Change in Environmental Impact by Substituting Meat for Alternatives in the Danish Diet

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The Danish National Survey of Diet and Physical Activity

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Synopsis

This research assessed the environmental impact of food consumption in Denmark, using data from the Danish National Survey of Diet and Physical Activity 2005-2008. In this population sample of 2025 Danish adults, the average meat consumption was 150.9 grams/day. On days when individuals consumed meat, their diets had higher greenhouse gas emissions (5.8 kg CO_2-eq/day) compared with days without meat consumption (2.7 kg CO_2-eq/day). Similarly, days with meat consumption showed higher levels of land use (7.5 m^2·year/day), compared with days without meat consumption (2.9 m^2·year/day).

If individuals replaced meat by meat substitutes (such as legumes, nuts/seeds, and eggs) in their daily diets, it could potentially lead to a reduction in greenhouse gas emissions of 2.1 kg CO_2-eq/day (by 33.4%) and land use of 2.8 m^2·year/day (by 31.2%). Therefore, lowering meat consumption in Denmark has the potential to reduce the environmental impact of food consumption.

Background

Our current food production and consumption practices have a significant impact on the environment, endangering planetary ecosystems. Globally, food systems contribute to approximately 30% of total greenhouse gas emissions and 40% of the global land use (Willett, 2019). Meat and dairy products are major contributors to this environmental impact (Biesbroek, 2014). There is an urgent need to shift towards a diet with less meat and dairy and more plant-based foods, which may substantially reduce environmental impact and enhance planetary health.

Denmark's newest Official Dietary Guidelines (Danish Veterinary and Food Administration, 2021) provide recommendations on eating not only healthier but also more climate-friendly. They recommended "eating plant-rich, varied, and not too much" and "eating less meat – choose legumes and fish." This research, using data from the Danish National Survey of Diet and Physical Activity (DANSDA) 2005-2008, assessed the greenhouse gas emissions and land use resulting from the daily diets of Danish adults on days they consumed meat or without meat. Additionally, this research calculated the potential reduction in environmental impact if individuals replaced meat with meat substitutes in their diets.

Research Results and Interpretation

Consumption Levels of Meat and Meat Substitutes

In this population sample of Danish adults (18-75 years), a total of 2025 participants recorded detailed information on food consumption on a total of 14119 days. Most participants (n = 2008) had food consumption records on 7 consecutive days, and all participants had at least 4 days of food consumption records. Of all consumption days, the average total meat consumption was 150.9 grams/day, with breakdowns for red meat of 71.9 grams/day (47.6%), processed meat of 34.5 grams/day (22.9%), white meat of 23.0 grams/day (15.2%), and seafood of 21.4 grams/day (14.2%) (**Figure 1a**). The average total meat substitutes consumption was 27.9 grams/day, which consists of legumes of 7.4 grams/day (26.5%), eggs of 17.6 grams/day (63.1%), and nuts/seeds of 2.9 grams/day (10.4%) (**Figure 1b**). This survey did not assess the consumption level of meat analogues. Of the total 14119 days of dietary assessments of 2025 participants, 219 (10.8%) participants had at least one day that they did not consume meat, accounting for 300 (2.1%) days without meat (**Table 1**).

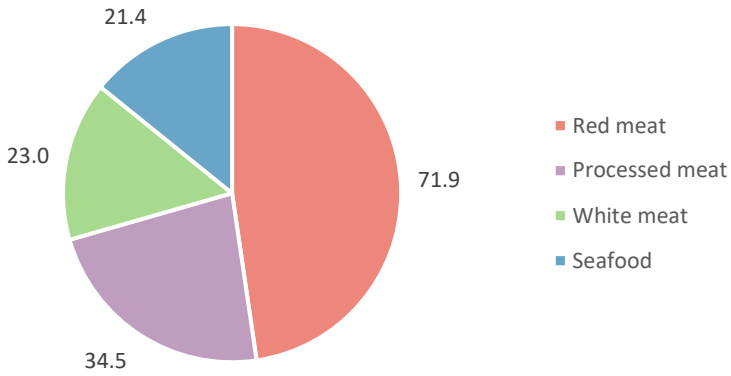
Table 1 – Numbers of participants and days with or without meat consumption

	Participants, n (%)	Days of dietary records, n (%)
Days consumed meat	1806 (89.2%)	13819 (97.9%)
Days without meat	219 (10.8%)[a]	300 (2.1%)
Total	2025	14119

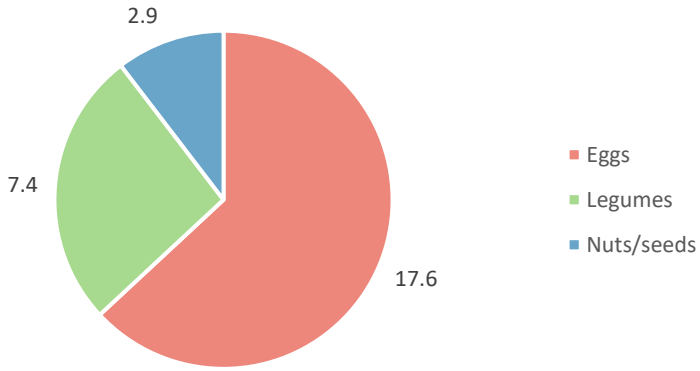
[a] Participants had at least one day that they did not consume meat.

Figure 1 – Average consumption of meat (a) and meat substitutes (b) in grams per day of the study population

(a) Meat consumption



(b) Meat substitutes consumption



Environmental Impact of Daily Diets

Table 2 shows the dietary environmental impact of Danish adults, separated into meat days and meat-free days. A meat day refers to an individual who ate meat and/or fish on a record day; while a meat-free day refers to an individual who did not eat meat and/or fish on a record day. On meat days, greenhouse gas emissions and land use amounted to 5.8 kg CO_2-eq/day and 7.5 m^2·year/day, respectively. On meat-free days, the environmental impact was lower, with greenhouse gas emissions and land use measuring 2.7 kg CO_2-eq/day and 2.9 m^2·year/day, respectively.

Given the difference in energy intake between meat days (2245 kcal/day on average) and meat-free days (1495 kcal/day on average), the observed environmental impact for each individual was scaled to 2000 kcal/day energy intake. This approach improves the comparability of environmental impact across different consumption days. While larger food quantities and higher calorie intake generally lead to higher environmental impact, individual choices – driven by food preferences or health considerations – may reduce calorie consumption from specific foods. Underreporting or omitting certain foods was also possible among participants, resulting in a lower observed energy intake. To address potential underreporting of energy intake in survey data, the environmental impact indicators were scaled to diets of 2000 kcal/day energy intake. On meat-free days, the environmental impact of 2000 kcal/day-scaled diets was higher than the observed values (**Table 2**), which was due to the low reported energy intake. However, the environmental impact (scaled to 2000 kcal/day) on meat-free days remained consistently lower than meat days.

In addition to energy intake, age and gender may also influence the environmental impact of diets. It is important to gain deeper insights into the extent to which meat consumption contributed to the dietary environmental impact, irrespective of these factors. To calculate this, regression models were applied. Results from the regression models showed that, of all consumption days, meat consumption was estimated to contribute to 1.8 kg CO_2-eq/day of greenhouse gas emissions and 2.7 m^2·year/day of land use. Further details of this regression analysis can be found in section **Methods and Explanation**.

Table 2 – Dietary environmental impact and energy intake on meat days and meat-free days[a]

	Total	Meat days	Meat-free days
Number of days, n	14119	13819	300
Energy intake, kcal	2229 (915)	2245 (911)	1495 (793)
Greenhouse gas emissions, kg CO_2-eq/day			
Observed	5.7 (2.9)	5.8 (2.8)	2.7 (1.5)
Per 2000 kcal	5.2 (1.8)	5.2 (1.7)	4.0 (2.1)
Land use, m^2·year/day			
Observed	7.4 (4.3)	7.5 (4.3)	2.9 (1.7)
Per 2000 kcal	6.6 (2.8)	6.7 (2.8)	4.1 (2.1)

[a] Data are presented as mean (standard deviation).

Reducing Environmental Impact by Replacing Meat by Meat Substitutes

Replacing meat by meat substitutes has the potential to mitigate the dietary environmental impact. Hence, substitution analyses were performed to estimate the potential reduction in greenhouse gas emissions and land use if individuals replaced meat with alternatives in their daily diets. Meat substitutes included eggs, legumes, and nuts/seeds, while plant-based meat substitutes did not include eggs. Meat analogues were not included in this analysis since they were not assessed in this DANSDA food consumption survey data.

Table 3 and **Figure 2** show the estimated average reduction per person in environmental impact that would be achieved if individuals replaced meat by meat substitutes in their daily diets. In the figures, the total height of each stacked bar represents the observed values of environmental impact on meat days and meat-free days, while the shadowed areas denote the estimated reduction in environmental impact that would be achieved by replacing meat by meat substitutes. If individuals replaced meat by meat substitutes, greenhouse gas emissions would decrease by 2.1 kg CO_2-eq/day (14.8 kg CO_2-eq/week) by 33.4%, and land use would decrease by 2.8 m^2·year/day (19.8 m^2·year/week) by 31.2%. This reduction would slightly increase to 2.2 kg CO_2-eq/day (15.4 kg CO_2-eq/week) for greenhouse gas emissions and 2.9 m^2·year/day (20.4 m^2·year/week) for land use per person on average if meat was replaced by plant-based meat substitutes.

Table 3 – Estimated reduction in environmental impact if individuals replaced meat by meat substitutes in their daily diets[a]

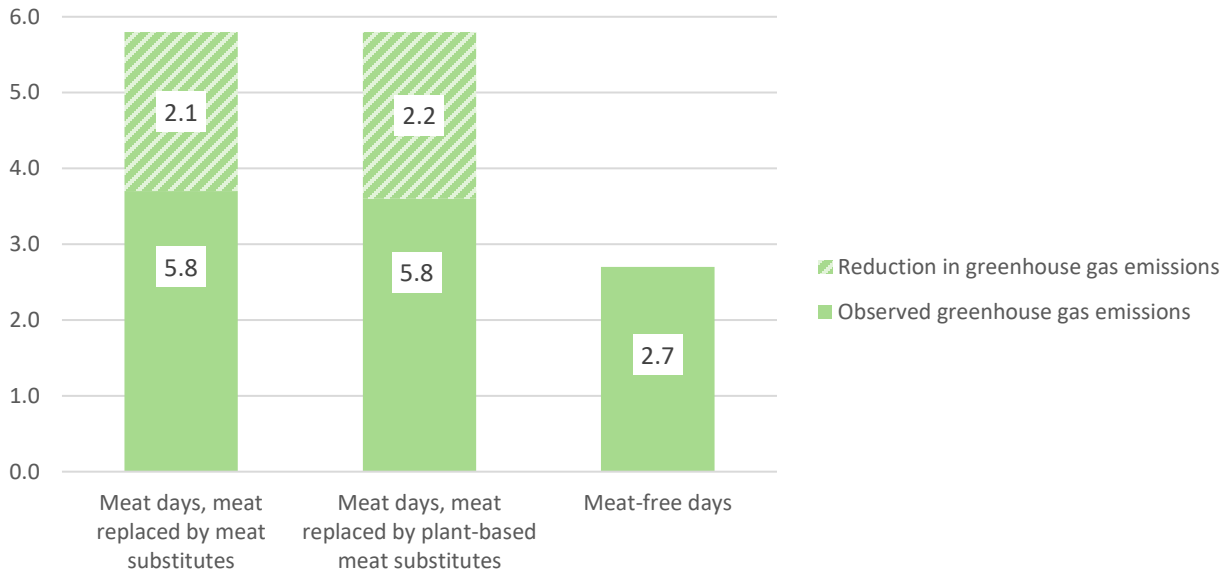
	Meat substitutes[b]	Plant-based meat substitutes[b]
Greenhouse gas emissions, kg CO_2-eq		
With 1 day change	2.1 (1.9)	2.2 (2.0)
With 1 week change	14.8 (13.4)	15.4 (13.8)
Percentage reduction, %	33.4 (16.6)	34.9 (17.0)
Land use, m^2·year		
With 1 day change	2.8 (3.1)	2.9 (3.2)
With 1 week change	19.8 (21.9)	20.4 (22.2)
Percentage reduction, %	31.2 (21.0)	32.5 (20.9)

[a] Data are presented as mean (standard deviation).

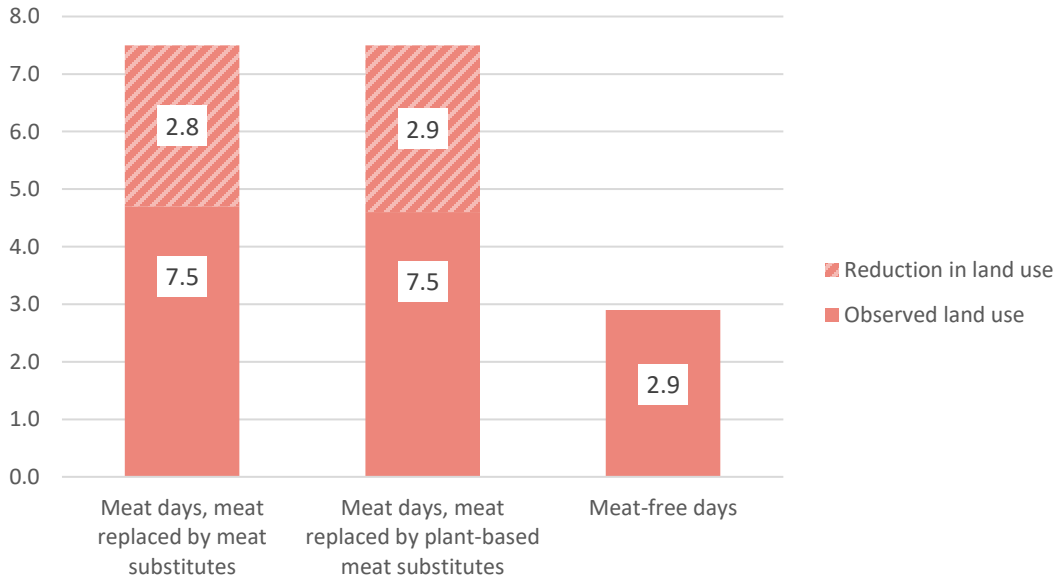
[b] Meat substitutes included eggs, legumes, and nuts/seeds; plant-based meat substitutes included legumes and nuts/seeds.

Figure 2 – Dietary environmental impact on meat days, meat-free days, and potential reduction in environmental impact by replacing meat with meat substitutes on meat days[a]

(a) Greenhouse gas emissions (kg CO_2-eq/day)



(b) Land use (m^2·year/day)



[a] Meat substitutes included eggs, legumes, and nuts/seeds; plant-based meat substitutes included legumes and nuts/seeds.

Methods and Explanation

Study Population

Information on daily food consumption was obtained from the Danish National Survey of Diet and Physical Activity (DANSDA) 2005-2008, conducted by the National Food Institute, Technical University of Denmark (Knudsen, 2012). This data was shared via the European Food Safety Authority (EFSA) as a part of the Comprehensive Food Consumption Database with permission from the Technical University of Denmark. For this research, data of 2025 Danish adults were used, with a total of 14119 days of dietary records. The survey sampling aimed to create a representative population sample in Denmark concerning age and gender. Demographic characteristics of the study population are presented in **Table 4**.

Dietary consumption was assessed using a food diary over seven consecutive days. The food diary followed a typical Danish diet structure, consisting of breakfast, lunch, dinner, and three snack meals, with pre-coded entries for commonly consumed foods and drinks. Participants could also record any additional food and drink items not listed in the pre-coded items. Portion sizes were estimated using common household measures (cups, glasses, etc.) and a series of 12 photographs showing different portion sizes of commonly eaten foods. Amount of food consumption, macro- and micronutrients intake were calculated using GIES (National Food Institute, Technical University of Denmark, Kgs Lyngby, Denmark), incorporating standard recipes, portion sizes, and data from the Danish Food Composition Database (https://frida.fooddata.dk/). The pre-coded food diary was validated against an objective measure of total energy expenditure (ActiReg®, PreMed AS, Oslo, Norway) and was found to be accurate in estimating total energy intake. A more detailed description of the DANSDA survey can be found elsewhere (Knudsen, 2012). All food items were further classified according to the FoodEx2 food classification system developed by EFSA. In this research, meat is defined as red meat, white meat, processed meat, fish, and other seafood.

Table 4 – Demographic characteristics of the study population[a]

Participants, n	2025
Female, n (%)	1093 (54.0)
Days of dietary assessments, n	14119
Age, years	46.8 (14.9)
Weight, kg	75.9 (15.6)
Height, cm	173.2 (9.2)
BMI, kg/m^2	25.2 (4.3)

[a] Data are presented as mean (standard deviation) if not specified.

Potential Influence on Environmental Impact due to Changes in Meat Consumption

This study used the data from the Danish National Survey of Diet and Physical Activity (DANSDA) 2005-2008. The most up-to-date national food consumption survey in Denmark was conducted between 2011-2013 (Pedersen, 2015). However, this data is not openly available via EFSA and is not directly available due to the European General Data Protection Regulation.

Although this study is based on a cross-sectional food consumption survey using data between 2005-2008, the calculations provide a reasonable estimate of how a meat-free day could help reduce dietary environmental impact. The summary report from the DANSDA 2011-2013 showed that the total meat consumption was 197 grams/day, consisting of 134 grams/day for red meat and processed meat (68.0%), 26 grams/day of white meat (13.2%), and 37 grams/day of seafood (18.8%), which was in total approximately 43 grams/day higher than the observed meat consumption in this study between 2005-2008 (Pedersen, 2015; Nordman, 2023). The proportion of consumption of different types of meat to total meat stayed basically unchanged. This higher meat consumption observed between 2011-2013 is estimated to account for a higher dietary environmental impact than currently estimated. Despite the unavailability of detailed data between 2011-2013, these estimates suggest a higher reduction in dietary environmental impact would be achieved if individuals replaced meat with vegetarian or plant-based meat substitutes in their diets.

However, it should be noted that the aforementioned comparisons and estimates are based on the total meat consumption level for the entire study population. The detailed consumption level for each individual is unknown. Changes in the consumption of other food products by individuals may also influence the overall dietary environmental impact, and consequently, the reduction in environmental impact if individuals replace meat with meat substitutes. Therefore, cautious interpretation is warranted. It is important to repeat the analysis when newer data become available. Nonetheless, the results from this study and the aforementioned estimates both substantiate the fact that eating meat-free (by replacing meat with meat substitutes) may contribute to a lower dietary environmental footprint, regardless of the changes in meat consumption. Substantial long-term benefits may be achieved in reducing the environmental impact of diets if individuals switch to more plant-based dietary patterns for a longer period. The newest Danish food consumption survey for 2021-2024 is in progress. Contemporary changes in diet and their associated environmental impact should be studied when the data become available.

Environmental Impact Indicators

The dietary environmental impact was calculated using the SHARP Indicators Database (SHARP-ID), which includes estimates of European average greenhouse gas emissions and land use of food items. The SHARP-ID was developed as part of the EU-funded SUSFANS project (H2020-SFS-2014-2, grant number 633692). In short, attributional life cycle assessment was applied to quantify the environmental impact throughout the entire life cycle of a food product, including primary production, primary packaging, transport, food losses/waste, and food preparations at home. The life cycle assessment data were adjusted for consumption amount using available conversion factors for production, edible portion, cooking losses and gains, and food losses and waste. The life cycle assessment data were available for 957 FoodEx2 coded foods, based on 182 primary food products, and were extrapolated to European countries. In this study, the environmental impact for greenhouse gas emissions and land use was linked to the DANSDA data using the FoodEx2 food classification codes (Mertens, 2019). Other environmental impact indicators, such as water use and biodiversity loss are not available, therefore, not included in this study. It is important to investigate the environmental impact of these indicators when data become available.

Regression Models

Meat consumption contributes substantially to dietary environmental impact. Additionally, age and gender may influence food consumption patterns and, consequently, the environmental impact of diets. Therefore, it is important to understand the specific contribution of meat consumption to dietary environmental impact, regardless of these other factors. To calculate this, two linear regression models were used for each environmental impact indicator. Taking greenhouse gas emissions as an example, in the first model, the values of dietary greenhouse gas emissions were set as the dependent variable, while age, gender, energy intake, and meat consumption (both amount and consuming meat on an assessment day or not) were set as the independent variables. The second model was identical but variables representing meat consumption were left out, i.e., it included age, gender, and energy intake as the independent variables. The sum of the difference of the greenhouse gas emissions predicted by these two models thus estimated the part of dietary greenhouse gas emissions that can be attributed to meat consumption. For land use, the same approach was applied.

The estimated environmental impact attributed to meat consumption is shown in **Table 5**. Of all consumption days, meat consumption was estimated to account for 1.8 kg CO_2-eq/day of greenhouse gas emissions and 2.7 m^2·year/day of land use.

It should be noted that other factors, such as education and income, could influence meat consumption and the environmental impact of daily diets. Unfortunately, these factors are not included in the current research data, so their influence could not be examined in this research.

Table 5 – Predicted dietary environmental impact on meat days and meat-free days[a]

	Meat days	Meat-free days	Environmental impact attributed to meat consumption[b]
Greenhouse gas emissions, kg CO2-eq/day			
Models considering meat consumption[c]	5.6 (3.0)	2.3 (0.6)	
Models not considering meat consumption[d]	5.5 (2.7)	4.0 (1.4)	
Difference	0.1 (1.4)	1.7 (0.8)	1.8
Land use, m^2·year/day			
Models considering meat consumption[c]	7.2 (4.7)	2.4 (0.7)	
Models not considering meat consumption[d]	7.0 (3.9)	4.9 (1.9)	
Difference	0.2 (2.5)	2.5 (1.2)	2.7

[a] Data are presented as mean (standard deviation) except for the environmental impact attributed to meat consumption.

[b] The sum of the difference in predicted values between the two models indicate the environmental impact attributed to meat consumption.

[c] Values predicted by models considering meat consumption, age, gender, and energy intake.

[d] Values predicted by models considering age, gender, and energy intake.

Other Considerations

This research estimated the potential reduction in dietary environmental impact if individuals replaced meat with meat substitutes. Underreporting of food consumption and energy intake is inevitably present, especially on meat-free days. The low energy intake reported on meat-free days could partly be explained by a higher proportion of female participants (65.8% of females had at least one meat-free day), who generally have a lower energy intake than males. Previous studies have shown that underreporting in DANSDA could be attributed to the experimenter effect on the first day and the fatigue effect on the last day of the 7-day dietary recording procedure. Social desirability may also lead to underreporting of energy-dense, high-sugar, and high-fat food products (Nordman, 2020). However, such underreporting is not expected to substantially influence the outcomes of this study. The main difference in dietary environmental impact is attributed to meat consumption, and there is no evidence of systematic underreporting of meat consumption. By scaling the environmental impact to diets of 2000 kcal/day, the potential impact of underreporting on dietary environmental impact is likely mitigated.

Limiting meat consumption not only affects dietary environmental impact, but many other dietary factors as well. Sufficient intake of nutrients should be guaranteed when switching to more plant-based diets. Animal-based foods are good dietary sources of iron, calcium, vitamin B1, vitamin B12, and vitamin D, while in plant-based foods these nutrients are in general limited (Tso, 2021).

Moreover, the environmental impact indicators used in this research are based on current estimates related to existing production systems. This research applied average EU data for greenhouse gas emissions and land use. However, the environmental footprints of diets in Denmark may differ from these EU averages. The environmental footprints of food items will be reduced when animal and plant/crop production systems become more environmentally sustainable.

Conclusions

In this research, we assessed the environmental impact of daily diets of Danish adults and estimated the potential reduction in environmental impact that would be achieved if individuals replaced meat by meat substitutes in their daily diets. Among the participants, the average daily meat consumption was 150.9 grams. Out of the 14119 days of dietary assessments, 300 days (2.1%) were meat-free. Meat days showed higher diet-related greenhouse gas emissions and land use compared with meat-free days. If individuals replaced meat by meat substitutes, this change could result in an average reduction of 2.1 kg CO_2-eq/day (a 33.4% decrease) in greenhouse gas emissions and 2.8 m^2·year/day (a 31.2% decrease) in land use. These findings underscore the substantial environmental benefits of limiting meat consumption in this Danish adult population.

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