



Substituting Meat with Alternatives: The Potential to Reduce Environmental Footprints of the French Diet

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The Third French Individual and National Food Consumption Survey (INCA3)

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TABLE OF CONTENTS

SYNOPSIS	3
BACKGROUND.....	4
RESEARCH RESULTS AND INTERPRETATION.....	5
CONSUMPTION LEVELS OF MEAT AND MEAT SUBSTITUTES	5
ENVIRONMENTAL IMPACT OF DAILY DIETS	7
REDUCING ENVIRONMENTAL IMPACT BY REPLACING MEAT BY MEAT SUBSTITUTES	9
METHODS AND EXPLANATION	12
STUDY POPULATION	12
ENVIRONMENTAL IMPACT INDICATORS.....	14
REGRESSION MODELS.....	15
OTHER CONSIDERATIONS	17
CONCLUSIONS	18
REFERENCES	19
ACKNOWLEDGEMENTS.....	20

Synopsis

This research assessed the environmental impact of food consumption in France, using data from the Third French Individual and National Food Consumption (INCA3) Survey (2014-2015). Among the 2514 French adults surveyed, the average meat consumption was 184.5 grams/day. On days when individuals consumed meat, their diets had higher greenhouse gas emissions at 6.7 kg CO₂-eq/day, compared with 3.2 kg CO₂-eq/day on days without meat. Similarly, land use was higher on days with meat consumption, reaching 8.6 m²·year/day, compared to 3.6 m²·year/day on days without meat.

If individuals would replace meat with alternatives such as legumes, nuts, seeds, eggs, and meat analogues in their daily diets, their dietary greenhouse gas emissions could decline by 2.8 kg CO₂-eq/day – a decrease of 35.4%. Land use could decline by 3.7 m²·year/day – a decrease of 32.8%. Therefore, lowering meat consumption in France has the potential to lessen the environmental impact of food consumption.

Background

Current food production and consumption patterns have a profound environmental impact, threatening our planetary ecosystems. Worldwide, food systems account for approximately 30% of total greenhouse gas emissions and 40% of land use (Willett, 2019). Among food products, meat and dairy products contribute disproportionately to this environmental burden (Biesbroek, 2014). Transitioning towards diets with less meat and dairy while increasing plant-based foods is urgently needed to reduce the environmental burden and improve planetary health.

The latest French food-based dietary guidelines recommend consuming legumes at least twice weekly, eating a small handful of unsalted nuts daily, and limiting red and processed meat consumption (Kesse-Guyot, 2021). Using data from the Third French Individual and National Food Consumption (INCA3) Survey (2014–2015), this study assessed greenhouse gas emissions and land use resulting from the daily diets of French adults on meat-consuming versus meat-free days. Additionally, this research estimated the potential reduction in environmental impact if individuals would replace meat with meat substitutes.

Research Results and Interpretation

Consumption Levels of Meat and Meat Substitutes

In this population sample of French adults (18-79 years), a total of 2514 participants had detailed information on food consumption on a total of 6935 days. Of all consumption days, the average total meat consumption was 184.5 grams/day, consisting of red meat of 68.5 grams/day (37.1%), white meat of 39.2 grams/day (21.2%), processed meat of 38.9 grams/day (21.1%), and seafood of 38.0 grams/day (20.6%) (**Figure 1a**). The average total meat substitutes consumption was 29.3 grams/day, which consisted of legumes of 8.4 grams/day (28.7%), eggs of 17.3 grams/day (59.0%), nuts/seeds of 3.3 grams/day (11.3%), and meat analogues of 0.3 grams/day (1.0%) (**Figure 1b**). Among the 2514 participants with a total of 6935 days of dietary assessments, 394 (15.7%) had at least one day that they did not consume meat, accounting for 479 (6.9%) of all dietary assessment days without meat consumption (**Table 1**). A meat day refers to an individual who consumed meat and/or fish on a dietary assessment day; while a meat-free day refers to an individual who did not consume meat and/or fish on a dietary assessment day.

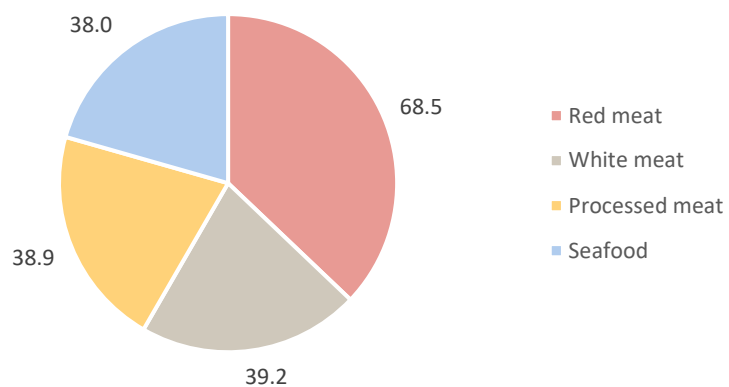
Table 1 – Numbers of participants and days with or without meat consumption

	Participants, n (%)	Days of dietary records, n (%)
Meat days	2120 (84.3%)	6456 (93.1%)
Meat-free days	394 (15.7%) ^a	479 (6.9%)
Total	2514	6935

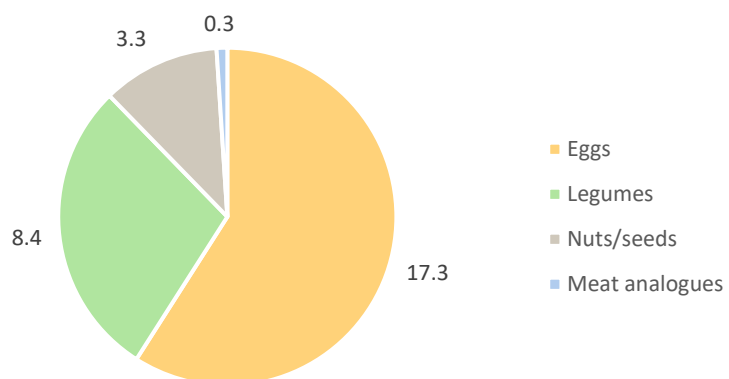
^a Participants had at least one day that they did not consume meat.

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

The dietary environmental impact of French adults is shown in **Table 2**, comparing meat days with meat-free days. The dietary environmental impact was consistently higher on meat days. Greenhouse gas emissions reached 6.7 kg CO₂-eq/day on meat days, compared with 3.2 kg CO₂-eq/day on meat-free days. Land use reached 8.6 m²·year/day on meat days, compared with 3.6 m²·year/day on meat-free days

Eating more food generally increases calorie intake and dietary environmental impact. Individual food preferences or health considerations, on the other hand, may reduce calorie intake. Some participants may have underreported or omitted certain foods, leading to a lower observed energy intake. Considering the difference in energy intake between meat days (2094 kcal/day on average) and meat-free days (1687 kcal/day on average), the observed environmental impact was scaled to 2000 kcal/day energy intake. This approach enhances the comparability of environmental impact across different consumption days. On meat-free days, the environmental impact of 2000 kcal/day-scaled diets was higher than the observed values (**Table 2**). However, the environmental impact (scaled to 2000 kcal/day) on meat-free days remained consistently lower than meat days, with 35.8% lower greenhouse gas emissions and 48.2% lower land use.

In addition to energy intake, sex may also influence the environmental impact of diets. To calculate the extent to which meat consumption contributed to the dietary environmental impact irrespective of energy intake and sex, regression models were applied. Results from the regression models showed that meat consumption was estimated to contribute to 2.8 kg CO₂-eq/day of greenhouse gas emissions and 3.6 m²·year/day of land use. Further details of this regression analysis can be found in **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	6935	6456	479
Energy intake, kcal	2066 (877)	2094 (873)	1687 (842)
Greenhouse gas emissions, kg CO ₂ -eq/day			
Observed	6.5 (3.8)	6.7 (3.8)	3.2 (1.8)
Per 2000 kcal	6.6 (6.9)	6.7 (3.6)	4.3 (2.7) ^b
Land use, m ² ·year/day			
Observed	8.2 (5.8)	8.6 (5.9)	3.6 (2.1)
Per 2000 kcal	8.2 (5.5)	8.5 (5.5)	4.4 (2.7) ^b

^a Data are presented as mean (standard deviation).

^b One dietary record day was excluded from the 2000 kcal/day-scaled dietary environmental impact calculation due to fasting.

Reducing Environmental Impact by Replacing Meat by Meat Substitutes

Replacing meat by meat substitutes has the potential to alleviate dietary environmental burden. 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, nuts/seeds, and meat analogues and plant-based meat substitutes only included legumes, nuts/seeds, and plant-based meat analogues.

The estimated per-person reduction in dietary environmental impact that would be achieved if individuals replaced meat with meat substitutes is shown in **Table 3** and **Figure 2**. In **Figure 2**, 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 2.8 kg CO₂-eq/day (19.5 kg CO₂-eq/week, 35.4% decrease), and land use would decrease by 3.7 m²-year/day (25.9 m²-year/week) by 32.8%. This reduction would slightly increase to 2.9 kg CO₂-eq/day (20.4 kg CO₂-eq/week) by 37.4% for greenhouse gas emissions and 4.0 m²-year/day (27.7 m²-year/week) by 35.8% 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

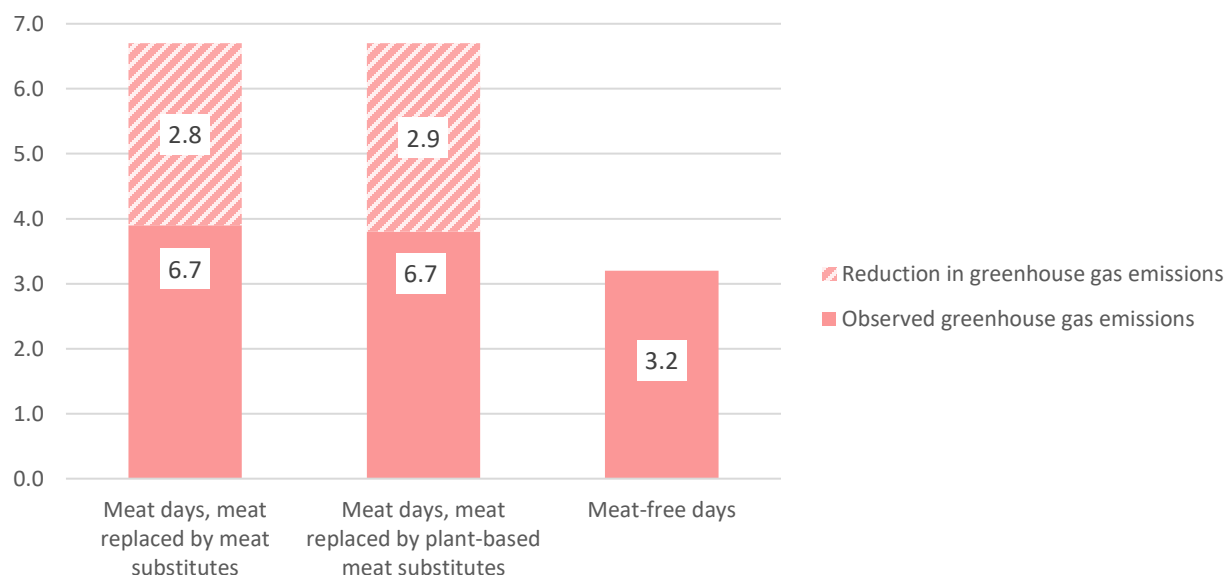
	Meat substitutes ^b	Plant-based meat substitutes ^b
Greenhouse gas emissions, kg CO ₂ -eq		
With 1 day change	2.8 (3.2)	2.9 (3.2)
With 1 week change	19.5 (22.1)	20.4 (22.6)
Percentage reduction, %	35.4 (22.3)	37.4 (22.7)
Land use, m ² ·year		
With 1 day change	3.7 (4.9)	4.0 (5.1)
With 1 week change	25.9 (34.6)	27.7 (35.6)
Percentage reduction, %	32.8 (25.3)	35.8 (25.9)

^a Data are presented as mean (standard deviation).

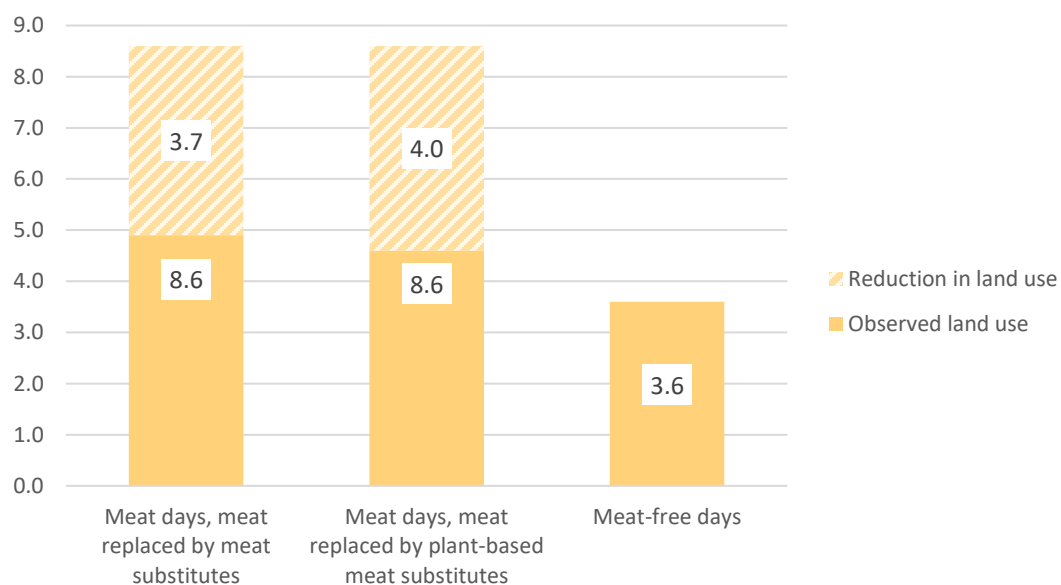
^b Meat substitutes included eggs, legumes, nuts/seeds, and meat analogues; plant-based meat substitutes included legumes, nuts/seeds, and plant-based meat analogues.

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 CO₂-eq/day)



(b) Land use (m²·year/day)



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

Methods and Explanation

Study Population

Data on daily food consumption was obtained from the Third French Individual and National Food Consumption (INCA3) Survey (2014-2015), conducted by the French Agency for Food, Environmental and Occupational Health and Safety (Dubuisson, 2019). The data were shared via the European Food Safety Authority (EFSA) as part of the Comprehensive Food Consumption Database (EFSA, 2022). For this research, data of 2514 French adults (18-79 years) were used, with a total of 6935 days of dietary records. The survey used a three-stage stratified random sampling method to create a representative population sample of mainland France. At the first level, 181 geographical primary sampling units were selected, comprising 37 large units ($\geq 40,000$ households) and 144 smaller units ($< 40,000$ households). These units were stratified by region (8 major areas) and city size (10,000 inhabitants). At the second level, 25,981 households from the 2011 national census were randomly selected within these units, allocated by region of residence and size of the primary sampling unit, with further stratification by children and adults. In each stratum, households were randomly allocated across five seasonal survey waves. At the third level, interviewers randomly selected one eligible household member (closest birthday to the recruitment date) within each household. Institutionalized individuals and those planning to move within two months were not eligible for this study (Dubuisson, 2019). **Table 4** presents the demographic characteristics of the study population.

Dietary consumption was assessed with three non-consecutive 24-hour dietary recalls (two weekdays and one weekend day or public holiday) over three separate weeks. Telephone interviews were conducted by trained interviewers using the GloboDiet software (IARC, Lyon, France) to record participants' previous-day food and beverage consumption. Portion sizes were estimated using food serving photographs, household measures, food shape/thickness diagrams, direct weight/volume reporting, and standard commercial portions. All food items were classified according to the FoodEx2 food classification system developed by EFSA (Dubuisson, 2019). Dietary consumption data were linked to food composition table derived from the database on the nutritional composition of foods from the French Information Centre on Food Quality (Ciqua, <https://ciqua.anses.fr/>) to calculate nutrient and energy intake. In this research, meat is defined as red meat, white meat, processed meat, and seafood (including fish).

Table 4 – Demographic characteristics of the study population^a

Participants, n	2514
Female, n (%)	1440 (57.3)
Days of dietary assessments, n	6935
Weight, kg	72.6 (15.8)
Height, cm	167.9 (9.3)
BMI, kg/m ²	25.7 (4.9)

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

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 (Mertens, 2019). 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 (Daas, 2025). Missing values were preferably supplemented with estimates for similar food items that were comparable in production method and/or ingredient composition. Alternatively, the mean value of the same (and if not available higher) level of the FoodEx2 classification was used. In this study, the environmental impact for greenhouse gas emissions and land use was linked to the Third French Individual and National Food Consumption (INCA3) Survey data using the FoodEx2 food classification codes. Other environmental impact indicators, such as water use and biodiversity loss, were not available, and therefore not included in this study. It is important to investigate the environmental impact of these indicators when data becomes available.

Regression Models

Meat consumption contributes substantially to dietary environmental impact. Sex may also influence food consumption patterns and consequently dietary environmental impact. Therefore, two linear regression models were applied to assess the specific contribution of meat consumption to dietary environmental impact. 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 sex, energy intake, and meat consumption (both amount and consuming meat on an assessment day or not) were set as independent variables. The second model was identical but variables representing meat consumption were left out, only including sex and energy intake as 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 attributed to meat consumption. For land use, the same approach was applied.

Table 5 shows the estimated environmental impact attributed to meat consumption. Of all consumption days, meat consumption was estimated to account for 2.8 kg CO₂-eq/day of greenhouse gas emissions and 3.6 m²-year/day of land use.

It should be noted that other factors, such as age, education, and income, could influence meat consumption and the environmental impact of daily diets. Detailed information on age was not provided in this survey data, considering privacy considerations from the data suppliers. Other factors were also not included in the research data, so their influence could not be examined in this research. However, incorporating these additional factors is not expected to substantially change the results, considering that meat consumption quantity remains the primary driver of dietary environmental impact.

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 CO ₂ -eq/day			
Models considering meat consumption ^c	6.5 (3.8)	2.8 (0.7)	
Models not considering meat consumption ^d	6.0 (2.7)	5.1 (2.0)	
Difference	0.5 (2.4)	2.3 (1.2)	2.8
Land use, m ² ·year/day			
Models considering meat consumption ^c	7.9 (5.6)	3.0 (0.9)	
Models not considering meat consumption ^d	7.3 (4.0)	6.0 (2.7)	
Difference	0.6 (3.4)	3.0 (1.8)	3.6

^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 indicates the environmental impact attributed to meat consumption.

^c Values predicted by models considering meat consumption, sex, and energy intake.

^d Values predicted by models considering sex and energy intake.

Other Considerations

This research estimated the potential reduction in dietary environmental impact if individuals would replace meat with meat substitutes. Underreporting of food consumption is possible, consequently leading to lower observed energy intake. It was estimated that approximately 17.8% of dietary records of energy intake were underreported in the Third French Individual and National Food Consumption (INCA3) Survey (2014–2015) (Dubuisson, 2019). Food items with a high chance of underreporting are generally energy-dense, such as fries, pastries, ice cream, and sweets, likely because of social desirability (Lafay, 2000). However, the underreporting of these food items is not expected to substantially influence the outcomes of this study. The main difference in dietary environmental impact between meat and meat-free days is primarily driven by meat consumption, and there is no evidence of systematic underreporting of meat consumption in this survey sample. By scaling the environmental impact to diets of 2000 kcal/day and applying the regression models, the potential impact of underreporting on dietary environmental impact is likely mitigated.

Although this study is based on a cross-sectional food consumption survey using data from 2014-2015, there is currently no newer national food consumption survey data available in France. However, substantial changes in meat consumption are not expected. The results from this study substantiate that eating meat-free (by replacing meat with meat substitutes) may result in a lower dietary environmental footprint. Substantial long-term benefits in reducing the dietary environmental impact may be achieved if individuals adopt more plant-based dietary patterns over a longer period. Contemporary changes in diet and their associated environmental impact should be studied once new data becomes available.

Additionally, 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 generally limited (Tso, 2021).

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

Conclusions

In this research, the dietary environmental impact of French adults was assessed, and the potential reduction in this impact was estimated if individuals would replace meat with meat substitutes. Among all participants, the average meat consumption was 184.5 grams/day. Out of the 6935 days of dietary assessments, 479 days (6.9%) were meat-free. Meat days showed a higher dietary environmental impact compared with meat-free days. If individuals would replace meat with meat substitutes, the average reduction would be 2.8 kg CO₂-eq/day (a 35.4% decrease) in greenhouse gas emissions and 3.7 m²·year/day (a 32.8% decrease) in land use. These findings highlight the substantial environmental benefits that could be achieved by reducing meat consumption among French adults.

References

- Biesbroek, S., Bueno-de-Mesquita, H. B., Peeters, P. H., et al. (2014). Reducing our environmental footprint and improving our health: greenhouse gas emission and land use of usual diet and mortality in EPIC-NL: a prospective cohort study. *Environmental Health*, 13(1), 1-9.
- Daas, M. C., van't Veer, P., Temme, E. H., Kuijsten, A., Gurinović, M., & Biesbroek, S. (2025). Diversity of dietary protein patterns across Europe—Impact on nutritional quality and environmental sustainability. *Current Research in Food Science*, 10, 101019.
- Dubuisson, C., Dufour, A., Carrillo, S., et al. (2019). The Third French Individual and National Food Consumption (INCA3) Survey 2014–2015: method, design and participation rate in the framework of a European harmonization process. *Public Health Nutrition*, 22(4), 584-600.
- EFSA (European Food Safety Authority). (2022). Food consumption data. Accessible via: <https://www.efsa.europa.eu/en/data-report/food-consumption-data>
- Kesse-Guyot, E., Chaltiel, D., Fezeu, L. K., et al. (2021). Association between adherence to the French dietary guidelines and the risk of type 2 diabetes. *Nutrition*, 84, 111107.
- Lafay, L., Mennen, L., Basdevant, A., et al. (2000). Does energy intake underreporting involve all kinds of food or only specific food items? Results from the Fleurbaix Laventie Ville Sante (FLVS) study. *International Journal of Obesity*, 24(11), 1500-1506.
- Mertens, E., Kaptijn, G., Kuijsten, A., et al. (2019). SHARP-Indicators Database towards a public database for environmental sustainability. *Data in Brief*, 27, 104617.
- Tso, R., & Forde, C. G. (2021). Unintended consequences: nutritional impact and potential pitfalls of switching from animal-to plant-based foods. *Nutrients*, 13(8), 2527.
- Willett, W., Rockström, J., Loken, B., et al. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*, 393(10170), 447-492.

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