al., 2020), animal welfare, and climate impact when they purchase food (Ditlevsen et al., 2020). In relation to this, a qualitative study from Germany found that German participants bought organic products because they wanted to help protect the environment and take responsibility for others (Winterstein et al., 2024). Alongside our results, this suggests that organic consumers

are generally more interested in a climate-friendly diet and that their choices are more likely to be affected by carbon footprint information than non-organic consumers.

4.7. Limitations of the study

In the text below, we suggest some limitations of our study regarding the study design and/or analytical approach. Firstly, we focused our analyses on the prospect of a behavioural shift away from eating beef. This focus was chosen deliberately because beef production has the largest climate impact and therefore the largest reduction in climate impact would be achieved by reducing the amount of beef eaten (and thereby produced), regardless of whether the beef was substituted with chicken, pork, fish, or a vegan meal. We have left it to future studies to address more detailed substitution patterns towards vegetarian or vegan diets, which have the potential for further reductions in climate impact and could involve other motives for dietary choices, e.g., human health and animal welfare issues. Secondly, we investigated preferences for a single meal and therefore do not know whether the identified effect is permanent or only exists temporarily. Thirdly, our results were obtained within a hypothetical setting and may therefore be subject to hypothetical bias, including social desirability bias. Previous studies (Nowak et al., 2024; Nordström et al., 2023; Thunström et al., 2016) have shown that information might be easier to ignore in a real-world setting than in a hypothetical setting, which could lead to an overestimation of the effect of information in hypothetical studies. Default interventions in both field studies and studies using a hypothetical setting offer promising results in terms of using defaults to promote sustainable food choices (e.g. Taufik et al., 2022). It would have been interesting but challenging to collect information about the individuals' preferences in a real-world setting. Fourthly, our results relating to the NAM variables may be sensitive to the specific items we used. To increase robustness of the design, we used NAM variables that have been validated in previous studies. However, we used a single-item variable to measure some constructs, which may affect the internal consistency or reliability of the construct. We suggest that future studies use more than one item to measure the social norm and generally aim for constructs with higher internal consistency and validity than we achieved. Finally, in this study, we focused on non-economic instruments (sometimes called 'soft instruments') affecting behaviour, and we look forward to engaging in future studies of how economic and non-economic incentive schemes can supplement each other to reach groups who are not very eager to change their diets.

In line with findings from the restaurant-based field experiments in Hansen et al. (2019), Gravert and Kurz (2021), and Taufik et al. (2022), we found that including a default dish with a low carbon footprint on the menu was an effective nudge to promote sustainable food choices (at least for some groups of consumers). While our results showed that information about the food's climate footprint effectively reduced the consumption of beef, the literature on the effects of this type of information in isolation in field experiments are mixed. We suggest future field experiments where two nudges – default options and information provision – are tested and evaluated, just as we advocate for studies involving both field and lab experiments.

5. Conclusion

We highlight four main conclusions. Firstly, serving a plant-based steak as the default option instead of beef, alongside placing the plant-based steak at the top of the choice list resulted in substantially fewer respondents choosing beef for their meal. Moreover, when beef was the default option and at the top of the choice list, we found that carbon footprint information induced respondents to substitute the beef with chicken, fish, or pork. When a plant-based steak was served as the default option, the carbon footprint information led to a more diverse consumption towards not only chicken, fish, or pork, but also plant-based steaks. Therefore, depending on the purpose of providing carbon footprint information, the default choice might also be considered a promising tool for changing behaviour.

Secondly, information about carbon footprints reduced the share of respondents who chose beef regardless of whether beef or a plant-based steak was presented as the default. Thirdly, the carbon footprint associated with the protein source in a dish decreased by 39 % in the hypothetical setting when the double nudge of changing the default option and providing carbon footprint information was used. Fourthly, we found that one third of the sampled consumers had a strong preference for beef and would need a considerable nudge to choose an alternative. Therefore, if the political goal is to change the behaviour of the most beef-loving among the population, then the suggested nudges are not sufficient. Instead, our results indicate that a policy aimed at a general increase in awareness about a food's climate impact and highlighting the importance of each person's contribution by reducing their carbon footprint might be effective. Furthermore, even stronger policy tools, such as providing economic motivation schemes like taxes or nudges involving more effort to choose beef might be needed to induce behavioural changes for the most beef-loving among the population. Identifying effective tools for the group that are currently the most reluctant to reduce their beef consumption is an important topic for future research.

CRediT authorship contribution statement

Sigrid Denver: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Jonas Nordström:** Writing – review & editing, Visualization, Validation, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Tove Christensen:** Writing – review & editing, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The reference group who advised on the project from which this paper originates had representatives from a Danish retailer, the dairy industry, a public authority, and a Danish agricultural association. However, the members of the group had no say in the final research plans or the subsequent analyses undertaken and presented in the paper. The authors collaborate with employees from the Danish food industry in separate projects with no links to the project here reported. The authors declare no other conflicts of interest. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2026.147617.

Data availability

The authors do not have permission to share data.

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