Institut für Agrarpolitik und Marktforschung
der Justus-Liebig-Universität Gießen
Professur Marktlehre der Agrar- und Ernährungswirtschaft

Arbeitsbericht

Nr. 73

Svenja Arendt

Wealth for Health? Affordability of a Healthy and Sustainable Diet – A Food Basket Study

Gießen im November 2023

Anschrift des Instituts:

Senckenbergstr. 3
35390 GIESSEN

Tel. Nr. 0641/99-37020/21
E-Mail: ramona.teuber@agrar.uni-giessen.de

Wealth for Health?
Affordability of a Healthy and Sustainable Diet – A Food Basket Study

Svenja Arendt[1]

[1]Justus Liebig University, Giessen, Germany

Objective: To model healthy and sustainable food baskets in order to calculate the monthly costs and minimum income required for an average German family.
Design: A food basket approach was used to construct six different diets based on the Planetary Health Diet (PHD), varying in meat consumption frequency (light, moderate, heavy meat consumption) and shopping style (organic and conventional farming). Actual food prices from REWE and ALDI Süd were collected to calculate total monthly costs and to analyse affordability, assuming 30% and 15% of disposable income per month spent on the food basket.
Setting: Giessen, Germany.
Participants: A theoretical reference family consisting of two adults and two children.
Results: Across the six dietary patterns, monthly food basket costs ranged from 467€ to 830€. Higher costs were associated with an organic shopping style and an increased meat consumption. The study also showed that if 30% of disposable income was spent on the food basket, a minimum income of 1557€ to 2767€ per month was needed, whereas if 15% was spent on the diet, a minimum income of 3113€ to 5533€ per month was required.
Conclusion: The data highlighted that less income is needed by choosing conventional food items and reducing meat consumption. Families who are willing to spend more on the food basket are more likely to be able to afford a healthy and sustainable diet, but not all families may have this option. Policy interventions are needed to ensure that healthy and sustainable diets are not a choice of wealth.

Keywords: Planetary Health Diet, affordability, food basket costs, meat consumption, organic, conventional

1. Introduction

Broad evidence shows that healthy and sustainable diets are crucial for human and planetary health[1–4]. In Germany, about 14% of deaths are associated with unhealthy diets[1], characterised by high intakes of calories, added sugars and saturated fats, processed foods and red meat[5]. More than half of the German population report being overweight[2], around seven million have diabetes and around five million have coronary heart disease[3]. At the same time, it is estimated that 21%-37% of the global anthropogenic greenhouse gas emissions may be emitted by the food system, contributing to global warming and climate change[4]. In addition, the food sector requires many resources, such as energy, land and water, uses large amounts of fertiliser and is a major driver of biodiversity loss[4].

Several studies showed that a healthy diet rich in plant-based foods, and therefore low in red and processed meat, has several beneficial effects, including reduced risk of diabetes[6–8], cardiovascular disease[7,9,10], mortality[11,12] and reduced greenhouse gas emissions[13–15]. In addition, a study by Clark et al. examining the environmental impact of different food items showed that vegetables, fruit and bread have a low environmental impact, whereas meat and dairy products have a high environmental impact[16]. Moreover, organic farming has some environmental benefits compared to conventional farming, including a lower impact on biodiversity loss, food production with less synthetic fertilisers and pesticides, and positive impacts on water protection, soil fertility and climate[17–19]. However, the latest National Nutrition Survey II (NVS II) from 2008 showed that the average diet in Germany is neither healthy nor environmentally friendly[5,20]. Most Germans do not meet the recommended fruit and vegetable intake, while too much meat is consumed on average[20]. At the same time, results from a self-report survey showed that people in higher income groups were more likely to report being in good health than those on lower incomes[21]. Previous research on factors influencing dietary patterns revealed that the price of food items appears to be an important factor in food choice[22–24], especially for low-income families[25,26]. Several studies showed that healthy foods rich in nutrients and low in calories, such as fresh vegetables, fruits, whole grains and lean meat, were generally more expensive than foods that are low in nutrients and high in calories, like refined grains, processed foods, added sugars and fats[23,27,28]. A study published in 2021 by Bai et al. analysing global food costs showed that in Germany, nutrients are about five times more expensive than calories[28]. In addition, organically produced food is generally more expensive than conventionally

produced food[19,22]. This highlights the importance of making healthy and sustainable diets affordable for everyone.

According to a standardised protocol on affordability and pricing methods by Lee et al., a diet is considered as affordable if expenditure on food is less than 30% of disposable income[29]. In Germany, the average household spent 11.7% on food and non-alcoholic beverages in 2021[30], demonstrating a large discrepancy between actual food spending in Germany and the aforementioned 30% threshold. Faced with high rates of chronic diseases and a changing climate[2–4], dietary changes may be substantial. However, changing to a healthy and sustainable diet can be challenging, especially for low-income families[25,26,31].

An example of a healthy and sustainable diet is the PHD developed by the EAT-Lancet Commission in 2019[5]. The PHD is rich in plant-based foods such as whole grains, vegetables, fruits, legumes, nuts and unsaturated vegetable oils, and low in meat, refined carbohydrates, processed foods, added sugars and saturated fats[5]. Therefore, the PHD can also be considered as a flexitarian diet, defined by a primary plant-based diet with occasional meat consumption[32]. At the same time, the developers underline the importance of improved agricultural production for a sustainable food production, like organic farming[5].

Presently, no study has analysed how much income an average German family would need to be able to afford a healthy and sustainable diet. Therefore, this comparative cost analysis will assess the cost of a PHD for a hypothetical family of two adults and two children living in Giessen and provide a calculation of the minimum income needed to ensure that such a diet can be afforded. Because meat consumption and different farming methods appear to play a central role in health and environment[5,22,26,27], this study will compare different variations of the PHD. Three different levels of meat frequency (light, moderate and heavy meat consumption) and two shopping styles (conventional and organic farming) will be compared to calculate the total monthly cost and the minimum income needed for this period. Two benchmarks will be considered to calculate the monthly income required, 30% as suggested by the framework of Lee et al.[29] and 15% to be closer to the current German spending of 11.7% on food and non-alcoholic beverages[30].

2. Methods

The objective of this study was to assess the cost and affordability of different food baskets based on the PHD, analysing the cost difference between different shopping styles and different levels of meat consumption frequency. The PHD was chosen for this purpose as it was developed to be both healthy and sustainable[5]. To analyse the cost and affordability of

the PHD, the food basket approach was used, which has been applied in several published studies, both internationally[33–36] and in Germany[22,26]. Following recent published studies, this study was conducted using a reference family of two adults and two children[26,29,34]. The age of the family members, activity levels and estimated energy intakes were chosen based on a study by Kabisch et al.[26] and made up as follows: A man and a woman, aged between 21 and 51 years, and two children, a boy and a girl, both aged between 10 and 13 years. The estimated energy intake for a man, woman, boy and girl with a Physical Activity Level (PAL) of 1.6 each was 2700 kcal, 2100 kcal, 2200 kcal and 2000 kcal, respectively[26].

2.1 Diets

All diets were modelled on the recommendations of the PHD[5]. Based on a study by Malek et al.[37], three levels of meat consumption frequency were used and adapted to the PHD, namely light, moderate and heavy meat consumption. It was assumed that one portion of meat weighs 124.25 g and can be replaced by one portion of tofu (60 g) or one portion of legumes (50 g). Further details of the calculation and the amounts of meat and meat replacements in each diet are given in Supplementary Material 1 and 4. According to the Cambridge Dictionary, meat is defined as "the flesh of an animal when it is used for food"[38], so the term meat is used here to refer to beef, pork, poultry and fish. For each level of meat consumption frequency, a food basket of conventional and organic food items was created, resulting in a list of six different food baskets (Table 1).

Table 1 Food baskets and the freqency of meat consumption

Food basket	**Frequency of meat consumption**
Heavy Conventional	4x meat/week
Heavy Organic	4x meat/week
Moderate Conventional	2x meat/week
Moderate Organic	2x meat/week
Light Conventional	0,5x meat/week (once every two weeks)
Light Organic	0,5x meat/week (once every two weeks)

2.2 Food baskets

The PHD provides quantities for food intake, therefore it was assumed that all the nutrients needed are provided by the EAT-Lancet Commission recommendations. The food basket in this study included 75 food items for adults and 74 foods for children (Table 2). Based on the PHD, the food items were categorised into nine food groups: 1) whole grains, 2) tubers/starchy vegetables, 3) vegetables, 4) fruits, 5) dairy foods, 6) protein sources, 7) added fats, 8) added sugars and sweets, 9) beverages. As there was no information on beverages in the PHD, this food group was added based on the recommendations of the German Nutrition Society (DGE)[39]. Although not recommended, but closer to reality, small amounts of alcoholic beverages were added to this food group for adults, and a soft drink and fruit juice for children. In addition, for the same reason as above, small amounts of chocolate and fruit gums were added to the food group 'added sugars' and therefore extended to 'added sugars and sweets'. Meals from takeaways, cafeterias or restaurants were excluded. As the PHD recommendations are a global concept, data from the German Federal Ministry of Food and Agriculture (BMEL) for 2020/2021[40,41], the NVS II Results Report, Part 2[20] and several surveys were used to ensure that the food basket included the food items most commonly consumed by the German population. A detailed description of the food basket methodology can be found in Supplementary Material 1, and the complete food baskets, including product names and quantities, are listed in Supplementary Material 4.

Table 2 Food groups and included food items in the food basket

Food group	Included food items
Whole grains	Whole grain rice, whole grain bread, whole grain bread rolls, oat flakes, whole grain noodles
Tubers/ Starchy vegetables	Potatoes
Vegetables	Kohlrabi, leek, spinach, iceberg lettuce, romaine lettuce, cucumber, zucchini, broccoli, carrots, whole tomatoes, strained tomatoes, chopped tomatoes, pepper, aubergine, white cabbage, cauliflower, onions, mushrooms, asparagus
Fruits	Apple, pear, plum, raspberry, blueberry, strawberry, table grapes, bananas, apricots, peach
Dairy foods	Milk, yoghurt, cream cheese, curd cheese, mozzarella, sour cream, Gouda, Emmental, Camembert
Protein sources	Minced beef, schnitzel, chicken breast, eggs, salmon, Alaska pollock, tuna, red lentils, brown lentils, kidney beans, green beans, chickpeas, white beans, natural tofu, smoked tofu, peanuts, almonds, hazelnuts
Added fats	Margarine, rapeseed oil, olive oil, linseed oil, butter
Added sugars and sweets	White sugar, chocolate bar, fruit gums
Beverages adults	Mineral water, coffee, tea, beer, red wine
Beverages children	Mineral water, tea, soft drink, fruit juice

2.3 Food prices

The prices in euro (€) for the food items were collected in two different grocery stores, REWE, a supermarket, and ALDI Süd, a discount store. This was done in order to have a wider range of food items and two price levels to calculate the average cost. Prices were collected online for REWE, where a store in Giessen was selected, and at an ALDI Süd store in Giessen, Hesse. The assessment was carried out in May 2023. If there was a choice, the cheapest product was chosen, price promotions were not considered. If there was a price promotion, the corresponding regular price was determined. If a product was available in three different sizes, the middle size was chosen. For each food item, the price of a conventionally and an organically produced product was investigated. In this study, organic foods were defined as food items with at least an EU organic logo. If a product of one shopping style was not available in one store, the price of the same food item was taken from the other store, as this study focused on the price difference between organic and

conventional foods and did not compare prices between retail stores. If a shopping style was not available at all in both stores, the price of the other shopping style was used instead. Prices were recorded as prices per kg. The total cost of the food basket was calculated according to the prices per kg and the respective dietary recommendations. See Supplementary Material 2 and 4 for further details.

2.4 Cost and affordability

First, the average costs per day at REWE and Aldi Süd were calculated for both the conventional and organic shopping style. This was done for each diet and each family member. Assuming that a month consists of 30 days, the amounts were multiplied by 30 to calculate the average cost per month. The monthly costs of each family member were then added to obtain the total costs of the reference family for each food basket. The change in cost according to meat frequency level and shopping style was calculated as a percentage (%). To calculate the cost shares by food group, the average cost of the two retail stores was calculated for each family member, meat frequency level and shopping style, and then for the whole household. The daily cost shares were then multiplied by 30 to get the monthly shares. Cost shares were expressed in euro (€).

Affordability was calculated assuming that 30% and 15% of disposable income was spent on the food basket. Therefore, the monthly costs were divided by the respective benchmark and multiplied by 100 to obtain the minimum income required per month. Further details can be found in Supplementary Material 3 and all calculations are traceable in Supplementary Material 4.

3. Results

3.1 Comparison of different meat frequency levels

The average costs of the different meat frequency levels are outlined in Figure 1. Across a four-person household, monthly food basket costs ranged from 467€ to 529€ for the conventional shopping style and from 685€ to 830€ for the organic shopping style. Costs were lowest in both shopping styles for the light meat consumption, followed by the moderate and heavy meat consumption. Reducing meat consumption from heavy to moderate resulted in a reduction of 6.99% (-37€) and 10.24% (-85€) for conventional and organic food items, respectively. A further reduction from moderate to light meat consumption resulted in smaller cost differences of 5.08% (-25€) and 8.05% (-60€) respectively. Reducing meat consumption from the heavy to the light meat consumption

diets resulted in a reduction of 11.72% (-62€) and 17.47% (-145€) for the conventional and organic shopping style, respectively.

3.2 Comparison of the conventional and organic shopping style

Comparing conventional and organic shopping styles, the organic shopping style was consistently more expensive, with cost increases of 56.90% (+301€), 51.42% (+253€) and 46.68% (+218€) for the heavy, moderate and light meat consumption diets, respectively (Figure 1). The cost difference between organic and conventional production narrowed as meat consumption decreased.

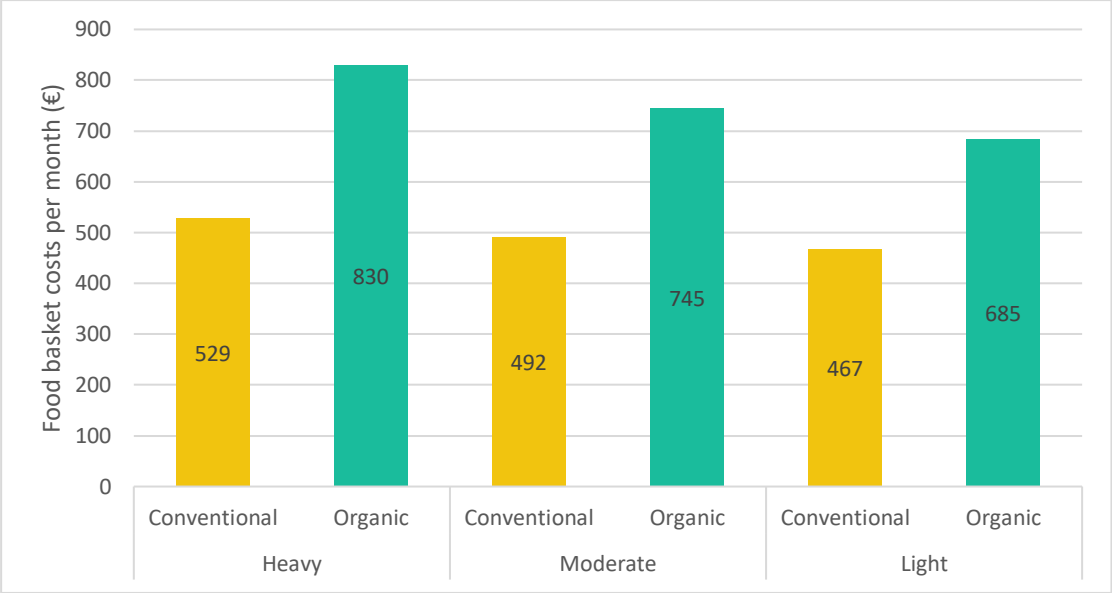

Figure 1 Monthly average food basket costs of the different diets, separated by shopping style and meat frequency level

3.3 Cost shares by food groups

The monthly average contribution of each food group to the total cost of the food basket is presented in Figure 2. The main drivers of higher costs were protein sources, followed by dairy foods, vegetables and whole grains. Organic protein sources, vegetables and beverages were considerably more expensive than their conventional counterparts. The impact of protein sources on total food costs decreased as meat consumption decreased but remained the main driver of food costs. Next to tubers/starchy vegetables, fats and sugars had the lowest cost share at all meat frequency levels.

Looking at the food group of protein sources in more detail, meat had the largest cost share in the heavy meat consumption diets, followed by nuts, legumes and soy (Figure 3). In the moderate diet, meat had the largest share only in the organic shopping style, whereas nuts had the largest cost share in the conventional shopping style. In the light meat consumption diet, nuts were the main cost driver, closely followed by legumes and soy.

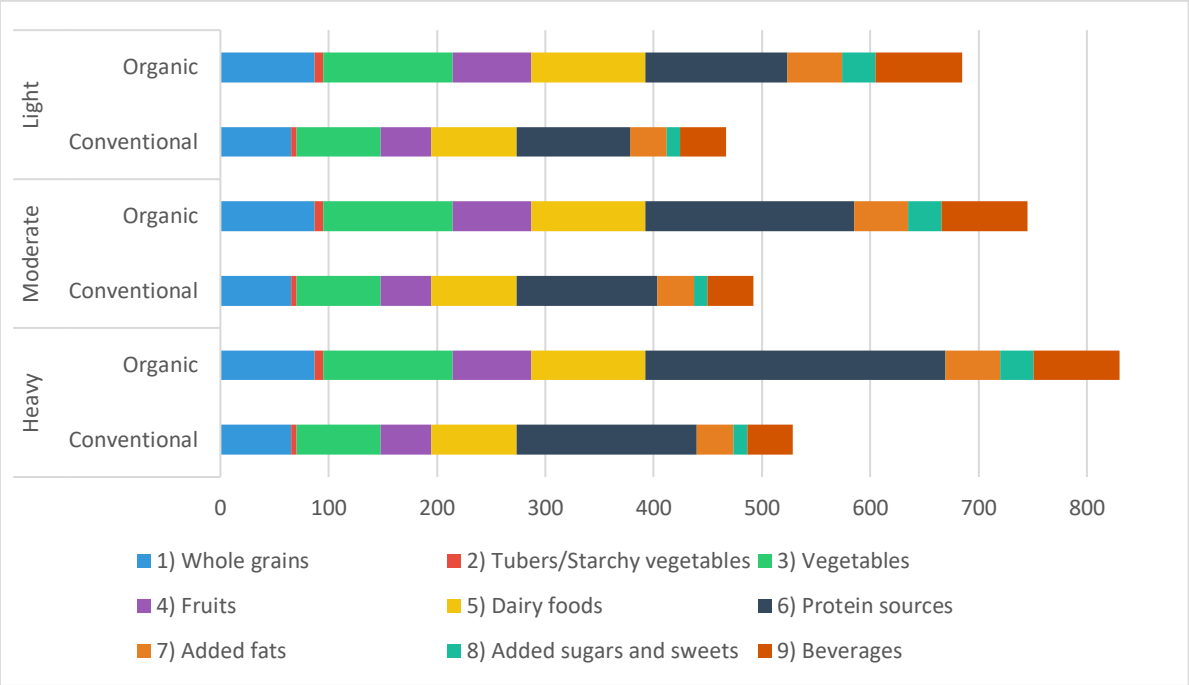

Figure 2 Monthly average cost shares by food group for each diet in euro (€)

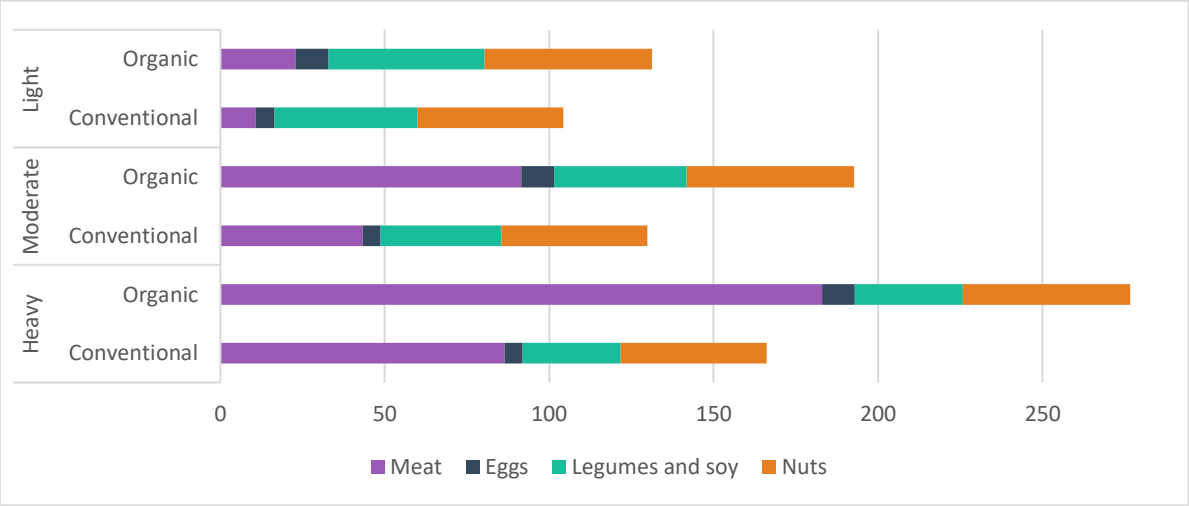

Figure 3 Monthly average cost shares of food items in the food group 'protein sources' for each diet in euro (€)

3.4 Affordability of the food baskets

The monthly income required for the different food baskets, assuming spending of 30% and 15% of disposable income, is outlined in Figure 4. Considering a 30% spending on the food basket, an average family of four would need at least 1557€ per month to afford the light conventional diet, while the light organic diet would require a minimum income of 2283€. The heavy conventional diet would require 1763€ per month, while the heavy organic diet would require 2767€. At 15% spending, the light conventional diet would require at least 3113€ per month, and the light organic diet would require 4567€ per month. The heavy conventional and organic diet would require 3527€ and 5533€ per month, respectively.

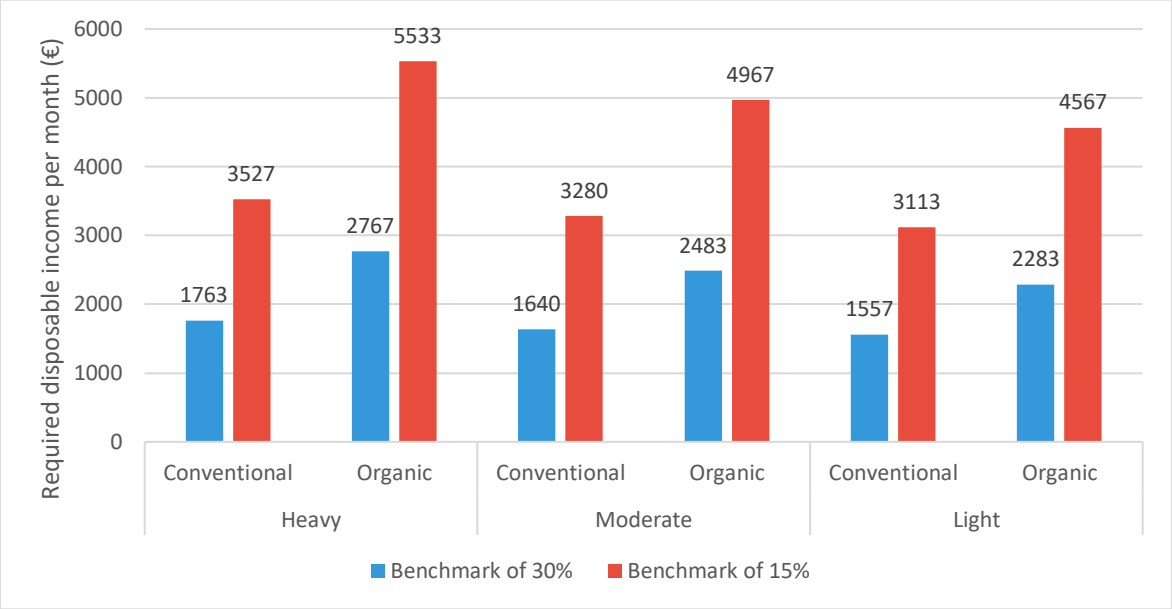

Figure 4 Monthly disposable income requirements assuming 30% and 15% spending on the food baskets

4. Discussion

This comparative cost analysis examined the affordability of a healthy and sustainable diet as suggested by the PHD for an average German family of two adults and two children. The data showed that organically produced food items contributed substantially to the total cost of the food basket, with costs increasing by around 52% at all meat frequency levels. The cost difference between the organic and conventional food baskets narrowed as meat consumption decreased, suggesting that cutting down on meat is especially cost-saving in the organic shopping style. Reducing meat consumption had a smaller effect on the total food basket cost than the shopping style, with an average cost reduction of about 15% when switching from heavy to light meat consumption. The study also outlines the monthly cost

shares of each food group, showing that protein sources accounted for the largest cost share in each diet, followed by dairy foods and vegetables. Potatoes excluded, fats and sugars had the lowest cost shares at all frequency levels and shopping styles, confirming the finding of other studies that nutrients are generally more expensive than calories[23,27,28]. Looking more closely at the food group of protein sources, meat was the main cost driver in the heavy meat consumption diets. By reducing meat consumption and replacing it with plant-based protein sources, the overall cost decreased, demonstrating the cost savings that can be achieved by switching to a more plant-based diet.

These results show that both the shopping style and the meat frequency level have a considerably impact on total food basket cost. Choosing a diet with organic food items and consuming meat frequently results in the highest cost, while choosing conventional food items and reducing meat frequency can reduce total food basket cost. These findings are consistent with previous assessments of food costs in Germany. A study by Seubelt and colleagues found that the cost of a food basket of organic foods was twice as high as that of conventional food items[22]. In addition, studies showed that diets with lower meat consumption, such as vegetarian or flexitarian diets, are less expensive than diets with higher meat consumption, such as the current German diet[14,22,26,42]. Springmann and colleagues found that in 2017, a flexitarian diet, such as the PHD, could save 6% of the costs compared to the current German diet, while a vegetarian diet could even save 21%-25%[14].

Compared to previous studies, the present analysis did not compare the costs with the costs of the current German dietary patterns, but analysed how much income a family of four would need to afford different variants of the PHD. According to the income statistics of the German Federal Statistical Office of 2021, about 36% of German families of four had a disposable income of less than 1833€ per month, of which 16% had a monthly income of less than about 1358€[43]. Assuming that 30% of disposable income is spent on the food basket, a PHD would be financially out of reach for them, requiring an income of at least 1557€ per month. However, around 64% had a disposable income of more than 1833€, suggesting that they could afford a PHD with conventional foods at all meat frequency levels. Even about 40% of German families had enough disposable income to afford a PHD with organic food, which would require at least 2283€ per month[43]. It is noteworthy that a threshold of 30% of disposable income spent on food is far away from the actual German spending of 11.7% on food and non-alcoholic beverages[30]. Therefore, this study also analysed a spending of 15% of disposable income on the food basket. This calculation

showed that only around 20% of families with an income of 3167€ and more would be able to afford the diets analysed in this study, as the most affordable diet was the light conventional diet, which would require an income of 3113€ per month. This finding highlights the importance of how much money families are willing to spend on their food basket. Germany's average spending on food is even lower than the EU average[30], so it may be essential to raise the value and importance of healthy and sustainable diets. This may be a challenge given the rising cost of living in various sectors such as housing, energy and food[44], which may also prevent some families from spending more on their food basket. In addition, the current average German diet is neither healthy nor sustainable[20], so many households would have to shift their diets considerably. However, it is worth noting that the last dietary survey in Germany was published in 2008[20]. According to a recent nutrition report published on behalf of the BMEL and a nutrition trend report published by Nutrition Hub and the Federal Agency for Agriculture and Food (BLE), plant-based diets, especially flexitarian diets, seem to be becoming more popular in Germany[45,46]. Therefore, the last dietary survey is probably outdated and needs to be updated to provide more accurate information on how many Germans are currently following a plant-based diet.

These results suggest that by spending more disposable income on food, choosing conventional food items and reducing meat consumption, a PHD would be affordable for many families in Germany. However, for consumers who value organic food it can be challenging as the cost rise considerably. The cheapest organic food basket costs more than the most expensive conventional food basket. Families on very low incomes are not even able to afford a PHD with less meat and conventional foods, indicating that income plays an important role in determining the feasibility of a healthy and sustainable diet.

To meet the urgent challenge of human and planetary health, comprehensive policy interventions are needed to broaden the acceptance of healthy and sustainable food choices and to raise awareness that dietary changes may be unavoidable to promote health, sustainability and affordability. It is also crucial to ensure that healthy and sustainable food options are affordable for everyone since some families cannot afford a PHD and may not be able to spend more disposable income on their food basket.

Policy actions such as fiscal policies, including taxes or subsidies, may enable and encourage consumers to make dietary changes. A meta-analysis by Afshin et al. found that a 10% reduction in the price of healthy foods increased their consumption by 12%[24]. Moreover, a meta-analysis by Andreyeva et al. showed a moderate association between fruit and

vegetable subsidies and increased sales[47]. A recently published German survey further highlighted the potential impact of financial incentives to encourage dietary change, as respondents indicated that they would buy more plant-based foods if they were less expensive[48]. To promote not only healthy but also sustainable diets, another approach by Springmann et al. proposed a greenhouse gas-related tax on food, with the highest tax on animal foods and the lowest tax on vegetables, fruits, grains and legumes[49].

Future research should further analyse the potential of financial incentives and other measures to promote healthy and sustainable diets, with the aim of ensuring affordability for all, regardless of the income level.

The present analysis has some methodological limitations. It was assumed that the recommended quantities for food intake cover the nutrient requirements, but this generalisation may not be accurate for each individual due to variations in dietary needs. In addition, the study assumed that replacing meat with plant-based alternatives did not lead to changes in calories and nutrient intakes. Also, the added beverages (alcoholic beverages for adults, soft drink and fruit juice for children) and the sweets were not considered in the total kcal per day, so the calorie and nutrient intakes are only an approximation. Seasonal price effects and costs related to food purchase, preparation and food waste were not taken into account. Prices were collected from only two retail stores in a single city, so price differences between regions were not captured. In addition, the average costs from two different retail stores were used, which may not reflect reality as consumers do not necessarily buy the food items in different retail stores. Moreover, not all food items in each shopping style were exclusively conventional or organic, as not every food item was available for both shopping styles. Therefore, the organic food baskets might be more expensive if they would contain exclusively organic food. Additionally, the analysis focused on a limited selection of foods and representative food items were chosen for each food group. Depending on individual preferences, this may not be representative for everyone, but it represents a generality based on the most popular foods in Germany. Furthermore, the study only included legumes and soy as a replacement for meat, but in reality, there is a wide range of meat substitutes available, and this choice can greatly impact the expenses. In addition, the cheapest food items were chosen, which may not represent the actual choice of each household. These limitations suggest that the results of this study should not be interpreted as an exact representation of reality, but as an approximation.

5. Conclusion

This study provides valuable insights into the affordability of a healthy and sustainable diet in Germany. It highlights the potential for cost savings by choosing conventional foods and reducing meat consumption. Furthermore, the findings show that with 30% of disposable income spent on the food basket, a healthy and sustainable diet is affordable for most households buying conventional food, but still out of reach for families on very low incomes. Purchasing organic food items considerably increase the cost of the food baskets, making the diet less affordable for many families. At 15% spending of disposable income, most German families could not afford a PHD, highlighting the importance of families' willingness and ability to increase their spending on the food basket. Comprehensive policy interventions are needed to broaden the acceptance of changing to a healthy and sustainable diet. In addition, financial incentives may be needed to reduce the burden on low-income families, ensuring that human and planetary health is not a choice of wealth.

List of abbreviations

BMEL - German Federal Ministry of Food and Agriculture

DGE – German Nutrition Society

NVS II – National Consumption Study II

PHD - Planetary Health Diet

Supplementary material

Supplementary Material 1: Methodology for modelling a food basket

Supplementary Material 2: Methodology for collecting price data

Supplementary Material 3: Calculations of cost and affordability

Supplementary Material 4: Excel file

References

1. Institute for Health Metrics and Evaluation (IHME) (2019) GBD Compare. https://vizhub.healthdata.org/gbd-compare/# (accessed October 2023).
2. Schienkiewitz A, Ronny Kuhnert R, Blume M, et al. (2022) Übergewicht und Adipositas – GEDA 2019/20200-EHIS. *Journal of Health Monitoring* **7**, 23–31.
3. Heidemann C, Scheidt-Nave C, Beyer A-K, et al. (2021) Gesundheitliche Lage von Erwachsenen in Deutschland – Ergebnisse zu ausgewählten Indikatoren der Studie GEDA 2019/2020-EHIS. *Journal of Health Monitoring* **6**, 3–27.
4. Pörtner H-O, Roberts DC, Poloczanska ES, et al. (2022) IPCC, 2022: Summary for policymakers. In *Climate Change and Land*, pp. 1–36. Cambridge University Press.
5. 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**, 447–492. Lancet Publishing Group.
6. Ojo O, Jiang Y, Ojo OO, et al. (2023) The Association of Planetary Health Diet with the Risk of Type 2 Diabetes and Related Complications: A Systematic Review. *Healthcare* **11**, 1120. MDPI.
7. Shi W, Huang X, Schooling CM, et al. (2023) Red meat consumption, cardiovascular diseases, and diabetes: a systematic review and meta-analysis. *Eur Heart J* **44**, 2626–2635. Oxford University Press (OUP).
8. Qian F, Liu G, Hu FB, et al. (2019) Association Between Plant-Based Dietary Patterns and Risk of Type 2 Diabetes. *JAMA Intern Med* **179**, 1335.
9. Arnett DK, Blumenthal RS, Albert MA, et al. (2019) 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*, e596–e646. NLM (Medline).
10. Gan ZH, Cheong HC, Tu YK, et al. (2021) Association between plant-based dietary patterns and risk of cardiovascular disease: A systematic review and meta-analysis of prospective cohort studies. *Nutrients* **13**, 3952. MDPI.
11. Patterson E, Eustachio Colombo P, Milner J, et al. (2021) Potential health impact of increasing adoption of sustainable dietary practices in Sweden. *BMC Public Health* **21**. BioMed Central Ltd.
12. Afshin A, Sur PJ, Fay KA, et al. (2019) Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet* **393**, 1958–1972. Lancet Publishing Group.

13. Soret S, Mejia A, Batech M, et al. (2014) Climate change mitigation and health effects of varied dietary patterns in real-life settings throughout North America. *American Journal of Clinical Nutrition* **100**. American Society for Nutrition.
14. Springmann M (2023) *Towards healthy and sustainable diets in Germany. An analysis of the environmental effects and policy implications of dietary change in Germany*. German Environment Agency.
15. Yacoub Bach L, Bach YL, Jana BE, et al. (2023) A sustainability analysis of environmental impact, nutritional quality, and price among six popular diets. *Front Sustain Food Syst* **7**, 1021906.
16. Clark M, Springmann M, Rayner M, et al. (2022) Estimating the environmental impacts of 57,000 food products. **119**, e2120584119.
17. Sanders J & Heß J (eds) (2019) *Leistungen des ökologischen Landbaus für Umwelt und Gesellschaft. 2. überarbeitete und ergänzte Auflage. Thünen Report 65*. Braunschweig.
18. Lichtenberg EM, Kennedy CM, Kremen C, et al. (2017) A global synthesis of the effects of diversified farming systems on arthropod diversity within fields and across agricultural landscapes. *Glob Chang Biol* **23**, 4946–4957. Blackwell Publishing Ltd.
19. Michalke A, Köhler S, Messmann L, et al. (2023) True cost accounting of organic and conventional food production. *J Clean Prod* **408**, 137134. Elsevier Ltd.
20. Max Rubner-Institut (2008) *Nationale Verzehrsstudie II, Ergebnisbericht, Teil 2, Die bundesweite Befragung zur Ernährung von Jugendlichen und Erwachsenen*. Karlsruhe.
21. Eurostat (2022) Self-perceived health by sex, age and income quintile. https://ec.europa.eu/eurostat/databrowser/view/HLTH_SILC_10__custom_7682016/default/table?lang=en (accessed October 2023).
22. Seubelt N, Michalke A & Gaugler T (2022) Influencing Factors for Sustainable Dietary Transformation—A Case Study of German Food Consumption. *Foods* **11**, 227. MDPI.
23. Darmon N & Drewnowski A (2015) Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: A systematic review and analysis. *Nutr Rev* **73**, 643–660. Oxford University Press.

24. Afshin A, Peñalvo JL, Gobbo L Del, et al. (2017) The prospective impact of food pricing on improving dietary consumption: A systematic review and meta-analysis. *PLoS One* **12**, e0172277. Public Library of Science.
25. Lewis M, McNaughton SA, Rychetnik L, et al. (2021) Dietary intake, cost and affordability by socioeconomic group in Australia. *Int J Environ Res Public Health* **18**, 13315. MDPI.
26. Kabisch S, Wenschuh S, Buccellato P, et al. (2021) Affordability of Different Isocaloric Healthy Diets in Germany—An Assessment of Food Prices for Seven Distinct Food Patterns. *Nutrients* **13**, 3037. MDPI AG.
27. Rao M, Afshin A, Singh G, et al. (2013) Do healthier foods and diet patterns cost more than less healthy options? A systematic review and meta-analysis. *BMJ Open* **3**, 4277.
28. Bai Y, Alemu R, Block SA, et al. (2021) Cost and affordability of nutritious diets at retail prices: Evidence from 177 countries. *Food Policy* **99**, 101983. Elsevier Ltd.
29. Lee AJ, Kane S, Lewis M, et al. (2018) Healthy diets ASAP - Australian Standardised Affordability and Pricing methods protocol. *Nutr J* **17**, 88. BioMed Central Ltd.
30. Eurostat (2023) Konsumausgaben der privaten Haushalte nach Verwendungszwecken. https://ec.europa.eu/eurostat/databrowser/view/tec00134/default/table?lang=de (accessed October 2023).
31. Wissenschaftlicher Beirat für Agrarpolitik & Ernährung und gesundheitlichen Verbraucherschutz beim BMEL (2023) *Ernährungsarmut unter Pandemiebedingungen. Stellungnahme.* Berlin.
32. Deutsche Gesellschaft für Ernährung (2013) Flexitarier — die flexiblen Vegetarier. https://www.dge.de/wissenschaft/weitere-publikationen/fachinformationen/flexitarier-die-flexiblen-vegetarier/ (accessed October 2023).
33. Barosh L, Friel S, Engelhardt K, et al. (2014) The cost of a healthy and sustainable diet - Who can afford it? *Aust N Z J Public Health* **38**, 7–12.
34. Hoenink JC, Waterlander W, Vandevijvere S, et al. (2022) The cost of healthy versus current diets in the Netherlands for households with a low, middle and high education. *SSM Popul Health* **20**, 101296. Elsevier Ltd.

35. Russell C, Whelan J & Love P (2022) Assessing the Cost of Healthy and Unhealthy Diets: A Systematic Review of Methods. *Curr Nutr Rep*, 600–617. Springer.
36. Goulding T, Lindberg R & Russell CG (2020) The affordability of a healthy and sustainable diet: An Australian case study. *Nutr J* **19**, 109. BioMed Central Ltd.
37. Malek L & Umberger WJ (2021) How flexible are flexitarians? Examining diversity in dietary patterns, motivations and future intentions. *Cleaner and Responsible Consumption* **3**, 100038. Elsevier Ltd.
38. Cambridge Dictionary Meat. *Cambridge University Press & Assessment* . https://dictionary.cambridge.org/dictionary/english/meat (accessed October 2023).
39. Deutsche Gesellschaft für Ernährung e. V. DGE-Ernährungskreis. Orientierungswerte. https://www.dge.de/gesunde-ernaehrung/dge-ernaehrungsempfehlungen/dge-ernaehrungskreis/speiseplan/standard-titel/ (accessed October 2023).
40. Bundesministerium für Ernährung und Landwirtschaft (2022) Ernährung, Fischerei. Tabellen zu Ernährung und Fischerei. SJT-4040500-0000.xlsx Verbrauch von Gemüse nach Arten. https://www.bmel-statistik.de/ernaehrung-fischerei/tabellen-zu-ernaehrung-und-fischerei (accessed May 2023).
41. Bundesministerium für Ernährung und Landwirtschaft (2022) Ernährung, Fischerei. Tabellen zu Ernährung und Fischerei. SJT-4040800-0000.xlsx Verbrauch von Obst nach Arten. https://www.bmel-statistik.de/ernaehrung-fischerei/tabellen-zu-ernaehrung-und-fischerei (accessed May 2023).
42. Hohoff E, Zahn H, Weder S, et al. (2022) Food costs for vegetarian, vegan and omni- vore child nutrition: is a sustainable diet feasible with Hartz IV? *Ernahrungs Umschau* **69**, 136–140. Umschau Zeitschriftenverlag Breidenstein GmbH.
43. Statistisches Bundesamt (Destatis) (2023) Ein Fünftel der Bevölkerung in Deutschland hatte 2021 ein Nettoeinkommen von unter 16 300 Euro im Jahr. https://www.destatis.de/DE/Presse/Pressemitteilungen/2022/10/PD22_N062_63.html (accessed October 2023).
44. Statistisches Bundesamt (Destatis) (2023) Konjunkturindikatoren. Verbraucherpreisindex für Deutschland. https://www.destatis.de/DE/Themen/Wirtschaft/Konjunkturindikatoren/Basisdaten/vpi001j.html (accessed October 2023).
45. forsa Gesellschaft für Sozialforschung und statistische Analysen mbH (2023) Ernährungsreport 2023. Ergebnisse einer repräsentativen Bevölkerungsbefragung.

https://www.bmel.de/SharedDocs/Downloads/DE/_Ernaehrung/forsa-ernaehrungsreport-2023-tabellen.pdf?__blob=publicationFile&v=2 (accessed October 2023).

46. Nutrition Hub & Bundesanstalt für Landwirtschaft und Ernährung (BLE) (2023) *Trendreport Ernährung 2023. Die 10 wichtigsten Ernährungstrends*.
47. Andreyeva T, Marple K, Moore TE, et al. (2022) Evaluation of Economic and Health Outcomes Associated with Food Taxes and Subsidies: A Systematic Review and Meta-analysis. *JAMA Netw Open* **5**, E2214371. American Medical Association.
48. forsa Gesellschaft für Sozialforschung und statistische Analysen mbH (2023) Pflanzenbetonte Ernährung Ergebnisse einer repräsentativen Bevölkerungsbefragung. https://www.bvlh.net/fileadmin/redaktion/downloads/pdf/2023/forsa-Umfrage_Pflanzenbetonte_Ernährung.pdf (accessed October 2023).
49. Springmann M, Mason-D'Croz D, Robinson S, et al. (2017) Mitigation potential and global health impacts from emissions pricing of food commodities. *Nat Clim Chang* **7**, 69–74. Nature Publishing Group.

Supplementary Material for: Wealth for Health? Affordability of a Healthy and Sustainable Diet – A Food Basket Study

Contents:

Supplementary Material 1

Methodology for modelling a food basket

Based on previous published studies analysing food prices[1–6], the food basket approach was selected in this study to analyse the cost and affordability of a healthy and sustainable diet. The Planetary Health Diet (PHD) was chosen as the reference diet to ensure that the diet was both healthy and sustainable[7] and it was assumed that the recommendations in g/day of the PHD would ensure coverage of daily nutrient requirements. Therefore, the recommendations in g/day were used to create a food basket, as Seubelt and colleagues did[5]. The PHD was selected as the reference diet because Springmann and colleagues analysed in their study that the PHD would be more sustainable than the current dietary recommendations of the German Nutrition Society (DGE)[8]. The PHD contains less meat and more vegetables, fruit, legumes and nuts, so the diet would result in lower greenhouse gas emissions than the DGE guidelines[8]. As the PHD is a global diet, a variety of data sources, including information from the German Federal Ministry of Food and Agriculture (BMEL) and surveys, were used to adapt the diet to German consumption patterns (see below for more details). All these data refer to the situation in May 2023. Based on recently published studies, a family of two adults and two children was chosen as the reference household[2,6,9]. Following a German study by Kabisch et al.[6] using a Physical Activity Level (PAL) of 1.6, the ages of the family members and the daily energy intakes were as follows: 2700 kcal for a 21-51 year old man, 2100 kcal for a woman of the same age, 2200 kcal for a 10-13 year old boy and 2000 kcal for a girl of the same age.

The PHD provides example recommendations for different food groups in g/day for an individual with a daily energy requirement of 2500 kcal. Therefore, the recommendations in g/day were adjusted for each household member based on their specific energy needs. An example is given below. All calculations can be found in Supplementary Material 4 on the respective sheets for each family member.

Sample calculation to adjust the daily energy requirement for a girl in the reference family:

PHD recommendations for 2500 kcal/day
Girl (PAL 1.6): 2000 kcal/day

$$\frac{2000\ kcal/day}{2500\ kcal/day} = 0.8$$

For each food item, the reference value in g/day was multiplied by 0.8 to get a total energy requirement of 2000 kcal per day. This adjustment was carried out for each member of the reference household.

Based on the PHD[7] and the DGE[10], the study included nine food groups: 1) whole grains, 2) tubers/starchy vegetables, 3) vegetables, 4) fruits, 5) dairy foods, 6) protein sources, 7) added fats, 8) added sugars and sweets, 9) beverages. The foods representing each food group were made up as follows:

Food group 1: Whole grains

As the PHD recommendations do not provide specific portion sizes for different types of whole grains, this food group was adapted to the German dietary patterns by using the recommendations of the Giessen Vegetarian Food Pyramid by Weder et al.[11]. In order to model the food basket as closely as possible, a sample menu for a week was created for an individual with 2500 kcal, assuming three meals per day consisting of cereals (here oat flakes as an example), whole grain bread, whole grain rice and whole grain noodles[11]. Furthermore, it was assumed that a portion of oat flakes is 40 g, based on a recipe from Die Ernährungs-Docs[12]. In addition to whole grain bread, it was assumed that the same amount of whole grain bread rolls were consumed to provide more variety, as bread is eaten in many varieties in Germany[13]. The different types of whole grains and the assumed portions in g/week are shown in Table 1. To match the total amount of whole grains per week recommended by the PHD, the amount of whole grain noodles was adjusted so that the portions added up to 1624 g/week.

At the end, the amounts were divided by seven to get the daily amount in grams.

Table 1 Assumed consumption of different types of whole grains for one week

Representative example of whole grains	**Assumed portion for one week**
Oat flakes	7 portions á 40g
Whole grain bread	3.5 portions á 100g (2 slices á 50g)
Multigrain bread rolls	3.5 portions á 100g
Whole grain rice (uncooked)	3.5 portions á 60g
Whole grain noodles (uncooked)	3.5 portions á 125g

Food group 2: Tubers/Starchy vegetables

Because cassava is not commonly consumed in Germany, only potatoes were included in this food group.

Food group 3: Vegetables

For vegetables, data from the BMEL 2021/2022 statistics[14] were used to select the most commonly consumed vegetables in Germany. Where several examples of a vegetable type were given, a single representative was chosen on the basis of availability in both retail stores (Table 2). In the category 'other vegetables together', four different vegetables were selected, namely zucchini, broccoli, aubergine and orange/red pepper, again based on their availability in both retail stores. A further analysis of which vegetables were chosen was not carried out due to lack of data and time. Although this subgroup ended up with a large share, only four representative vegetables were chosen for simplicity's sake.

Table 2 Chosen vegetable if more than one example was given in the BMEL statistics

Vegetable type with several examples	**Chosen vegetable as representative**
White cabbage, red cabbage	White cabbage
Savoy cabbage, kohlrabi, Chinese cabbage	Kohlrabi
Cauliflower, kale	Cauliflower
Carrots, beetroot	Carrots
Lettuce and iceberg lettuce	Iceberg lettuce
Other lettuces	Romaine lettuce
Other vegetables together	Zucchini, broccoli, aubergine, pepper orange/red

A distribution of shares was calculated on the basis of the consumption data in kg/person given in the BMEL statistics. These amounts were calculated in g/year and g/day assuming that a year has 365 days. Legumes were excluded from this list as they belong to the food group of protein sources in the PHD. Only vegetables with a share of more than 1% were used for this calculation, so Brussels sprouts and celery were excluded. Because the PHD is divided into dark green, orange/red and other vegetables, the food items were divided into these categories. The share of each vegetable was then multiplied by the reference amount

in g/day to calculate the quantities for each vegetable. An example is given below. All shares were calculated in Supplementary Material 4 on the 'Calculations of share' sheet.

Example calculation of the daily cost of a cucumber:
Data from the BMEL statistics: 7.5420 kg/year

1. Calculation in g/year
*7.5421 kg/year * 1000 = 7542.05 g/year*

2. Calculation in g/day

$$\frac{7542.05\ g/year}{365} = 20.66\ g/day$$

3. Calculation of the share
Cucumbers were categorised as dark green vegetables. The total amount of dark green vegetables according to the BMEL statistics was 84.57 g/day. Therefore, the amount of cucumber was divided by the total amount to calculate the proportion.

$$\frac{20.66\ g/day}{84.57\ g/day} = 0.2443$$

4. Calculation of the recommended daily intake according to the PHD
The PHD recommends 100g of dark green vegetables per day.

*0.2443*100g = 24.434 g/day*

The food basket based on the PHD contains an intake of 24.434 g of cucumber per day.

Tomatoes were assumed to be consumed fresh, chopped in tins and strained in tins to provide more variety. This results in a total of 19 different types of vegetables in this food group, including fresh, frozen and tinned products, as it was assumed that not only fresh products would be bought. The choice of fresh, frozen or tinned food items was made based on availability in both stores. Further product details and calculations can be found in Supplementary Material 4.

Food group 4: Fruits

For fruits, data from the BMEL 2021/2022 statistics[15] were used to select the most commonly consumed fruits in Germany. The procedure was the same as for vegetables. Currants and blackberries were excluded as their share was less than 1%. Cherries were not available in both stores and were therefore excluded. A total of 10 fruits were assessed, including both fresh and frozen options. Again, the choice of fresh and frozen options was made based on availability in both retail stores. See also Supplementary Material 4 for further details and calculations.

Food group 5: Dairy foods

The different types of dairy foods were chosen according to the results of the National Nutrition Survey II (NVS II) Results Report, Part 2[13] and data from the Federal Office for Agriculture and Food (BLE)[16]. According to the NVS II[13], whole milk was the most consumed product in this food group and therefore accounted for the largest share. Milk products were the second most consumed, followed by cheese and curd cheese. Plain yogurt was chosen as a representative example of milk products. Where there was more than one option for fat content, the low-fat option was chosen. Due to time constraints, a detailed analysis of the choice of fat content was not carried out. To cover different types of cheese, one item of each type of cheese from the BLE was chosen as a representative (Table 3), assuming that they were consumed in the same quantities per day (10 g/day)[16,17].

Table 3 Type of cheese according to the BLE data and the chosen food item as a representative [16]

Type of cheese	**Chosen cheese as a representative**
Semi-hard cheese	Gouda cheese[17]
Pasta Filata Cheese	Mozzarella
Hard cheese	Emmental[17]
Curdled milk	Sour cream, 10% fat
Cream cheese	Plain cream cheese
Soft cheese	Camembert[17]
Processed cheese	Excluded as no processed food in the PHD

Food group 6: Protein sources

Meat

Meat, as defined by the Cambridge Dictionary, includes beef, pork, poultry and fish[18]. One representative was chosen for beef, pork and poultry. In order to have the same variety for fish as for livestock meat, three different fish products were chosen according to the most popular fish types in Germany[19]. It was assumed that these three types were consumed in equal quantities.

Eggs

Eggs of size M were assessed and it was assumed that an egg weighs 50 g. Therefore, it was assumed that a package with ten eggs weighs 500 g. As the organic variant at REWE was only available with six eggs, it was assumed that this package weighs 300 g.

Legumes

Because of the central role of legumes in the PHD, six different types were assessed to provide a wide variety[20]. In addition, uncooked, frozen and tinned legumes were selected based on availability. It was assumed that all types of legumes were consumed in equal amounts. Peanuts were excluded here as they belong to the subgroup of nuts in the PHD.

Soy

Natural tofu and smoked tofu were assessed as representatives in this subgroup. It was assumed that they were consumed in the same amounts.

Nuts

In the PHD, nuts were divided into peanuts and tree nuts. For the subgroup of tree nuts, the two most popular nut types in Germany after peanuts were chosen[21], assuming that they were consumed in equal quantities.

Calculation of meat replacement

Because this study analysed different variants of the PHD with different amounts of meat consumed per day, the subcategories beef, pork, poultry, fish, legumes and soy were adjusted for each level of meat frequency. The EAT-Lancet Commission recommendations for a daily energy intake of 2500 kcal suggested a weekly meat consumption of 497 g[7]. Using three different levels of meat consumption by Malek et al.[22], this would be equivalent to

consuming meat four times a week, resulting in 124.25 g per portion and falling into the first meat frequency level of heavy meat consumption. The second level, moderate meat consumption, with meat consumed twice a week, would result in 248.5 g, and the third level, light meat consumption, with meat consumed once every two weeks, would result in 62.125 g per week. In this study it was assumed that one portion of meat can be replaced by 60 g of tofu or 50 g of legumes (uncooked). The choice and amount of meat substitutes were made based on the Giessen Vegetarian Food Pyramid[11] and the recommendations for a vegetarian diet by Leitzmann and Keller[23].

First, the share of each type of meat in the reference PHD was calculated. Then, the quantities for the moderate and light diets were adjusted to this distribution. Lastly, the amounts were divided by seven to obtain the amount per day. For simplicity, it was assumed that by replacing meat, the total daily calorie intake would not change and that all the required nutrients would still be obtained. The calculations and requirements in g/day for each meat frequency level are listed in Supplementary Material 4 in the sheets "Light (L) PHD", "Moderate (M) PHD" and "Heavy (H) PHD", changes are highlighted in red.

Food group 7: Added fats

As it is not common to use pure palm oil in Germany, margarine, which often contains palm oil as an ingredient, was added here instead. Unsaturated oils were represented by rapeseed, olive and linseed oil[23–25]. Instead of lard/tallow, salted butter was chosen as a more common animal fat in Germany[25].

Food group 8: Added sugars and sweets

To be closer to reality, it was assumed that in addition to simple sugars, sweets were also consumed, so this food group was extended to 'added sugars and sweets'. Chocolate and fruit gums were chosen as representatives, as they belong to the most popular sweets in Germany[26]. Although the chosen sweets contain other ingredients besides sugar, they were only added to the food group 'added sugars and sweets' and it was assumed that white sugar, chocolate and fruit gums were consumed equally. For simplicity, the total kcal of the food basket for each individual was not changed.

Food group 9: Beverages

This food group was added to the PHD in accordance with the recommendations of the DGE[10]. Only bottled mineral water was evaluated, as this seems to be the preferred choice

in Germany[27]. Moreover, it was assumed that adults drink one cup of coffee and one cup of tea (200 ml each) per day[28], whereas children drink two cups of tea per day and no coffee. The most popular type of tea was chosen as representative[29] and it was assumed that one tea bag was needed for a 200 ml cup. For coffee, it was assumed that 12 g of coffee powder was needed for a 200 ml cup[30]. For the sake of simplicity, the additional cost of tap water needed for coffee and tea was not included. To calculate the distribution of beverages for each household member, it was assumed that the amount of coffee and tea was always 200 ml for one cup, and the consumption of mineral water was the difference between the total amount needed per day and the coffee and tea. Although not recommended, but closer to reality, it was assumed that alcoholic beverages were also consumed by the adults. Therefore, one beer (0.33 l) and one glass of red wine (0.25 l) per week were chosen, as these were among the most popular alcoholic beverages in Germany[28]. Similar assumptions were made for children. It was assumed that children drink one glass of a soft drink and one glass of a fruit juice (200 ml each) per week, with the most popular options selected[28,31]. The alcoholic beverages, the soft drink and the fruit juice were added to the recommended intake of beverages and to the individual energy requirements without making any adjustments for sake of simplicity.

This resulted in a list of 75 foods for adults and 74 foods for children. All selected food items and the daily amounts are listed in Supplementary Material 4.

Supplementary Material 2

Methodology for collecting price data

Two local food retailers in Giessen, Hesse, Germany, were chosen to calculate the average cost of the food baskets. Prices were collected in euro (€) in May 2023, online at REWE, where a store in Giessen was selected, and locally at an ALDI Süd store. For each retail store, an Excel sheet was used to collect product names, product prices and prices per kilogram (kg). All these data are listed in Supplementary Material 4 in the sheets "Price list REWE" and "Price list ALDI Süd".

REWE and ALDI Süd were chosen because they are two different types of stores, a supermarket and a discounter, in order to have a wide range of products (more products at REWE), and the lowest prices (lower prices at ALDI Süd) to calculate the average cost. In this study, a detailed analysis of the price difference between the two stores was not carried out, as this study only focused on the price difference of different shopping styles and the frequency of meat consumption. Organic food was defined as food item with at least an EU organic logo. If a product was not available in one shopping style, the price of the product in the other selected retail store was collected. If a product was not available there either, the other shopping style was chosen. If a product was not available at all in one store (neither conventional nor organic), the price was taken over from the other store. Differences in package size between conventional and organic products were not considered, as organic products are often smaller in size.

The cheapest products were selected. In case there were multiple options, the medium size was chosen. If a product was on sale, the regular price was recorded after the price promotion. For products in tins or jars, the total filling amount was used to calculate the price per kg instead of the drained amount, as the total product price was relevant.

In the food group of vegetables, average weights were determined for kohlrabi, leek, cucumber, aubergine, iceberg lettuce and romaine lettuce, because only unit prices were available instead of prices per kg. Therefore, median weights from the Federal Office for Consumer Protection and Food Safety were used[32] and are presented in Table 4. Median weights were chosen to avoid outliers. As no data was available for romaine lettuce, three samples from each store were weighed and the middle one used as the median weight.

Table 4 Median weight of different vegetables

Vegetable	**Median weight**
Kohlrabi	307 g[32]
Leek	240 g[32]
Iceberg lettuce	703 g[32]
Romaine lettuce	240 g (self-weighed at ALDI Süd) 383 g (self-weighed at REWE)
Cucumber	456 g[32]
Aubergine	338 g[32]

Supplementary Material 3

Calculations of cost and affordability

1. **Calculation of costs**

Costs were calculated by using Excel, with separate sheets were for each meat frequency level and family member. The required quantities of each food item were multiplied by the price in kg for each product to obtain the cost of each food item per day. This was done in the same way for each family member for each retail store, shopping style and meat frequency level. An example is shown below. Then the prices of all the food items were summed up to get the total price per day and then multiplied by 30, assuming that a month consists of 30 days.

Example of calculating the daily cost of kohlrabi at ALDI Süd for a girl:

Product name: Kohlrabi, fresh
Product price: 0.69€

As only the price per unit was given for kohlrabi, it was assumed that one kohlrabi weighed 307 g[32].

First, the price per kg of fresh kohlrabi was calculated:

$$\frac{1000}{307g} * 0.69€ = 2.25€\ per\ kg$$

Secondly, the price per kg was multiplied by the required intake for the family member. For a girl with an energy intake of 2000 kcal/day, she would need 6.548 g of kohlrabi per day:

$$\frac{2.25€}{1000} * \frac{6.548g}{day} = 0.02€\ per\ day$$

The price of fresh kohlrabi for a girl in the reference family would be 0.02€ per day.

The average monthly cost of the two grocery stores was then calculated for each person and shopping style. Finally, the food basket costs for each family member were added to get the

cost for the whole family. See Supplementary Material 4 for the daily and monthly food basket costs for each family member and the costs for the whole family.

2. Calculation of cost changes between the diets

The influence of the shopping style and meat frequency level was calculated as a percentage change using the following mathematical formula:

$$\textit{Cost difference (\%)} = \left(\frac{Total\ cost\ diet\ 1 - Total\ cost\ diet\ 2}{Total\ cost\ diet\ 2}\right) * 100$$

See Supplementary Material 4 (Sheet "Total cost and affordability") for further details.

3. Calculation of cost shares

The cost shares of each food group were calculated as an average for the whole family.
First, the average cost of the two retail stores was calculated for each food group, for each household member, shopping style and meat frequency level. The average cost shares of each family member were then added to obtain the average cost share for the whole household. Finally, all costs were multiplied by 30 to get the monthly shares. The cost shares were expressed in euro (€).
Meat, as defined by the Cambridge Dictionary, includes beef, pork, poultry and fish[18], so these were grouped together as meat. Legumes and soy were also grouped together for this calculation because both were examples of plant-based alternatives. This was done as the study aimed to determine the overall cost change when meat was replaced, rather than identifying the most affordable meat alternative. See Supplementary Material 4 (Sheet "Calculation cost shares") for more details.

4. Calculation of affordability

The monthly costs and the 30% and 15% benchmarks were used to estimate the monthly disposable income required. An example calculation is shown below.

Example calculation of monthly income required:

Diet: Heavy Conventional
Total cost: 529€

For a benchmark of spending 30% of disposable income:

$$\frac{529€}{30} * 100 = 1763€$$

An average German family spending 30% of their disposable income on food and beverages would need at least 1763€ per month to afford the heavy conventional diet.

For a benchmark of 15% spending of disposable income:

$$\frac{529€}{15} * 100 = 3527€$$

An average German family spending 15% of their disposable income on food and beverages would need at least 3527€ per month to afford the heavy conventional diet.

See Supplementary Material 4 (Sheet "Total cost and affordability") for further details. All final results have been rounded to whole numbers for ease of reading and understanding.

References

1. Barosh L, Friel S, Engelhardt K, et al. (2014) The cost of a healthy and sustainable diet - Who can afford it? *Aust N Z J Public Health* **38**, 7–12.
2. Hoenink JC, Waterlander W, Vandevijvere S, et al. (2022) The cost of healthy versus current diets in the Netherlands for households with a low, middle and high education. *SSM Popul Health* **20**, 101296. Elsevier Ltd.
3. Russell C, Whelan J & Love P (2022) Assessing the Cost of Healthy and Unhealthy Diets: A Systematic Review of Methods. *Curr Nutr Rep*, 600–617. Springer.
4. Goulding T, Lindberg R & Russell CG (2020) The affordability of a healthy and sustainable diet: An Australian case study. *Nutr J* **19**, 109. BioMed Central Ltd.
5. Seubelt N, Michalke A & Gaugler T (2022) Influencing Factors for Sustainable Dietary Transformation—A Case Study of German Food Consumption. *Foods* **11**, 227. MDPI.
6. Kabisch S, Wenschuh S, Buccellato P, et al. (2021) Affordability of Different Isocaloric Healthy Diets in Germany—An Assessment of Food Prices for Seven Distinct Food Patterns. *Nutrients* **13**, 3037. MDPI AG.
7. 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**, 447–492. Lancet Publishing Group.
8. Springmann M (2023) *Towards healthy and sustainable diets in Germany. An analysis of the environmental effects and policy implications of dietary change in Germany*. German Environment Agency.
9. Lee AJ, Kane S, Lewis M, et al. (2018) Healthy diets ASAP - Australian Standardised Affordability and Pricing methods protocol. *Nutr J* **17**, 88. BioMed Central Ltd.
10. Deutsche Gesellschaft für Ernährung e. V. DGE-Ernährungskreis. Orientierungswerte. https://www.dge.de/gesunde-ernaehrung/dge-ernaehrungsempfehlungen/dge-ernaehrungskreis/speiseplan/standard-titel/ (accessed October 2023).
11. Weder S, Leitzmann C & Markus K (2019) Die Gießener Vegetarische Lebensmittelpyramide - Ein Update. *Ernährung im Fokus 03*, 206–212.
12. Die Ernährungs-Docs Beeren-Porridge. https://www.ndr.de/ratgeber/kochen/rezepte/Beeren-Porridge,rezept2324.html (accessed October 2023).

13. Max Rubner-Institut (2008) *Nationale Verzehrsstudie II, Ergebnisbericht, Teil 2, Die bundesweite Befragung zur Ernährung von Jugendlichen und Erwachsenen*. Karlsruhe.
14. Bundesministerium für Ernährung und Landwirtschaft (2022) Ernährung, Fischerei. Tabellen zu Ernährung und Fischerei. SJT-4040500-0000.xlsx Verbrauch von Gemüse nach Arten. https://www.bmel-statistik.de/ernaehrung-fischerei/tabellen-zu-ernaehrung-und-fischerei (accessed May 2023).
15. Bundesministerium für Ernährung und Landwirtschaft (2022) Ernährung, Fischerei. Tabellen zu Ernährung und Fischerei. SJT-4040800-0000.xlsx Verbrauch von Obst nach Arten. https://www.bmel-statistik.de/ernaehrung-fischerei/tabellen-zu-ernaehrung-und-fischerei (accessed May 2023).
16. Bundesanstalt für Landwirtschaft und Ernährung (2023) Bericht zur Markt-und Versorgungslage mit Milch und Milcherzeugnissen. Bonn. https://www.ble.de/SharedDocs/Downloads/DE/BZL/Daten-Berichte/MilchUndMilcherzeugnisse/JaehrlicheErgebnisse/Deutschland/2023BerichtMilch.pdf?__blob=publicationFile&v=2 (accessed October 2023).
17. Börgermann B (2019) Gouda ist der Lieblingskäse der Deutschen. *Milchindustrieverband*. https://milchindustrie.de/pressemitteilungen/gouda-ist-der-lieblingskaese-der-deutschen/ (accessed October 2023).
18. Cambridge Dictionary Meat. *Cambridge University Press & Assessment* . https://dictionary.cambridge.org/dictionary/english/meat (accessed October 2023).
19. Fisch-Informationszentrum e.V. (2021) Infografik Fischmarktfavoriten 2021. https://www.fischinfo.de/index.php/markt/114-infografiken (accessed July 2023).
20. Ettischer A (2019) Superfoods Linsen, Bohnen & Co.: Liste der beliebtesten Hülsenfrüchte. *Gesundnah. AOK Baden-Württemberg*. https://www.aok.de/bw-gesundnah/ernaehrung-und-rezepte/huelsenfruechte-liste-gaengiger-sorten (accessed October 2023).
21. Bundesanstalt für Landwirtschaft und Ernährung (2021) Nussbilanz 2020: Erdnüsse, Mandeln und Haselnüsse am beliebtesten. https://www.ble.de/SharedDocs/Pressemitteilungen/DE/2021/211117_Nussbilanz.html (accessed October 2023).
22. Malek L & Umberger WJ (2021) How flexible are flexitarians? Examining diversity in dietary patterns, motivations and future intentions. *Cleaner and Responsible Consumption* **3**, 100038. Elsevier Ltd.

23. Leitzmann C & Keller M (2020) *Vegetarische und vegane Ernährung*. 4th ed. Stuttgart: utb GmbH.
24. OVID Verband der ölsaatenverarbeitenden Industrie in Deutschland e. V. (2023) Rapsöl bleibt beliebtestes Speiseöl. https://www.ovid-verband.de/artikel/meldungen/rapsoel-bleibt-beliebtestes-speiseoel (accessed October 2023).
25. Deutsche Gesellschaft für Ernährung e.V. DGE-Ernährungskreis. Öle und Fette. https://www.dge.de/gesunde-ernaehrung/dge-ernaehrungsempfehlungen/dge-ernaehrungskreis/oele-und-fette/ (accessed October 2023).
26. Janson M (2020) Die beliebtesten Süßigkeiten der Deutschen. *Statista*. https://de.statista.com/infografik/23644/befragte-die-mindestens-woechentlich-folgende-suessigkeiten-verzehren/ (accessed May 2023).
27. Rückert-John J, Kröger M & Ritter J (2020) Konsum von Leitungs- und Flaschenwasser. *Umweltbundesamt*. https://www.umweltbundesamt.de/sites/default/files/medien/2503/dokumente/fact_sheet_leitungs_flaschenwasser.pdf (accessed October 2023).
28. IfD Allensbach (2022) Ranking der meistgekauften bzw. meistkonsumierten Getränke in der Bevölkerung in Deutschland in den Jahren 2020 bis 2022. *Statista*. https://de.statista.com/statistik/daten/studie/170892/umfrage/ranking-der-meistgekauften-konsumierten-getraenke/ (accessed May 2023).
29. Sonnenberg A-K (2020) Deutsche trinken eher Tee als Briten. *YouGov PLC.* https://yougov.de/topics/consumer/articles-reports/2020/11/13/deutsche-trinken-eher-tee-als-briten (accessed October 2023).
30. Coffee Circle Wie viel Kaffeepulver pro Tasse? Die optimale Kaffeedosierung. https://www.coffeecircle.com/de/e/kaffee-dosierung (accessed October 2023).
31. Verband der deutschen Fruchtsaft-Industrie (2023) Pro-Kopf-Konsum der beliebtesten Fruchtsäfte in Deutschland in den Jahren 2005 bis 2022. *Statista*. https://de.statista.com/statistik/daten/studie/6185/umfrage/pro-kopf-verbrauch-der-4-beliebtesten-fruchtsaefte/ (accessed October 2023).
32. Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (2002) Mittlere Gewichte einzelner Obst- und Gemüseerzeugnisse. https://www.bvl.bund.de/SharedDocs/Downloads/04_Pflanzenschutzmittel/rueckst_gew_obst_gemüde_pdf.pdf;jsessionid=8E6B3DA7A0B1612185A7F141F2ED8F86.internet941?__blob=publicationFile&v=4 (accessed October 2023).