Cleaner and Responsible Consumption 12 (2024) 100164

Contents lists available at ScienceDirect

Cleaner and Responsible Consumption

journal homepage: www.journals.elsevier.com/cleaner-and-responsible-consumption

The impact of voluntary sustainability adjustments on greenhouse gas emissions from food consumption – The case of Denmark

Jonas Nordström [a,b,c,d,*], Sigrid Denver [a]

[a] Department of Food and Resource Economics, University of Copenhagen, Frederiksberg, Denmark
[b] School of Economics and Management, Agrifood Economics Centre, Lund University, Lund, Sweden
[c] Department of Economics, Swedish University of Agricultural Sciences, Lund, Sweden
[d] Department of Business, Economics and Law, Dalarna University, Falun, Sweden

ARTICLE INFO

Keywords:
Carbon footprint
Greenhouse gas emissions
Food consumption
Consumer behavior
Sustainability actions
Spillover effects

ABSTRACT

In this study we ask how a range of environmental sustainability adjustments that consumers find it easy to adopt affect the carbon footprint of their food consumption. The study is based on information about real purchases of food products and responses to a questionnaire about the various sustainability adjustments that the study participants apply and their concern about climate change. Based on principal component and regression analysis the results from the study indicate that sustainability adjustments such as organic consumption, buying domestically produced food and eating seasonal produce, as well as concern about climate change, are associated with a reduced carbon footprint from food consumption. The largest reductions were found for organic consumers. The results suggested that most committed organic consumers have a carbon footprint that is about one third smaller than that of consumers who seldom buy organic food products. The results also indicate that these voluntary sustainability adjustments are not sufficient to secure conformity with today's goals for reduced greenhouse gas emissions.

1. Introduction

Annual global emissions of greenhouse gases have increased substantially over the last few decades and need to be reduced (IPCC, 2021). The world's food system is a significant contributor to anthropogenic climate change (Godfray et al., 2018; Poore and Nemecek, 2018) and accounts for about 25–30% of total greenhouse gas emissions (Mbow and Rosenzweig, 2019). To reduce the climate impact of the food sector and bring it into line with food-related Sustainability Development Goals and greenhouse gas emissions commitments under the Paris Agreement a shift in our current consumption patterns is vital (Willet et al., 2019; Prag and Henriksen, 2020).

The carbon footprint of food can be reduced by various policy tools involving soft regulation (e.g. information or nudging) or hard regulation (e.g. taxes). For a discussion about regulation of food consumption see Bonnet et al. (2020). Voluntary sustainability adjustments undertaken by the consumer will also be important, however, if the footprint is to be reduced. In this study we explore a range of behavioral adjustments, or habits, or strategies that the consumers can adopt in an effort to limit their own greenhouse gas emissions. We call these "sustainability adjustments" and ask how these adjustments affect the household's carbon footprint from food consumption. Previous studies suggest that there may be behavioral spillover within and across various domains, including the environment, health and pro-social behavior (Bech-Larsen and Kazbare, 2014; Margetts and Kashima, 2017; Lanzini and Thøgersen, 2014; Sintov et al., 2019). These spillover effects can be both positive (Sintov et al., 2019; Margetts and Kashima, 2017) and negative (Maki et al., 2019) and thus reduce or increase the carbon footprint left by food consumption. Results from previous studies are also mixed about the strength of the effect of consumer adjustments (Maki et al., 2019; Nash et al., 2017), with both significant and non-significant results. Lanzini and Thøgersen (2014) found, for example, a positive spillover from green purchase behavior to other pro-environmental behaviors, but mainly for "low-cost" behavior. The sustainability adjustments that are explored in this study can have a direct effect on the greenhouse gas emissions from food consumptions (such as eat according to season) or a spillover effect (e.g. uses own shopping bags when shopping).

In addition, we will examine how the individual's concerns about climate change and/or concerns about the impact of food production on

* Corresponding author. School of Economics and Management, Agrifood Economics Centre, Lund University, Box 7080, SE-220 07, Lund, Sweden.
E-mail address: Jonas.Nordstrom@agrifood.lu.se (J. Nordström).

https://doi.org/10.1016/j.clrc.2023.100164
Received 1 July 2023; Received in revised form 9 December 2023; Accepted 14 December 2023
Available online 20 December 2023

climate, affects household consumption and ultimately the carbon footprint of food consumption. Problem awareness or concerns about climate change can be seen as the first step in the norm activation model (NAM) developed by Schwartz (1977), where pro-social behavior (e.g. behavior aimed at securing sustainable consumption) is the final step.

Based on a survey from 2019 including 1500 respondents Vesterbæk et al. (2019) found that Danish consumers are concerned about sustainability and are willing to change their behavior for the sake of the climate, the environment and sustainability. In particularly, two third of the respondents think about sustainability to "some" or "a high" degree when shopping for food. Moreover, 95% have either changed their behavior or are willing to change their behavior for reasons of climate, environment or sustainability. Among these, 40% are definitely willing to change their behavior, while 45% to some extent are willing to change behavior. Previous studies also show that there is a substantial climate mitigation potential from changing food consumption (Carlsson-Kanyama, 1998). Girod et al. (2014) investigated the potential related to food, shelter, mobility as well as to goods and services. With respect to food, the authors identified three consumption options associated with low emissions: increase intake of plant-based foods, avoid vegetables that are transported by air or come from heated greenhouses and avoid meat from ruminants. Potential barriers include complexities such as difficulties in identifying whether vegetables are transported by plane or grown in heated greenhouses.

To assess the sustainability adjustments that Danish consumers undertake, and to assess the impact these adjustments have on the carbon footprint of food consumption we carry out an analysis based on food purchases recorded by a panel of Danish households and their responses to a questionnaire. The questionnaire (developed by the market research institute GfK ConsumerTracking Scandinavia) contained questions about the food related sustainability adjustments: buying domestically and locally produced food, buying food and drink with minimal/no packing, buying discount food close to the expiration date, buying organic food, eating according to season, and other behavioral sustainability adjustments such as avoiding food waste in the household and the use of shopping lists and own shopping bags. Based on this information we put forward our first exploratory research question related to the questionnaire data.

RQ1. To what extend are consumers' climate concerns and various behavioral sustainability adjustments related?

To address our second research question, the questionnaire data were combined with observed food purchase data. For each purchased item, the food purchase data were matched with information on greenhouse gas emissions, as measured in CO_2 equivalents (CO_2e) based on lifecycle analysis. Our second research question is:

RQ2. Which impact do climate concerns and different sustainability adjustments have on the carbon footprint of food consumption?

The rest of the paper is organized as follows. In the next section we carry out a literature review with focus on studies that have studied sustainability adjustments or have used the same sustainability adjustment variables as we include in this study. The data and the statistical methods used to investigate the two research questions are described in Section 3 and 4, respectively, while results of the analysis are presented in Section 5. Our findings are discussed in Section 6 and concluded upon in Section 7.

2. Previous studies

Dubois et al. (2019) studied the effect of reducing emissions associated with private consumption in four European mid-sized cities in France, Germany, Norway and Sweden. In contrast to our study, which is based on revealed preference data, they used a forward-looking approach, where they asked 308 households about their adaptation and behavioral change to reduce their carbon footprint with 50% by 2030. Carbon emissions from the consumption categories food and recycling, transport, housing and "other" were studied. For these households the largest voluntary behavioral adjustment was found for food and recycling followed by housing. To reduce their carbon footprint, around two-thirds of the consumers were willing to buy products with less or greener packaging and 45% would increase their consumption of locally produced food by 30%. With respect to consumption of organic food, the results revealed that 40% and 15% of the consumers were willing to increase their organic consumption by 30% and 60%, respectively. In a survey of Danish consumers concerning food Vesterbæk et al. (2019) found that the five sustainability adjustments consumers find easiest to implement in their daily life are: eating more fruit/vegetables, using fewer plastic bags, eating seasonal produce, buying domestically produced food and reducing food waste. Another sustainability adjustment often linked with a more sustainable lifestyle is organic consumption. Azzurra et al. (2019) found, for example, that Italian consumers with high levels of organic consumption express a higher level of sustainability concern in their general food choices and have a more sustainable lifestyle. Choosing the organic option when buying food is ranked as eighth by Vesterbæk et al. (2019) when it comes to easily adopted sustainability adjustments that can be carried out in everyday life.

Baudry (2019) studied French consumers and their sustainability features in relation to varying levels of organic food consumption. Their results indicated that higher organic food consumption is associated with higher consumption of plant-based food, lower consumption of meat, and overall better nutritional quality (higher dietary scores). Baudry (2019) also found that diet-related greenhouse gas emissions gradually decreased with increasing organic food consumption. Also using French data, Seconda et al. (2017) looked at adherence to nutritional recommendations and Mediterranean diets in organic and conventional consumers. For a definition of the Mediterranean diet, see Sofi et al. (2014) and Seconda et al. (2017). Two proxy variables were used to measure the environmental footprint of food intake: animal and plant protein consumption and origin of the animal proteins consumed. The study concluded that adherence to nutritional recommendations was higher among the organic-Mediterranean and conventional-Mediterranean consumer groups. On the other hand, individuals in the conventional-no Mediterranean group exhibited the highest animal protein intakes, and these were associated with high environmental impacts.

For Belgian consumers, de Bauw et al. (2022) found that more than half of the respondents stated that they buy local/organic food to protect the environment. Buying organic and locally produced food is also seen as good strategies to reduce greenhouse gas emissions by UK consumers. Kause et al. (2019) studied the rules UK consumers used to reduce greenhouse gas emissions of produce, dairy, and protein-rich products. For these three food categories the most frequently used rule was to buy locally produced products. Buying organic products was also among the three most frequently used rules. Specifically for produce "Reduced packing" was the third most frequently used rule and for dairy and protein-rich food the second most frequently applied rule was to buy less processed food.

Guiné et al. (2021) have recently examined behavior and motivations influencing individual food consumption towards sustainability in 13 countries, including countries in Europe, South and North America. Their results suggested that consumers favor fresh, local, seasonal foods and foods packed in sustainable ways. The consumer's motivation for choosing fresh, local, seasonal foods is that this allows transportation and storage (e.g. in refrigerators) to be reduced, thereby cutting energy use. Onozaka et al. (2023) used a quantitative survey to investigate the preferences for salmon among consumers in the US, France and Japan. In all countries, the authors identified a considerable share of the consumers that prefers domestic salmon, partly because it is considered more sustainable. Using a food frequency questionnaire Lacour et al. (2018) examined the relationship between the overall structure of a daily diet (measured using a pro-vegetarian score which identified preferences for plant-based products as opposed to animal-based products) and diet-related environmental impacts. Greenhouse gas emissions, cumulative energy demand and land occupation were used to assess diet-related environmental impacts. The results of this study indicated that a higher pro-vegetarian score was associated with lower environmental impacts. Organic food consumption was also an important modulator of the relationship between pro-vegetarian dietary patterns and environmental impacts, but only among participants with diets rich in plant-based products.

In their systematic review article Elhoushy and Lanzini (2021) found that both organic food consumption and food waste are indicators that researchers commonly use to study sustainable consumer behavior. However, the studies included in their review do not assess the impacts of organic food consumption and food waste behavior on the carbon food footprint of food consumption. More than half (54%) of the respondents in a UK survey reported that they tried to avoid or minimizing food waste (Statistics UK, 2021). About one fourth reported to do so to limit the effects of climate change. The results revealed that it was more common that younger individuals tried to reduce food waste to limit the effects of climate change. Begho and Fadare (2023) also found that the most common motivation for reducing food waste among UK consumers was environmental considerations. In addition, results in Filipová et al. (2017) for the Czech Republic and in Liu et al. (2023) for Shanghai, China, suggested that individuals with a higher income and education had more food waste that other individuals.

For the 13 countries included in the study by Guiné et al. (2021), the results indicated that while individuals avoid food waste at home, consciousness of food waste at restaurants needs to be improved. The study also revealed that there is a considerable heterogeneity among groups of consumers concerning their food choice motivations and behavior.

Concerning the use of shopping lists Gajdzik et al. (2023) found that half of Polish e-consumers, defined as consumers 'seeking the highest quality products', 'intending to save money during shopping', or 'dedicating the least amount of time to shopping', stick to shopping lists. On the other hand, the more impulsive consumers frequently tend to shop in store without any preceding planning. Table 1 highlight the factors that have been examined by the different authors.

3. Data

To carry out the analysis, the actual food purchasing behaviour of Danish consumers was tracked through purchase data for the year 2020. The data were obtained from the market research institute GfK ConsumerTracking Scandinavia. Daily registrations of food purchases were made by a panel including more than 2000 Danish households. More information about the panel is provided in Smed (2008). For each purchased item, the data indicated product type, price, quantity, whether or not the product was organic, and carbon footprint as measured in CO_2e. Information about the CO_2e was obtained from the Danish LCA-Food database (Saxe, 2014) and the Ecoinvent database version 2.2 (Hischier et al., 2010) using Simapro 7.3 software. Where the LCA-Food and Ecoinvent databases did not furnish the information, supplementary data that best fit Danish production conditions were taken from the literature (see Saxe (2014); Saxe et al. (2018); Saxe (2019); Weidema et al. (2005)). All environmental impacts were calculated according to the ISO standard 14040 (2006). Differences in environmental impacts between conventionally and organically produced food were taken from two databases: Williams et al. (2006) and Saxe (2014). Land use, for example, is included in calculations of CO_2e.

In principle, the data covered all food purchases made for the household in grocery stores and specialist stores. According to Denver et al. (2017) the data set covered around 50–60% of the total household food budget; missing reports, restaurant meals, and lunches in canteens and the like were estimated to account for the remaining share of the food budget. However, more detailed information on this was not available in the dataset. In the autumn of 2019, detailed background information on socio-demographic characteristics and a range of attitudinal and behavioural variables were collected by the market research institute for all panel members.

Drawing on the results in Vesterbæk et al. (2019), a selection of questions about sustainability adjustments that may be taken by consumers in connection with their grocery purchases were used. However, sustainability was not mentioned in the wording of the questions which took the form: "How often do you do the following?: use own shopping bags when shopping; avoid food waste in the household; buy Danish-produced food and beverages; eat according to season (food and drink that is in season/seasonal); buy locally produced food and beverages; and buy food and drink with minimal/no packing". The last two actions were ranked relatively low as regards their applicability in everyday life, but they are actions that was believed to have a large impact on the carbon footprint. In addition, a pair of questions about the use of a shopping list when grocery shopping and buying food and drinks that are discounted because they are close the expiration date were put. These two questions were not included in Vesterbæk et al. (2019). For each question the individual was asked to mark how often the action was carried out on a five-point Likert scale, with the response categories: 1 = never, 2 = rarely, 3 = occasionally, 4 = often, 5 = always. The exception was for the question about the use of shopping list, where the response categories were from 1 = totally disagree to 6 = totally agree.

As a measure of concern about climate change we used two variables based on the following questions about how the respondents perceived climate issues: "Some will argue that the world faces the challenges below over the next 10–15 years. Are you concerned about?: climate change/global warming; the impact of food production on the climate". For both questions it was possible to answer Yes or No.

To ensure that households with very low reporting rates did not skew the results, households were only included in the analysis if they reported purchases of at least DKK 2000 (€268) per year and had provided the background information about householders' perceptions and household characteristics. Following the application of these criteria, the analyses were based on findings from 1785 households and included 30 food product groups (Table A5 in the Appendix shows the product groups).

In comparison with the general population in Denmark our sample had fewer respondents from the capital region and fewer with an age below 40 years; individuals aged 65 years or more were overrepresented (see Table 2).

Table 1
Studies that have used the sustainability adjustment variables.

Variable	Source
Organic consumption	Seconda et al. (2017); Lacour et al. (2018); Azzurra et al. (2019); Baudry (2019); Dubois et al. (2019); Kause et al. (2019); Vesterbæk et al. (2019); Elhoushy and Lanzini (2021); de Bauw et al. (2022)
Avoids food waste in the household	Filipová et al. (2017); Vesterbæk et al. (2019); Elhoushy and Lanzini (2021); Guiné et al. (2021); Statistics UK (2021); Begho and Fadare (2023); Liu et al. (2023)
Always make a shopping list when grocery shopping	Vesterbæk et al. (2019); Gajdzik et al. (2023)
Eats according to the season (food and drink that is in season/seasonal)	Vesterbæk et al. (2019); Guiné et al. (2021)
Buys food and drink with minimal/no packaging	Dubois et al. (2019); Kause et al. (2019); Guiné et al. (2021)
Buys domestically produced food and beverages	Vesterbæk et al. (2019); Onozaka et al. (2023)
Buys locally produced food and beverages	Dubois et al. (2019); Kause et al. (2019); Vesterbæk et al. (2019); Guiné et al. (2021); de Bauw et al. (2022)

Table 2
Description of variables used in the principal component analysis.

Variable	Mean
Concerned about climate change/impact of food production[a]	1.9
Sustainability adjustments, observed purchase data	
Organic consumption (budget share)	13.3
Sustainability adjustments, stated data	
Uses own shopping bags when shopping [b]	4.6
Avoids food waste in the household [b]	4.3
Buys domestically produced (Danish) food [b]	3.8
Eat according to season (food and drink that is in season/seasonal) [b]	3.7
Often buys food and drinks that are discounted because they are close to their expiration date [b]	3.3
Buys locally produced food and beverages [b]	3.1
Buys food and drink with minimal/no packaging [b]	2.9
Always make a shopping list when grocery shopping [c]	4.6

Note: [a] Response categories: 1 = not concerned (concerned about neither climate change/global warming nor the impact of food production on the climate), 2 = moderately concerned (concerned about climate change/global warming or the impact of food production on the climate), 3 = highly concerned (concerned about climate change/global warming and about the impact of food production on the climate). [b] Response categories: 1 = never, 2 = rarely, 3 = occasionally, 4 = often, 5 = always. [c] Response categories: Likert scale from 1 = totally disagree to 6 = totally agree.

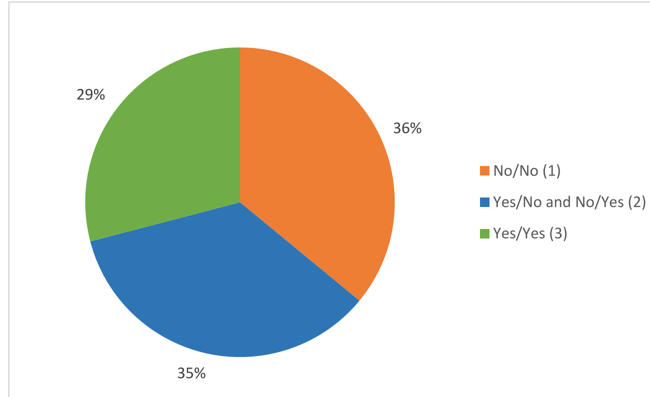

Fig. 1. Percentage of individuals in three groups based on concern. *Note*: No/No [Yes/Yes] refers to respondents that answered No [Yes] to both questions about "Concerned about climate change/impact of food production". Yes/No and No/Yes refers to respondents that answered Yes to one of the questions and No to the other. 1 = not concerned (concerned about neither climate change/global warming nor the impact of food production on the climate), 2 = moderately concerned (concerned about climate change/global warming or the impact of food production on the climate), 3 = highly concerned (concerned about climate change/global warming and about the impact of food production on the climate).

4. Method

To address RQ1 and investigate how climate concerns and sustainability adjustments are related, we applied a principal component analysis. Thereby, we identified variables with strong co-variation that could be grouped into meaningful orthogonal components. More specifically, the analysis includes variables relating to climate concerns, a sustainability adjustment based on observed purchase data (organic consumption) and a number of sustainability adjustments based on stated data. See Table 2 for an overview of variables included in the principal component analysis.

With respect to concern about climate change/global warming and concern about the impact of food production on the climate, we found that a larger fraction of the respondents were concerned about climate change/global warming (58.8%) than were concerned about the impact of food production on the climate (34.3%). More than a third (36%) of the respondents were concerned about neither climate change/global warming nor the impact of food production on the climate, while 29% were concerned about both factors. The two variables related to concern were added together to reduce the number of variables containing information about respondents' concerns. Specifically, we added the two dichotomous variables, each of which was coded as 0 if the answer was No, and 1 if the answer was Yes. To this sum we then added 1 to obtain a variable in the range 1–3. For different degrees of concern, we divided the consumers into the three groups: 1 = not concerned, 2 = moderately concerned and 3 = highly concerned. Fig. 1 shows the new composed variable which we refer to as "Concerned about climate change/impact of food production". The mean value for the composed variable is 1.9 (see Table 2).

To measure the degree of the respondent's organic consumption we used the share of the total food budget that they spent on organic food varieties. This is in line with earlier studies of Danish purchase data from GfK ConsumerTracking Scandinavia (see e.g. Denver et al., 2012 & 2015; Wier et al., 2008). The calculations of the organic budget shares were based on 27 food product groups for which information about organic status is available. Around 5% of all purchases did not include information about the organic or conventional production of the food product. These purchases were excluded in estimations of organic budget shares.

In Table 2, we present descriptive statistics for the variables that were used in the principal component analysis. Table A1 in the Appendix shows the correlation matrix for the variables. As can be seen from Table 2, the most common sustainability adjustments are use of own shopping bags when shopping, avoidance of food waste and always make a shopping list when grocery shopping. Many consumers also buy Danish-produced food and beverages and eat seasonal produce. The least common adjustment is buying food and drink with minimal/no packing, followed by buying locally produced food and beverages and buying food and drinks that are discounted because they are close to their expiration date.

In the principal component analysis the factor loadings have been estimated by applying orthogonal rotation and can be interpreted as correlations with values between −1 and +1. We followed the rule of thumb that factor loadings with an absolute value larger than 0.4 are salient (SAS Institute Inc, 2018).

To compare differences between consumers with different levels of organic consumption, four organic user groups were defined. Guided by Denver et al. (2019), we defined the groups in terms of organic budget shares as follows. Consumers with an organic budget share lower than 2.5% were categorized as light users, those with shares of 2.5–10% were categorized as medium users, and those with shares of 10–20% and 20% or more were categorized as heavy and super users, respectively. In total, 17% of the consumers belonged to the group of light users, 41% were medium users, 21% were heavy users while 21% were super users.

To address RQ2, we will use the consumers' scores on the principal components together with other explanatory variables (such as household characteristics) in a regression analysis to analyze their impact on the carbon footprint.

Since the household's registration frequency in the consumption panel is likely to affect its aggregate carbon footprint, we used two normalized carbon footprint variables in the analysis that do not depend on the registration frequency. The first was 'CO_2e per food product purchased' and the second was 'CO_2e per DKK 10 spent' (exchange rate in 2020: € 1 ~ DKK 7.45). We added an analysis based on the household's aggregate carbon footprint (total emissions in terms of CO_2e). We used these three variables as dependent variables in three models to obtain more robust and general results.

To account for possible non-linearities and economics of scale in households with more than one adult and for the number of children at various ages, we added a set of dummy variables as control variables in the regression model. In the regression analysis we also controlled for the total value of purchases and the number of purchases to assess whether differences in the amount reported and number of purchases reported could have affected the carbon footprint of a household. Note that low numbers can be an indicator of under-reporting but can also reflect systematic differences in consumption patterns. Descriptive statistics for these variables are presented in Table 3.

To increase the robustness of our results, we did a sensitivity analysis where we reduce the emissions associated with fresh beef by 50%. We choose to focus on beef in the sensitivity analysis as a substantial share of the carbon footprint related to food consumption comes from beef.

To obtain an indication of the impact on the reduction of CO_2 emissions from using the sustainability adjustments with the largest factor loadings and largest parameter estimates, we carried out a follow-up analysis. As shown in the result sections, we compared: the mean CO_2 emissions of the different organic user groups, consumers with different degrees of concerns, and consumers who buy domestically produced food and eat according to the season to varying degrees.

5. Results

In this section we present the results of the principal component analysis that answer our first research questions and the regression models with the carbon footprint as the dependent variable that answer our second research question.

An initial evaluation of the data identified four principal components with eigenvalues larger than 1. Table A2 in the Appendix shows the estimated principal components and the associated factor loadings. In Fig. 2, we present the estimated principal components and the associated factor loadings with an absolute value larger than 0.4.

The numbers on the arrows represent the size of the factor loadings. To reduce the number of digits in the figure the factor loadings have been multiplied by 10. The value of 79, on the top arrow in the figure, thus correspond to a factor loading with a value/correlation of 0.79.

The principal component analysis shows interesting correlations between consumers' sustainability adjustments. The first component (PC1) revealed a correlation between four adjustments that we identify as choices that can be made in the supermarket: to buy domestically produced food and beverages, local products, seasonal products, and food and drink with minimal/no packaging. The second component (PC2) identifies a correlation between three sustainability adjustments that are more likely to be based on decisions taken at home: avoidance of food waste in the household, use of own shopping bags, and use of a shopping list. The third component (PC3) shows a correlation between organic consumption and concern about climate change/concern about the impact of food production on the climate. Fig. 3 also reveals this pattern: thus 44% of the consumers with an organic budget share above 20% (super users) are much more concerned about both the climate change and the impact of food production on the climate than the 20% of consumers with an organic budget share less than 2.5% (light users). The final component (PC4) reveals a correlation between another set of strategies and sustainability adjustments that can be said to be carried out in the supermarket: buying food close to the expiration date and buying food and drink with minimal/no packing.

Many of the sustainability adjustments, such as the decisions to buy the organic alternative, locally produced foods, food close to expiration date, products with minimal packaging, and items that are expected to involve low levels of food waste at household level, can be carried out in the supermarket as well as being planned at home. Therefore, we interpret the classification of decisions taken at home and in the supermarket as a loose generalization of the results, not literally.

These four principal components were used as explanatory variables, together with the control variables presented in Table 2, to address RQ 2 and study the effects of the various strategies on the household's carbon footprint from food consumption. The reference individual in the regression models is a single adult, aged above 65 years, without children living at home, and with vocational education, who does not live in the capital city.

As can be seen from Table 4, all the models gave similar results. The results are thus robust to the three different definitions of the carbon footprint we used: *CO_2e per food product purchased, CO_2e relative to expenditure (DKK 10 spent)* and *Total CO_2e in the household*. All three models suggest that PC3, a higher degree of organic consumption, concerns about climate change and concerns about the impact of food production on the climate gives the largest reduction in carbon footprint. For reduction in carbon footprint the second largest effect is found for PC1 and the four actions related to purchasing of domestically (Danish) products, local foods, seasonal products, and products with minimal/no packaging. PC4, and the two actions of buying food close to the expiration date and use of a shopping list, is associated with an increase in carbon footprint. PC2, and the three actions of avoiding food waste, using own shopping bags and using a shopping list, is statistically insignificant, and small in all models.

In comparison with households without children, households with children aged 0–6 years have a smaller carbon footprint from food consumption. However, the effect is generally not statistically significant. Households with children aged 7–22 years, on the other hand, have a larger carbon footprint than households without children. This pattern is statistically significant in all models, and also for the models in which the dependent variable is CO_2e per food product purchased and CO_2e per DKK 10 spent, which suggests that households with children older than 6 years have stronger preferences for food with higher CO_2 emissions than households without children.

In addition, the results reveal that younger individuals tend to have a larger carbon footprint from food consumption. Moreover, emissions were higher for respondents with vocational training than they were for individuals with a university education (Bachelor's degree) at a 5% significance level.

Finally, CO_2 emissions per food product purchased were positively correlated with the total amount spent on food and negatively correlated with the number of products purchased. The reverse pattern was found for CO_2e relative to expenditure on food. As can be seen from Table 4, the explanatory power, in terms of adjusted R^2, is good for cross sections data and is highest for the model with total CO_2e as the dependent variable, followed by the model with CO_2e per food product purchased as the dependent variable.

In additional analysis, we compared the mean CO_2 emissions of the

Table 3
Descriptive statistics household characteristics.

Variable	Description of panel
Household with one adult	40.6%
Household with two adults	55.2%
Household with three or more adults (age >20)	4.0%
One child 0–6 years	4.1%
Two or more children 0–6 years	1.2%
One child 7–14 years	5.6%
Two or more children 7–14 years	3.8%
One child 15–20 years	7.5%
Two or more children 15–20 year	2.5%
Age <40 years	11.2%
40 ≤ age <65	48.2%
Age ≥65	40.6%
Living in the capital region (Copenhagen)	21.2%
Primary school	17.7%
High school (or up to A level)	22.1%
Vocational education	27.9%
University education, Bachelor's degree or more	32.2%
Total value of purchases in 2020, mean in DKK	13,423 (std. dev: 8240)
Mean number of purchases reported	609 (std. dev: 334)
Number of observations (households)	1785

Note: In the general population at the end of 2020, 31.8% live in the capital region/province. For individuals above 17 years, 34.4% were below 40 years, 40.6% were in the age interval 40–64 years and 25% were 65 years or older (Statistic Denmark www.dst.dk/en/Statistik/emner/borgere/befolkning).

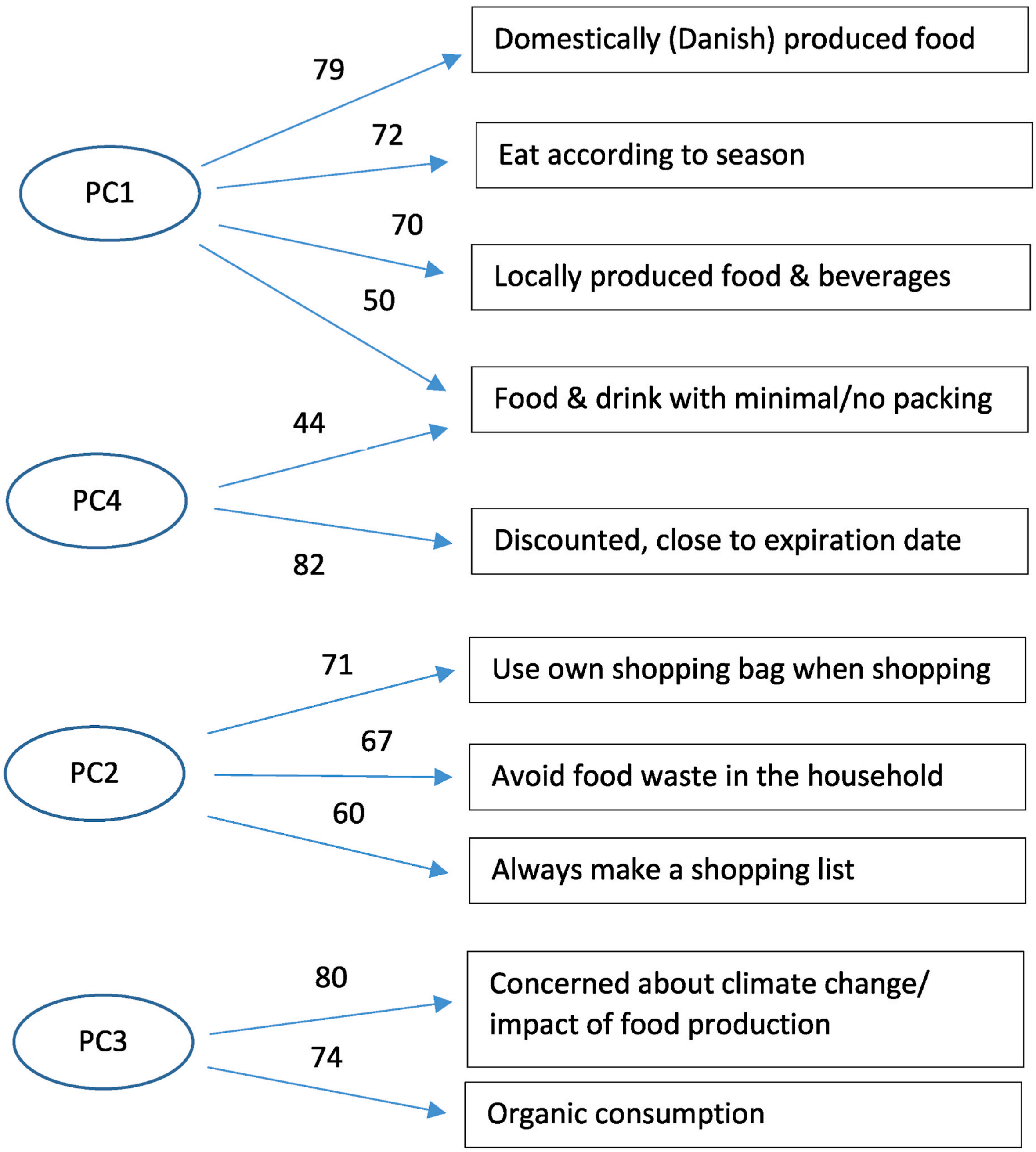

Fig. 2. Estimated principal components and factor loadings with an absolute value larger than 0.4. *Note*: The factor loadings have been multiplied by 100. A value/correlation of 0.4 thus correspond to the value 40 in the figure. The estimations were carried out in SAS 9.4.

different organic users groups, consumers with different degrees of concerns as well as for consumers who buy domestically produced food and eat according to the season to varying degrees, see Table 5. For the two strategies of buying domestically produced food and eating according to season we divided the consumers into two groups. Those in one group had marked the three lowest alternatives on the Likert scale (never to occasionally) and those in the other had marked the two highest answers on the Likert scale (often to always).

Our calculations, shown in Table 5, indicated that the food-related carbon footprint of organic super users is about 33–39% smaller than that of light users. For heavy users, the CO_2 emissions are 15–28% lower than that of light users for the normalized measures of carbon footprint, CO_2e per food product purchased and CO_2e per DKK 10 spent. For medium users, the contrast with light users was 0–16%. Wilcoxon's scores test revealed that these differences are significant at a 1% level. It also showed that the differences in CO_2 emissions between medium and super users, heavy and super users, and heavy and medium users, are all statistically significant at a 1% significance level.

For concern about climate change, we found smaller differences in the CO_2 emissions of the different consumer groups than those seen between the organic user groups. The results suggest that the carbon food footprint for highly concerned consumers is about 7–12% smaller than it is for the group of consumers that are concerned neither about climate change nor about the impact of food production on the climate. For the moderately concerned group the CO_2 emissions is about 2–6% lower than it is for the group of consumers that are not concerned.

The reductions in CO_2 emissions are very similar for the sustainability adjustments of buying domestically produced food and eating according to season for the two measures CO_2e per food product purchased and CO_2e per DKK 10 spent. For both sustainability adjustments

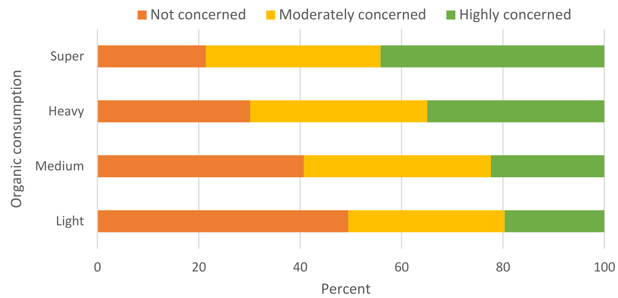

Fig. 3. Share of individuals in three groups based on concern for different organic user groups. *Note*: The four organic user-groups are based on the organic budget share (OBS) defined as follows: light users: OBS<2.5%, medium users: 2.5 ≤ OBS<10%, heavy users: 10% ≤ OBS<20%, super users: OBS≥20%. Not concerned = concerned about neither climate change/global warming nor the impact of food production on the climate; moderately concerned = concerned about climate change/global warming or the impact of food production on the climate; highly concerned = concerned about climate change/global warming and about the impact of food production on the climate.

there is a reduction in the CO_2 emissions of 3–7% for the group of consumers that adopt these adjustments to a higher (always/often) degree than those applying the adjustments to a lower degree (never/rarely/occasionally). Where total CO_2 emissions were concerned, we observed an increase in the emissions for households using these two strategies more frequently, which may be an effect of the larger size of these households.

The results of the sensitivity analysis are shown in the appendix on Tables A3 and A4. Overall, there are only minor differences between the results from the main analysis and from the sensitivity analysis. In contrast to the main analysis, the sensitivity analysis shown on Table A3 suggest that PC2 significantly increased the emissions related to food consumption. This indicated that consumers who were likely to use own shopping bag, reduce food waste and use a shopping list had had a higher carbon food print than other consumers. Table A4 suggest that, despite a smaller reduction in the differences in emissions between the diverse groups, the overall conclusions from the main analysis remain unchanged. The sensitivity analysis thus suggests that our estimations are robust with respect to a reduction of 50% in the carbon emissions linked to beef.

6. Discussion

In this study we have explored how a range of sustainability adjustments connected with food consumption, and consumers' concern about climate change, are related to the household's food-related carbon footprint. In this regard, the principal component analysis suggested that the sustainability adjustments and concern about climate change could be divided into four contrasting groups of highly correlated variables. The first group (PC1) consisted of adjustments which can be seen as food choices the consumer makes in the supermarket (buying domestically produced (Danish) food, buying locally produced food and beverages, buying food and drink with minimal/no packing, and eating seasonal produce). The second group (PC2) consisted of adjustments that can be applied at home, either before or after shopping for groceries, and included: using a shopping list, using own shopping bags, and avoiding food waste in the household. These sustainability adjustments can also be characterized as actions appealing to consumers with a high degree of economic awareness. The third group (PC3) revealed a strong correlation between concern about climate change and organic consumption, which suggests that organic consumption tends to go hand-in-hand with concerns about climate change. The fourth and final group (PC4) consisted of sustainability adjustments that can be seen as adjustments performed in the supermarket – purchasing discounted food close to its expiration date and buying food and drink with minimal/no packing.

As regards the household's carbon footprint, we confirmed that the sustainability adjustments in PC1 and PC3 reduced the household's footprint from food consumption in statistically significant ways. The effect was larger for the compound variables in PC3 (concern about climate change and organic consumption) than it was for the compound adjustments in PC1 (the adjustments related to buying domestically/locally produced food and eating according to season). An analysis of the individual effects of the variables in the different groups of principal components also revealed that increased concern had a relatively large impact on carbon footprint reduction. This was especially so for

Table 4
Results from the regression analysis.

Variable	CO_2 equivalents per food product purchased			CO_2 equivalents per DKK 10 spent			Total CO_2 equivalents		
	Parameter Estimate	s.e.		Parameter Estimate	s.e.		Parameter Estimate	s.e.	
Intercept	3.611	0.112	***	1.651	0.046	***	−117.77	66.67	*
PC1	−0.107	0.035	***	−0.061	0.014	***	−77.81	20.98	***
PC2	0.029	0.035		0.019	0.014		16.20	20.99	
PC3	−0.470	0.036	***	−0.216	0.015	***	−279.45	21.16	***
PC4	0.157	0.035	***	0.072	0.014	***	101.94	20.53	***
Two adults	0.359	0.079	***	0.115	0.032	***	175.21	47.28	***
Three or more adults	0.658	0.186	***	0.217	0.076	***	448.78	110.81	***
One child 0–6 years	−0.028	0.188		−0.117	0.077		−198.44	111.74	*
Two or more children 0–6 years	−0.396	0.329		−0.276	0.134	**	−299.23	195.65	
One child 7–14 years	0.274	0.163	*	0.137	0.066	**	265.81	96.78	***
Two or more children 7–14 years	0.924	0.185	***	0.374	0.075	***	575.24	109.86	***
One child 15–20 years	0.519	0.140	***	0.237	0.057	***	345.19	83.29	***
Two or more child. 15–20 years	0.455	0.224	**	0.234	0.091	**	437.37	133.00	***
Age <40 years	0.262	0.135	*	0.248	0.055	***	187.82	80.14	**
40 ≤ age <65	0.167	0.084	**	0.074	0.034	**	90.47	49.88	*
Capital region/province (Copenhagen)	−0.115	0.086		−0.059	0.035	*	−53.26	51.24	
Primary school	0.037	0.108		0.030	0.044		28.66	64.39	
High School	−0.172	0.097	*	−0.064	0.040		−69.15	57.98	
University Edu. ≥ 3 years	−0.282	0.090	***	−0.090	0.037	**	−122.98	53.75	**
Total value of purchases [a]	0.219	0.009	***	−0.010	0.004	***	140.62	5.59	***
Number of purchases	−0.005	0.000	***	0.0002	0.0001	***	0.71	0.13	***
Adjusted R2	0.347			0.204			0.742		

Note: *** 1% significance level, ** 5% significance level, * 10% significance level. [a] in DKK 1000. N = 1785.

Table 5
Mean CO_2 emissions for different sustainability adjustments.

	CO_2 equivalents per food product purchased	Percentage diff. against high emitting group	CO_2 equivalents per DKK 10 spent	Percentage diff. against high emitting group	Total CO_2 equi-valents	Percentage diff. against first group
Organic user-group						
Light user	4.88		2.08		2671	
Medium user	4.10	−16% ***	1.95	−6% ***	2614	−2%
Heavy user	3.52	−28% ***	1.68	−19% ***	2268	−15% ***
Super user	3.00	−39% ***	1.31	−37% ***	1793	−33% ***
Concerned about climate change						
Not concerned	4.11		1.86		2449	
Moderately concerned	3.87	−6% *	1.80	−3%	2388	−2%
Highly concerned	3.62	−12% ***	1.66	−11% ***	2287	−7% *
Buy domestically produced food						
To a lower degree	3.97		1.87		2234	
To a higher degree	3.85	−3%	1.75	−7% ***	2432	9% ***
Eat according to season						
To a lower degree	3.97		1.86		2278	
To a higher degree	3.84	−3%	1.74	−6% ***	2437	7% ***

Note: The asterisks indicate results from a two-sided Wilcoxon two-sample scores test. *** indicates that the Z value is significant at a 1% level, ** at a 5% significance level and * at a 10% significance level.

individuals who were concerned about both global warming and the impact of food production on climate. This finding is in line with the results in Reichel et al. (2021), who find that respondents 'certainty about the reality of global warming' is an important driver on their willingness to donate to climate mitigation measures. Although the impact of concerns about climate change is important, however, our results suggest that the effect of organic consumption on carbon footprint is even greater, with consumers with the highest organic budget shares (super users) on average having a carbon footprint from food consumption that is about one third smaller than that of consumers who seldom buy organic varieties. However, the strong association between concern about climate change and organic consumption, where a higher level of concern is associated with greater organic consumption, implies that the individual effects should be interpreted with caution.

The difference in the food-related carbon footprints of organic and conventional consumers is the result of at least two effects. The first is differences in the climate impacts of conventionally and organically produced food, such as those connected with the higher levels of land use in organic production. This was accounted for in the CO_2e coefficients used in this study (see Saxe, 2014). To the extent that there is a difference of this kind between the two production practices, this will affect the results, either in a positive or in a negative direction (Saxe, 2014). The second effect relates to differences in the dietary habits of consumers with a low and a high level of organic consumption. Many studies have found that high organic consumption tends to be associated with diets containing more vegetables and less meat than the diets of non-organic consumers (e.g. Christensen et al., 2019; Denver and Christensen, 2015; Denver et al., 2019). Hence, the larger intake of low carbon-emitting foods is also reflected in the results of these studies. The reduced carbon footprint of organic consumption that we identify in the present study will be the resulting effect of differences in emissions from production as well as differences in dietary habits.

No spillover effect on the carbon footprint from food consumption was found for the composite effect of avoiding food waste and using own shopping bags and shopping lists. One might have expected households stating that they avoid food waste to a high degree to have a smaller carbon footprint, but this was not supported by our results. One explanation may be related to our methodology. We estimated carbon footprint per products purchased or per DKK 10 spent. This meant we were unlikely to identify differences in carbon footprint related to purchases of fewer products, and the latter may be commoner in households that avoid waste.

The composite effects for the variables in PC4 resulted in a larger carbon footprint. Thus, people who tend buy food products close to their expiration date also tend to have a larger carbon footprint from food consumption. The tendency to buy discounted items may imply that one ends up buying a product with a bigger carbon footprint than one had actually intended to buy, on entering the food store, due to the discount. This explanation is supported by results in Yildrim and Aydin (2012), which indicate that prepared shopping lists can be altered by supermarket announcements. The positive relation we identified between buying food close to its expiration date and having a large carbon footprint could also be related to the general food consumption patterns of people who choose to take advantage of these offers. The carbon footprint from food waste by supermarkets is not accounted for in the carbon footprint measure that we use. Thus, if the products close to expiration date would have ended up as waste for the supermarket had they not been bought, the action of buying close to expiration may result in an overall lower carbon footprint, as it replaces other food consumption. Since we do not have information about food waste in supermarkets, we cannot evaluate whether this adjustment has the potential to reduce the overall carbon footprint from food consumption. Nevertheless, the result here shows that the supermarket management's knowledge and ability to predict true consumer demand is of importance. Hence, reduced food waste from supermarkets will affect both reductions in carbon emission and profit positively.

The purchasing of multiple discounted products can of course add to the amount of unspent money that is available to buy other products, which may increase the total carbon footprint. However, Waterlander et al. (2012) studied a 25% decrease in the price for fruit and vegetables and found no evidence of increased purchasing of other foods. As regards the effects from choosing food and drinks with low/no packing, the results were mixed. This sustainability adjustment is included in both PC1 and PC4, and as these components point in different directions, the resulting effect of seeking to reduce packing on carbon footprint is uncertain.

In line with the results presented in Nordström et al. (2020), we found a statistically significant increase in the carbon footprint of households with children of seven years or older that was not identified in households with younger children. The results also indicate that individuals with higher education tend to have a lower carbon food footprint. This may be because individuals with higher education tend to have healthier diets containing more fruit and vegetables, and thus an associated smaller carbon footprint (Growth et al., 2001). Nordström et al. (2020) and Lévaly et al. (2021) studied food-related carbon footprints in Sweden and Belgium, respectively, and found that younger individuals have a lower carbon footprint from food consumption. Our results do not confirm this. They are instead in line with the findings presented by Büchs and Schnepf (2013) following their study of total CO_2 emissions from consumption for different categories of household in the UK.

In this study, we have only focused on emissions from food consumption at home. It could be interesting to extend the study to also include food related behavior when traveling or sustainability adjustments in areas other than food. In this regard, Nekmahmud et al. (2022) studied stated green consumption habits on tourist trips among more than 700 European residents. The study found that two out of three respondents preferred to purchase recyclable, reusable, and bioproducts during their travels. In addition, almost half of the respondents bought organic or vegan food, while almost 40% stated that they would like to visit eco-friendly restaurants. Brock et al. (2023) examined preferences for different carbon reduction behaviours including electricity (for lighting or appliances), overseas travel, clothes, waste, heating, water, domestic travel, and diet among almost 400 UK respondents. The results indicated a clear tendency for respondents to prefer making minor changes to behaviour rather than making more extensive personal lifestyle changes involving diet and transport. Hence, many respondents were unwilling to make major changes that could lead to substantial reductions in emissions. Using a slightly different setup, Lindemann-Matthies et al. (2023) investigated whether self-commitment to behavioral adjustments could lead to a decrease in emissions. For one week, 101 participants carried out a self-selected sustainability behavior. Most participants committed themselves to plastic-free shopping or vegan nutrition while few committed themselves to car-free mobility. The authors concluded that the voluntary self-commitment approach was promising. In particular, they found positive spillover effects between different sustainability adjustments and that many participants continued to perform the adjustments after the trial period. The studies by Brock et al. (2023) and Lindemann-Matthies et al. (2023) seemed to agree that it is difficult for people to commit to making more extensive personal lifestyle changes, such as their choice mode of transportation, while the results regarding the interest in changing the diet where mixed.

Our findings suggest that additional policy instruments would be needed to support a further reduction in the carbon footprint associated with food consumption. In this respect our results are in line with Dubois et al. (2019) and Brock et al. (2023). Edenbrandt et al. (2021) show, for example, that carbon labeling may be an efficient policy tool with which to reduce the carbon footprint from food consumption, and the results presented in Dogbe and Gil (2018) indicate that a targeted carbon tax would reduce the consumption of foods with a substantial carbon footprint.

7. Conclusions

We found that sustainability adjustments such as organic consumption, eating seasonal produce and buying domestically produced food, as well as concern about climate change, reduced the household's footprint from food consumption. Although, increased concern had a relatively large impact on carbon footprint reduction, our results suggested that the effect on carbon footprint of having a high organic consumption is even larger.

The results also showed that consumers' stated voluntary sustainability adjustments can be linked to reduced carbon footprint in their observed food consumption. However, the reduction achieved through the adjustments we have investigated would not be large enough to secure conformity with the obligations imposed by the Paris agreement – at least, if that requires a reduction in greenhouse gas emissions from the food sector at the stipulated 70%. Even if an important sustainability adjustment is missing from our study, it is likely that additional policy instruments would be needed to support a further reduction in the carbon footprint associated with food consumption.

Funding

The research reported in this paper was conducted as part of the project SO-FOOD. SO-FOOD is part of the Organic RDD 6 programme, which is coordinated by International Centre for Research in Organic Food Systems (ICROFS). It has received grants from the Green Growth and Development programme (GUDP) under the Danish Ministry of Environment and Food. Project number: 34009-20-1705.

CRediT authorship contribution statement

Jonas Nordström: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Sigrid Denver:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

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

Data availability

The authors do not have permission to share data.

Acknowledgement

The authors are grateful to Tove Christensen and three anonymous reviewers for their insightful comments on an earlier version of this paper.

Appendix

Table A1
Pearson Correlation Coefficients

Pearson Correlation Coefficients, N = 1785
Prob > |r| under H0: Rho = 0

	Organic consumption (budget share)	Concerned about climate change and concerned about the impact of food production on the climate	Use own shopping bag	Avoid food waste in the household	Domestically (Danish) produced food
Organic consumption (budget share)	1.00000	0.24046 <.0001	0.04324 0.0678	0.04299 0.0694	0.10152 <.0001

(continued on next page)

Table A1 (*continued*)

Pearson Correlation Coefficients, N = 1785
Prob > |r| under H0: Rho = 0

	Organic consumption (budget share)	Concerned about climate change and concerned about the impact of food production on the climate	Use own shopping bag	Avoid food waste in the household	Domestically (Danish) produced food
Concerned about climate change and concerned about the impact of food production on the climate	0.24046	1.00000	0.03737	0.05625	0.08506
	<.0001		0.1145	0.0175	0.0003
Use own shopping bag	0.04324	0.03737	1.00000	0.32139	0.11430
	0.0678	0.1145		<.0001	<.0001
Avoid food waste in the household	0.04299	0.05625	0.32139	1.00000	0.27123
	0.0694	0.0175	<.0001		<.0001
Domestically (Danish) produced food	0.10152	0.08506	0.11430	0.27123	1.00000
	<.0001	0.0003	<.0001	<.0001	
Eat according to season	0.12783	0.09362	0.18087	0.35993	0.45263
	<.0001	<.0001	<.0001	<.0001	<.0001
Discounted, close to expiration date	0.04791	0.04801	0.13041	0.27020	0.01759
	0.0430	0.0426	<.0001	<.0001	0.4577
Locally produced food & beverages	0.16588	0.13032	0.07144	0.13360	0.33927
	<.0001	<.0001	0.0025	<.0001	<.0001
Food & drink with minimal/no packing	0.12846	0.17627	0.09147	0.16696	0.17886
	<.0001	<.0001	0.0001	<.0001	<.0001
Use a shopping list	−0.03738	0.03120	0.16243	0.15852	0.08820
	0.1144	0.1877	<.0001	<.0001	0.0002

Pearson Correlation Coefficients, N = 1785
Prob > |r| under H0: Rho = 0

	Eat according to season	Discounted, close to expiration date	Locally produced food & beverages	Food & drink with minimal/no packing	Use a shopping list
Organic consumption (budget share)	0.12783	0.04791	0.16588	0.12846	−0.03738
	<.0001	0.0430	<.0001	<.0001	0.1144
Concerned about climate change and concerned about the impact of food production on the climate	0.09362	0.04801	0.13032	0.17627	0.03120
	<.0001	0.0426	<.0001	<.0001	0.1877
Use own shopping bag	0.18087	0.13041	0.07144	0.09147	0.16243
	<.0001	<.0001	0.0025	0.0001	<.0001
Avoid food waste in the household	0.35993	0.27020	0.13360	0.16696	0.15852
	<.0001	<.0001	<.0001	<.0001	<.0001
Domestically (Danish) produced food	0.45263	0.01759	0.33927	0.17886	0.08820
	<.0001	0.4577	<.0001	<.0001	0.0002
Eat according to season	1.00000	0.17849	0.34228	0.27574	0.10204
		<.0001	<.0001	<.0001	<.0001
Discounted, close to expiration date	0.17849	1.00000	0.20894	0.20420	−0.03720
	<.0001		<.0001	<.0001	0.1161
Locally produced food & beverages	0.34228	0.20894	1.00000	0.44591	−0.03599
	<.0001	<.0001		<.0001	0.1285
Food & drink with minimal/no packing	0.27574	0.20420	0.44591	1.00000	−0.00847
	<.0001	<.0001	<.0001		0.7206
Use a shopping list	0.10204	−0.03720	−0.03599	−0.00847	1.00000
	<.0001	0.1161	0.1285	0.7206	

Table A2
Variables and factor loadings for the principal components (orthogonal rotated factor loading)

	PC1		PC2		PC3		PC4	
Organic consumption	11		−1		74	*	3	
Concerned about climate change and the impact of food production on the climate	4		7		80	*	1	
Uses own shopping bags when shopping	1		71	*	6		17	
Avoid food waste in the household	29		67	*	−4		26	
Buys (domestically) Danish-produced food and beverages	79	*	16		0		−22	
Eat according to the season (food and drink that is in season/seasonal)	72	*	30		3		6	
Often buys food and drinks that are discounted because they are close to the expiration date	4		24		−1		81	*
Buy locally produced food and beverages	70	*	−13		17		32	
Buy food and drink with minimal/no packaging	50	*	−6		24		44	*
Use a shopping list	3		60	*	4		−40	
Variance explained	1.97		1.52		1.28		1.27	

Note: The factor loading in the table are multiplied by 100 and rounded to the nearest integer. Absolute values greater than 0.4 (40 in the table) are marked with an * to indicate salient factor loadings. N = 1785.

Table A3
Results from the regression analysis, sensitivity analysis greenhouse gas emissions from beef is reduced by 50%.

	CO_2 equivalents per food product purchased			CO_2 equivalents per DKK 10 spent			Total CO_2 equivalents		
Variable	Parameter Estimate	s.e.		Parameter Estimate	s.e.		Parameter Estimate	s.e.	
Intercept	3.088	0.075	***	1.410	0.029	***	−4.43	42.64	
PC1	−0.048	0.024	**	−0.033	0.009	***	−42.24	13.42	***
PC2	0.052	0.024	**	0.028	0.009	***	30.84	13.42	**
PC3	−0.331	0.024	***	−0.153	0.009	***	−196.75	13.53	***
PC4	0.111	0.023	***	0.051	0.009	***	71.11	13.13	***
Two adults	0.289	0.053	***	0.097	0.021	***	147.70	30.24	***
Three or more adults	0.488	0.125	***	0.165	0.048	***	309.61	70.87	***
One child 0–6 years	0.065	0.126		−0.052	0.049		−100.30	71.46	
Two or more children 0–6 years	−0.132	0.220		−0.126	0.085		−146.62	125.13	
One child 7–14 years	0.187	0.109	*	0.096	0.042	**	159.69	61.89	**
Two or more children 7–14 years	0.536	0.124	***	0.197	0.048	***	305.80	70.26	***
One child 15–20 years	0.236	0.094	**	0.116	0.036	***	162.21	53.26	***
Two or more child. 15–20 years	0.228	0.150		0.129	0.058	**	267.56	85.06	***
Age <40 years	0.009	0.090		0.099	0.035	***	59.22	51.25	
40 ≤ age <65	0.068	0.056		0.033	0.022		36.57	31.90	
Capital region/province (Copenhagen)	−0.118	0.058	**	−0.052	0.022	**	−53.23	32.77	
Primary school	0.057	0.073		0.034	0.028		21.98	41.18	
High School	−0.115	0.065	*	−0.046	0.025	*	−54.50	37.08	
University Edu. ≥ 3 years	−0.189	0.061	***	−0.057	0.023	**	−84.96	34.38	**
Total value of purchases [a]	0.174	0.006	***	−0.011	0.002	***	111.54	3.58	***
Number of purchases	−0.004	0.000	***	0.000	0.000	***	0.55	0.08	***
Adjusted R2	0.411			0.233			0.813		

Note: n = 1785, *** 1% significance level, ** 5% significance level, * 10% significance level. [a] in DKK 1000.

Table A4
Mean CO_2 emissions for different sustainability adjustments, sensitivity analysis –greenhouse gas emissions from beef is reduced by 50%

	CO_2 equivalents per food product purchased	Percentage diff. against high emitting group	CO_2 equivalents per DKK 10 spent	Percentage diff. against high emitting group	Total CO_2 equi-valents	Percentage diff. against first group
Organic user-group						
Light user	3.94		1.67		2135	
Medium user	3.30	−16% ***	1.57	−6% ***	2094	−2%
Heavy user	2.91	−26% ***	1.38	−17% ***	1862	−13% ***
Super user	2.56	−35% ***	1.13	−33% ***	1520	−29% ***
Concerned						
Not concerned	3.34		1.51		1982	
Moderately concerned	3.15	−6% *	1.47	−3% *	1934	−2%
Highly concerned	2.99	−11% ***	1.37	−10% ***	1874	−5% *
Buy domestically produced food						
To a lower degree	3.18		1.50		1786	
To a higher degree	3.17	−0%	1.44	−4% ***	1985	11% ***
Eat according to season						
To a lower degree	3.18		1.49		1821	
To a higher degree	3.17	−0%	1.43	−4% **	1995	10% ***

Note: The asterisks indicate results from a two-sided Wilcoxon two-sample scores test. *** indicates that the Z value is significant at a 1% level, ** at a 5% significance level and * at a 10% significance level.

Table A5
List of the 30 product groups used in the analysis.

Butter and composite products
Margarine
Chips and Snacks
Eggs
Milk
Cultured dairy
Rye bread
Wheat bread
Coffee
Crispbread
Tea
Sugar, honey, and syrups

(*continued on next page*)

Table A5 (*continued*)

Flour
Cereals
Ice cream
Marmalade
Chicken and poultry
Frozen fruits and vegetables
Sliced cheeses
Pasta
Sliced and spreadable chocolate
Ketchup and Puree
Table wine
Fruits
Vegetables
Edible oils
Cold (meat) cuts
Fish and seafood
Pasta- and rice-dishes
Fruit juices

References

Annunziata, A., Agovino, M., Mariani, A., 2019. Measuring sustainable food consumption: a case study on organic Food. Sustain. Prod. Consum. 17 (2019), 95–107. https://doi.org/10.1016/j.spc.2018.09.007.

Baudry, et al., 2019. Improvement of diet sustainability with increased level of organic food in the diet: findings from the BioNutriNet cohort. Am. J. Clin. Nutr. 109, 1173–1188. https://doi.org/10.1093/ajcn/nqy361.

Bech-Larsen, T., Kazbare, L., 2014. Spillover of diet changes on intentions to approach healthy food and avoid unhealthy food. Health Educ. 114, 367–377. https://doi.org/10.1108/HE-04-2013-0014.

Begho, T., Fadare, O., 2023. Does household food waste prevention and reduction depend on bundled motivation and food management practices? Clean. Respons. Consumpt. 11, 100142 https://doi.org/10.1016/j.clrc.2023.100142.

Bonnet, C., Bouamra-Mechemache, Z., Réquillart, V., Treich, N., 2020. Viewpoint: Regulating Meat Consumption to Improve Health, the Environment and Animal Welfare. https://doi.org/10.1016/j.foodpol.2020.101847.

Brock, A., Williams, I., Kemp, S., 2023. "I'll take the easiest option please." Carbon reduction preferences of the public. J. Clean. Prod. 429, 139398 https://doi.org/10.1016/j.jclepro.2023.139398.

Büchs, M., Schnepf, S.V., 2013. Who emit most? Association between socio-economic factors and UK households' home energy, transport, indirect and total CO2 emissions. Ecol. Econ. 90, 114–123. https://doi.org/10.1016/j.ecolecon.2013.03.007.

Carlsson-Kanyama, A., 1998. Climate change and dietary choices — how can emissions of greenhouse gases from food consumption be reduced? Food Pol. 23, 277–293.

Christensen, T., Denver, S., Olsen, S.B., 2019. Consumer preferences for organic food and for the shares of meat and vegetables in an everyday meal. J. Int. Food & Agribus. Mark. 32 (3), 234–246. https://doi.org/10.1080/08974438.2019.1599758.

de Bauw, M., Franssens, S., Vranken, L., 2022. Trading off environmental attributes in food consumption choices. Food Pol. 112, 102338 https://doi.org/10.1016/j.foodpol.2022.102338.

Denver, S., Christensen, T., 2015. Organic food and health concerns: a dietary approach using observed data. NJAS - Wageningen J. Life Sci. 74–75, 9–15. https://doi.org/10.1016/j.njas.2015.05.001.

Denver, S., Christensen, T., Jensen, J.D., Jensen, K.O., 2012. The stability and instability of organic expenditures in Denmark, Great Britain, and Italy. J. Int. Food Agribu. Mark. 24 (1), 47–65.

Denver, S., Christensen, T., Nordström, J., 2017. Det er lidt dyrere at vaere en økologiskforbruger – men ikke kun på grund af merpriserne. [In Danish]. Tidsskrift for Landøkonomi 203 (1), 47–54.

Denver, S., Nordström, J., Christensen, T., 2019. Is increased organic consumption accompanied by a healthier diet? A comparison of changes in eating habits among Danish consumers. J. Food Prod. Market. 25, 479–499. https://doi.org/10.1080/10454446.2019.1600449.

Dogbe, W., Gil, J., 2018. Effectiveness of a carbon tax to promote a climate-friendly food consumption. Food Pol. 79, 235–246. https://doi.org/10.1016/j.foodpol.2018.08.003.

Dubois, G., Sovacool, B., Aall, C., Nilsson, M., Barbier, C., Herrmann, A., Bruyere, S., Andersson, C., Skold, B., Nadaud, F., Dorner, F., Moberg, K.R., Ceron, J.P., Fischer, H., Amelung, D., Baltruszewicz, M., Fischer, J., Benevise, F., Louis, V.R., Sauerborn, R., 2019. It starts at home? Climate policies targeting household consumption and behavioral decisions are key to low-carbon futures. Energy Res. Social Sci. 52, 144–158. https://doi.org/10.1016/j.erss.2019.02.001.

Edenbrandt, A., Lagerkvist, C.-L., Nordström, J., 2021. Interested, indifferent or active information avoider of carbon labels: cognitive dissonance and ascription of responsibility as motivating factors. Food Pol. 101, 102036 https://doi.org/10.1016/j.foodpol.2021.102036.

Elhoushy, S., Lanzini, P., 2021. Factors affecting sustainable consumer behavior in the mena region: a systematic review. J. Int. Consum. Market. 33 (3), 256–279. https://doi.org/10.1080/08961530.2020.1781735.

Filipová, A., Mokrejšová, V., Šulc, Z., Zeman, J., 2017. Characteristics of food-wasting consumers in the Czech Republic. Int. J. Consum. Stud. 41, 714–722. https://doi.org/10.1111/ijcs.12384.

Gajdzik, B., Jaciow, M., Wolny, R., 2023. Types of E-consumers and their implications for sustainable consumption—a study of the behavior of polish E-consumers in the second decade of the 21st century. Sustainability 15, 12647. https://doi.org/10.3390/su151612647.

Girod, B., van Vuuren, D.P., Hertwich, E.G., 2014. Climate policy through changing consumption choices: options and obstacles for reducing greenhouse gas emissions. Global Environ. Change 25, 5–15. https://doi.org/10.1016/j.gloenvcha.2014.01.004.

Godfray, H.C.J., Aveyard, P., Garnett, T., Hall, J.W., Key, T.J., Lorimer, J., et al., 2018. Meat Consumption, Health, and the Environment. Science, New York, N.Y., p. 361, 6399.

Growth, M.V., Fagt, S., Brøndsted, L., 2001. Social determinants of dietary habits in Denmark. Eur. J. Clin. Nutr. 55, 959–966. https://doi.org/10.1038/sj.ejcn.1601251.

Guiné, R.P.F., Bartkiene, E., Florença, S.G., Djekic, I., Bizjak, M.C., Tarcea, M., Leal, M., Ferreira, V., Rumbak, I., Orfanos, P., et al., 2021. Environmental issues as drivers for food choice: study from a multinational framework. Sustainability 13, 2869. https://doi.org/10.3390/su13052869.

Hischier, R., Weidema, B., Althaus, H.-J., Bauer, C., Doka, G., Dones, R., Frischknecht, R., Hellweg, S., Humbert, S., Jungbluth, N., Köllner, T., Loerincik, Y., Margni, M., Nemecek, T., 2010. Implementation of Life Cycle Impact Assessment Methods. Ecoinvent Report No. 3, v2.2. Swiss Centre for Life Cycle Inventories, Dübendorf.

IPCC, 2021. Climate Change 2021 the Physical Science Basis. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf.

ISO14040, 2006. Environmental Management — Life Cycle Assessment — Principles and Framework. www.iso.org/standard/37456.html.

Kause, A., de Bruin, W.B., Millward-Hopkins, J., Olsson, H., 2019. Environ. Res. Lett. 14, 114005 https://doi.org/10.1088/1748-9326/ab465d.

Lacour, C., Seconda, L., Allès, B., Hercberg, S., Langevin, B., Pointereau, P., Lairon, D., Baudry, J., Kesse-Guyot, E., 2018. Environmental impacts of plant-based diets: how does organic food consumption contribute to environmental sustainability? Front. Nutr. 5, 8. https://doi.org/10.3389/fnut.2018.00008.

Lanzini, P., Thøgersen, J., 2014. Behavioural spillover in the environmental domain: an intervention study. J. Environ. Psychol. 40, 381–390. https://doi.org/10.1016/j.jenvp.2014.09.006.

Lévaly, P.Z., Vanhille, J., Goedemé, T., Verbist, G., 2021. The association between the carbon footprint and the socio-economic characteristics of Belgian households. Ecol. Econ. 186, 107065 https://doi.org/10.1016/j.ecolecon.2021.107065.

Lindemann-Matthies, P., Werdermann, J., Remmele, M., 2023. 'Simply make a change'—individual commitment as a stepping stone for sustainable behaviors. Sustainability 15, 12163. https://doi.org/10.3390/su151612163.

Liu, C., Shang, J., Liu, C., 2023. Exploring household food waste reduction for carbon footprint mitigation: a case study in Shanghai, China. Foods 12, 3211 https://doi.org/10.3390/.

Maki, A., Carrico, R.A., Raimi, T.K., Truelove, H.B., Araujo, B., Yeung, K.L., 2019. Meta-analysis of pro-environmental behavior spillover. Nat. Sustain. 2, 307–315. https://doi.org/10.1038/s41893-019-0263-9.

Margetts, E.A., Kashima, Y., 2017. Spillover between pro-environmental behaviours: the role of resources and perceived similarity. J. Environ. Psychol. 49, 30–42. https://doi.org/10.1016/j.jenvp.2016.07.005.

Mbow, C., Rosenzweig, C., 2019. IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. https://doi.org/10.4337/9781784710644.

Nash, N., Whitmarsh, L., Capstick, S., Hargreaves, T., Poortinga, W., Thomas, G., Sautkina, E., Xenias, D., 2017. Climate-relevant behavioral spillover and the potential contribution of social practice theory. WIREs Clim. Change 8, e481.

Nekmahmud, Md, Ramkissoon, H., Fekete-Farkas, M., 2022. Green purchase and sustainable consumption: a comparative study between European and non-European tourists. Tourism Manag. Perspect. 43, 100980 https://doi.org/10.1016/j.tmp.2022.100980.

Nordström, J., Shogren, J.F., Thunström, L., 2020. Do parents counter-balance the carbon emissions of their children? PLoS One. https://doi.org/10.1371/journal.pone.0231105. April 15.

Onozaka, Y., Honkanen, P., Altintzoglou, T., 2023. Sustainability, perceived quality and country of origin of farmed salmon: impact on consumer choices in the USA, France and Japan. Food Pol. 117, 102452 https://doi.org/10.1016/j.foodpol.2023.102452.

Poore, J., Nemecek, T., 2018. Reducing food's environmental impacts through producers and consumers. Science 360, 987–992. https://doi.org/10.1126/science.aaq0216.

Prag, A.A., Henriksen, C.B., 2020. Transition from animal-based to plant-based food production to reduce greenhouse gas emissions from agriculture—the case of Denmark. Sustainability 2020 (12), 8228. https://doi.org/10.3390/su12198228.

Reichel, J., Cohen, J.J., Klöckner, C.A., Kollman, A., 2021. The drivers of individual climate actions in Europe. Global Environ. Change 71, 102390. https://www.sciencedirect.com/science/article/pii/S0959378021001692.

SAS Institute Inc, 2018. SAS/STAT® 15.1 User's Guide. SAS Institute Inc, Cary, NC.

Saxe, H., 2014. The New Nordic Diet is an effective tool in environmental protection: it reduces the associated socioeconomic cost of diets. Am. J. Clin. Nutr. 99, 1117–1125. https://doi.org/10.3945/ajcn.113.066746.

Saxe, H., 2019. Konsulentrapport til COOP, Scenarier for Madpyramidens klimaaftryk, revisited. In: Danish.

Saxe, H., Hamelin, L., Hinrichsen, T., Wenzel, H., 2018. Production of pig feed under future atmospheric CO2 concentrations: changes in crop content and chemical composition, land use, environmental impact, and socio-economic consequences. Sustainability 10 (9), 3184. https://doi.org/10.3390/su10093184.

Schwartz, S.H., 1977. Normative influences on altruism. In: Berkowitz (Ed.), Advances in Experimental Social Psychology. Academic Press, New York, pp. 221–279.

Seconda, L., Baudry, J., Allès, B., Hamza, O., Boizot-Szantai, C., Soler, L.-G., Galan, P., Hercberg, S., Lairon, D., Kesse-Guyot, E., 2017. Assessment of the sustainability of the mediterranean diet combined with organic food consumption: an individual behaviour approach. Nutrients 9 (1), 61. https://doi.org/10.3390/nu9010061.

Sintov, N., Geislar, S., White, V.L., 2019. Cognitive accessability as a new factor in proenvironmental spillover: results from a field study of household food waste management. Environ. Behav. 51 (1), 50–80. https://doi.org/10.1177/0013916517735638.

Sofi, F., Macchi, C., Abbate, R., Gensini, G.F., Casini, A., 2014. Mediterranean diet and health status: an updated meta-analysis and a proposal for a literature-based adherence score. Publ. Health Nutr. 17, 2769–2782. https://doi.org/10.1017/S1368980013003169.

Statistics, U.K., 2021. A Review of Household Behaviour in Relation to Food Waste, Recycling, Energy Use and Air Travel, 2021. Office of national statistics UK.

Vesterbæk, P., Preus, N., Logo-Koefoed, C., 2019. Analyse Af Danskeres Syn På Klima Og Bæredygdighed. Danish Agriculture & Food Council, Copenhagen, Denmark.

Waterlander, W.E., Steenhuis, I.H., de Boer, M.R., et al., 2012. The effects of a 25% discount on fruits and vegetables: results of a randomized trial in a three-dimensional web-based supermarket. Int. J. Behav. Nutr. Phys. Activ. 9, 11. https://doi.org/10.1186/1479-5868-9-11.

Weidema, B.P., Nielsen, A.M., Christiansen, K., Norris, G., Notten, P., Suh, S., Madsen, J., 2005. 2.-0 LCA Consultants, Prioritisation within the Integrated Product Policy. Danish Ministry of Environment, Environmental Project Nr, p. 980.

Wier, M., Jensen, K. O'D., Andersen, L.M., Millock, K., 2008. The character of demand in mature organic food markets. Great Britain and Denmark Compared. Food Pol. 33 (5), 406–421. https://doi.org/10.1016/j.foodpol.2008.01.002.

Willet, W., et al., 2019. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Lancet Comm. 373 (2), 447–492.

Williams, A.G., Audsley, E., Sandars, D.L., 2006. Final Report to Defra on Project IS0205: Determining the Environmental Burdens and Resource Use in the Production of Agricultural and Horticultural Commodities. Obtainable via. https://webarchive.nationalarchives.gov.uk/ukgwa/20090731144157. http://www.defra.gov.uk/science/, then search for IS0205.

Yildrim, Y., Aydin, O., 2012. Investigation of the effects of discount announcement on consumers' purchase decisions: a case study in a supermarket. Proc. – Soc. Behav. Sci. 62, 1235–1244. https://doi.org/10.1016/j.sbspro.2012.09.212.