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Dietary shifts for climate and Health: Socioeconomic perspectives from Spain

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ABSTRACT

This study examines the carbon footprints (CFs) of Spanish household food consumption in 2022, based on survey-based data. The results are assessed considering differences in food consumption patterns across socio-economic status (SES), categorised by their job status and level of education into high and middle-high, middle, middle-low, and low SES. The analysis included weight, energy, and nitrogen intake and used Life Cycle Assessment (LCA) to assess greenhouse gas (GHG) emissions in terms of carbon dioxide equivalent (CO_2eq). Observed patterns are compared to three reference diets, i.e., the Mediterranean diet (MD), the Planetary healthy diet (PHD), and the Spanish Guideline (SG), selected for their health benefits, low environmental impacts, and cultural relevance. The results revealed overconsumption of ultra-processed foods (UPF) in the average diet, especially processed pork meat, and underconsumption of vegetables and pulses, compared to the reference diets. This overconsumption was higher for high SES, while underconsumption was more evident in lower SES. As a result, high SES show average CFs that are 24% higher than those of low SES, ranging from 2.05 to 2.69 kgCO_2eq/person/day. Compared with the reference diets, the average Spanish household consumption showed a CF 29% higher. Shifting towards healthier and low-carbon diets would require reducing UPFs consumption per capita while increasing the consumption of vegetables, pulses, and plant-based products. The study highlights the importance of including a socioeconomic perspective to tackle the debate on agri-food transition with different target group policies.

1. Introduction

The current agri-food systems play a central role in shaping global dietary patterns, many of which are unsustainable and detrimental to human health (FAO, 2024). Nowadays, unhealthy diets are a top risk factor for disability and death and were responsible for an alarming 11 million deaths worldwide in 2017 alone (Afshin et al., 2019). A major driver of this global health crisis is the unaffordability of healthy diets, which remain out of reach for over one-third of the global population (Ambikapathi et al., 2022; Gaupp et al., 2021). In addition, after decades of slow progress, global undernutrition is rising again (Fanzo and Miachon, 2023). While we fail to provide healthy, sustainable, and affordable diets to everyone, we also lose nearly 20% of the food we produce (Forbes et al., 2021).

The impacts of these dietary patterns extend beyond individuals to affect broader socio-environmental systems. Recent studies estimate that the global cost of unhealthy diets is 3.5 trillion dollars a year (FAO, 2024; Global Diet Quality Project, 2022, p. 4), burdening low-income countries especially. Moreover, food production occupies between 38% and 55% of the Earth's habitable land (Boakes et al., 2024) and contributes up to 34% of total global GHG emissions (Crippa et al., 2021; Tubiello et al., 2022), along with 70% of global water withdrawals and

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more than 80% of withdrawals in agrarian economies (Uhlenbrook et al., 2022). This has resulted in extensive deforestation, air and water pollution, soil degradation, and significant biodiversity loss (Downs et al., 2024; Springmann et al., 2018).

The UN Sustainable Development Goals (SDGs) offer a clear mandate, indicating that national and transnational institutions should rethink a sustainable, healthy future for food systems worldwide. Agri-food system transformation is thus a key accelerator for achieving the SDGs (Sachs, 2016; Valentini et al., 2019). The EAT-Lancet Commission addresses this challenge by underlining dietary solutions for improving health while remaining within environmental planetary boundaries. In this context, Wilkinson (2024) propose the PHD, which is characterised by a high intake of vegetables, fruits, whole grains, nuts, pulses, and unsaturated oils, while recommending a low intake of red meat, sugar, and refined grains. This diet is designed to align with health and environmental standards, considering thresholds for GHG emissions, nitrogen and phosphorus application, water use, biodiversity, and land use (Willett et al., 2019). However, while the PHD serves as a valuable starting point, it is inherently generalised and does not account for the specific contexts in which food choices are made (Hirvonen et al., 2020; Klapp et al., 2025). These choices are influenced by cultural norms, individual preferences (Biesbroek et al., 2023), and socioeconomic factors, all of which must be considered to ensure the creation of a socially acceptable and contextually relevant dietary transition.

In Spain, the transition from the traditional Mediterranean diet to a more Western, unhealthy eating pattern has been linked to higher rates of diet-related chronic diseases and increasing obesity prevalence (Billen et al., 2024; Lassaletta et al., 2014). These patterns have also led to an increase in excessive nitrogen consumption, which results in an excessive protein intake, especially from animal sources (Westhoek et al., 2015). The PHD could be an alternative that needs to be adapted to the national context. In Spain, the Spanish Agency for Food Safety and Nutrition has developed the National Dietary Guidelines, which incorporate the traditionally healthy elements of the Mediterranean and Atlantic diets alongside environmental considerations (López García et al., 2022). Moreover, Spain has pioneered detailed analyses of the interconnections within agri-food systems across system and spatial scales (Rodríguez-Espinosa et al., 2023); the latter positions the country as a valuable international reference for advancing an integrated and system-level understanding of agri-food system complexity.

The shift towards healthier and more sustainable diets is thus becoming a central topic in our societies, and several indicators have been proposed. The CF is widely regarded as one of the most effective indicators for assessing climate change, as it quantifies the total GHG emissions associated with human activities. In agri-food systems, CF is commonly expressed in CO_2eq, calculated at the proportional contribution of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) to global warming (FAO, 2022, p. 3). Studies assess the water and carbon footprint of Spanish dietary patterns and compare them to the PHD and MD, as well as the 2005 Spanish Strategy for Nutrition, Physical Activity, and the Prevention of Obesity (Cambeses-Franco et al., 2022). Their findings highlight the negative environmental impacts of Spanish Dietary Patterns and underscore the need for environmentally oriented behavioural changes. These analyses have evolved to incorporate environmental and socio-economic factors, including regional (Batlle-Bayer et al., 2020; Esteve-Llorens et al., 2020) and climatic zone stratification (Esteve-Llorens et al., 2021). Similarly, González-García et al. (2020) examine the affordability of healthy diets, revealing that the cost of unhealthy diets exceeds that of the Spanish dietary recommendations.

In order to influence food choices, scholars highlight the importance of sewing interventions and policies onto real-life groups of people, considering their traditions, cultural backgrounds, and socio-economic characteristics (Biesbroek et al., 2023). The level of education and income also have significant effects on the way we eat: less nutrient-rich foods are usually cheaper and preferred by lower SES, while healthier food tends to be either more expensive or cheaper but less palatable (Darmon and Drewnowski, 2015). Recent literature explores these trends at the national level and better understands the quality of diets in relation to sociodemographic variables: Spanish-based studies started taking into account gender (Cerrillo et al., 2023), age (Martinez et al., 2022), as well as the cost of healthy diets (González-García et al., 2020), and differences at the NUTS 2 level (Esteve-Llorens et al., 2021). Studies conducted outside of Spain also emphasise other aspects of the contextualization, considering variables such as local consumption patterns, income, gender, traditions, and socioeconomic status (Brocard, 2022; Klapp et al., 2025; Minetto Gellert Paris et al., 2024; Vieux et al., 2018).

Our goal is to build on these studies, analysing food consumption patterns of food consumed at home in Spanish households in 2022 in terms of carbon footprints and weight, nitrogen and energy intakes, compared to three reference diets: the MD, the SG, and the PHD. We also consider the relative performance across SES, categorised based on education level and job status. This study aims to identify dietary shifts in Spanish households that can reduce GHG emissions and enhance nutritional performance, considering the role of diverse population groups as a key driver to design effective and just interventions for dietary shifts.

2. Materials and methods

2.1. Data collection and Spanish dietary habits

The Spanish average diet was obtained from the 2022 Household Average Consumption Survey of the Ministry of Agriculture, Fisheries, and Food (MAPA, 2022b). The survey is conducted on a representative sample of 12,500 households distributed across the entire country, taking into consideration household characteristics such as age, region, and socioeconomic groups. Survey data differentiates consumption habits based on SES across high and middle-high (H-MH), medium (M), medium-low (ML), and low (L) socioeconomic households. SES is obtained as a function of education level and the job status of the primary individual in the household. It must be noted that food consumption per capita does not consider that consumed outside the household, which can make up to 13% of annual consumption in weight (MAPA, 2022a, p. 415). The MAPA database has 687 entries organised by food categories and sub-categories (MAPA, 2022b), aggregated into 458 entries for the sake of the analysis. Beverages were excluded from the analysis. The consumption is registered in kilograms or litres per person per year. The dataset already provides the conversion from household to consumption per capita.

The daily weight intake (g/person/day) is integrated with energy intake (kcal/person/day) and protein intake expressed in nitrogen (kgN/person/year), as these are key elements in diets. Protein intake is expressed in nitrogen to link food consumption patterns with their underlying nitrogen emissions (Westhoek et al., 2015).

In this study, nutritional data were obtained from the database of the Nutritional Characteristics of the Main Foodstuff of our Diet by the Spanish Ministry of Food, Fishery, and Agriculture and complemented, if needed, with the Spanish Food Composition Database BEDCA by the Agriculture and the Food and Agriculture Organization (see **SM**).

We assess the energy intake of the average and SES-related Spanish household consumption in 2022, as well as the energy intake for the MD, the PHD, and the SG, using the following formula:

$$EI = \sum (Qfi \ x \ Efi)$$

Where EI is the energy intake, Q_{fi} is the quantity consumed per food item, and E_{fi} is the energy content of each food item.

We then assessed the nitrogen intake, calculated as:

$$NI = \sum (Qfi \ x \ Pfi \ x \ C)$$

Where NI is the nitrogen intake, Q_{fi} is the quantity consumed of each food item, P_{fi} is the protein content of each food item, and C is the conversion factor, considered to be 16%.

2.2. Dietary recommendations

For comparison purposes, we considered the three above-mentioned dietary recommendations, re-categorised into the main 13 food categories in Table 1. These diets have been chosen for their representativeness both in terms of environmental and health targets and their cultural aspects.

The category "Others" includes different items, depending on the diet. a: sugar equivalent and vegetable oil; b: oil, lard or tallow, and added sugars; c: olive oil; d: snack and olives, honey, bakery items, cookies, breakfast cornflakes, chocolate, cocoa and surrogates, sugar, olive and non-olive oil, margarine, vinegar, broth and juices, coffee and infusions, sauces, seaweeds, spices and condiments, salt, sweet diaries (like smoothies and whipped cream), and butter. *These groups include both fresh and processed foodstuffs.

These guidelines give weight intake and/or servings per person per day. The MD as estimated by Castaldi et al. (2022); the PHD by the EAT-Lancet Commission (Willett et al., 2019); and the 2022 SG by the AESAN (López García et al., 2022). The three alternative diets are defined as in Table 1. As previously done with the average Spanish consumption, we estimated the energy and nitrogen content of the recommended diets.

To facilitate the comparison, we created the food group "others (oil)", which includes items with different characteristics. Oil is included in this group because different recommendations include different kinds of oil (vegetable oil for the MD and PHD, olive oil for the SG). It also includes items that are only in one diet (added sugars for the PHD).

This category is also useful for the SHC. Apart from fats and oils and added sugars (like honey and sugar), this group include all the non-recommended items the Spanish population consumes, such as sweets (bakery items, cookies, smoothies, sweet breakfast cornflakes, to name a few) and culinary aids (vinegar, broth, sauces, etc.). Given the importance of ready-to-eat food in recent decades, we decided to maintain this category separated from other food groups.

Table 1

Weight, energy, and nitrogen intake of dietary food groups estimated for the Mediterranean diet, the Planetary healthy diet, the Spanish guideline, and the Spanish household consumption (SHC).

Weight intake g/person/day				
Food Group	Mediterranean diet (MD)	Planetary healthy diet (PHD)	Spanish guideline (SG)	Spanish consumption (SHC)
Grains	271	232	240	106
Starchy vegetables	86	50	50	72
Vegetables	400	300	525	171*
Fruit	300	200	320	221
Dairy foods	336	250	270	232
Poultry and white meat	29	29	32	32
Pork	7	7	8	55*
Beef and red meat	7	7	8	13*
Eggs	29	13	33	23
Fish and shellfish	64	28	64	53*
Pulses	21	100	43	9
Nuts	30	25	18	9
Others (oil)	60[a] (40)	83[b] (40)	20[c] (20)	178[d] (20)
Total	**1640**	**1324**	**1632**	**1174**
Energy intake kcal/person/day				
Grains	834	666	737	314
Starchy vegetables	75	44	44	52
Vegetables	104	78	137	36*
Fruit	135	90	144	113
Dairy foods	328	214	231	190
Poultry and white meat	48	48	54	56
Pork	24	24	27	139*
Beef and red meat	10	10	11	29*
Eggs	45	20	50	34
Fish and shellfish	59	25	59	51*
Pulses	75	350	151	33
Nuts	181	151	108	54
Others (oil)	426[a] (355)	465[b] (355)	178[c] (178)	474[d] (178)
Total	**2343**	**2186**	**1929**	**1641**
Nitrogen intake kgN/person/year				
Grains	1.38	1.18	1.22	0.51
Starchy vegetables	0.13	0.07	0.07	0.09
Vegetables	0.35	0.26	0.46	0.11*
Fruit	0.12	0.08	0.13	0.09
Dairy foods	0.67	0.50	0.54	0.57
Poultry and white meat	0.34	0.34	0.38	0.38
Pork	0.07	0.07	0.08	1.24*
Beef and red meat	0.10	0.10	0.11	0.31*
Eggs	0.20	0.09	0.24	0.17
Fish and shellfish	0.66	0.29	0.66	0.53*
Pulses	0.27	1.24	0.54	0.11
Nuts	0.31	0.26	0.18	0.09
Others (oil)	0[a] (0)	0[b] (0)	0[c] (0)	0.29[d] (0)
Total	**4.60**	**4.48**	**4.61**	**4.61**

Using a modified categorisation defined by Euromonitor (Baker et al., 2020), we also calculated the energy intake from UPFs. This category includes baked goods, dairy and non-dairy-based sweets, processed meat and fish, meat substitutes, ready-to-eat food, frozen processed potatoes, and dressings and sauces, and it is transversal to several food groups.

2.3. Environmental impact assessment

2.3.1. Carbon footprint

An LCA approach is used to estimate the CF of the Spanish household food consumption, assessing the GHG emissions (ISO 14040/44). We quantified the GHG emissions associated with the food consumed in Spain, following a structured approach: 1) goal and scope 2) system boundaries; and 3) data collection and impact assessment.

2.3.1.1. Goal and scope. For the purpose of this study, the food consumption of Spanish households for the four above-mentioned SES was considered. The functional unit (FU) of diets was 1 g of product per person per day at home. However, each product has been calculated differently based on the existing data in the literature. The functional unit was 1 kg of fresh product for 125 items, including fresh vegetables and fruit, starchy vegetables, cereals, dairy products and other animal-based products. For most fresh and frozen meat, the functional unit was 1 kg of live weight (23 items) or carcass weight (4 items). In these cases, the post-farm allocation also helped with the homogenization of the data. Moreover, the LCA of 16 items, including milk and dairy products, was calculated using as functional unit either 1 kg of fat and protein-corrected milk or 1 kg of energy-corrected milk. In the interest of this study, the two units were considered comparable. The functional units for processed items were 1 kg of pre-cooked product, 1 kg of unpacked product, and 1 kg of canned product.

2.3.1.2. System boundaries. In this study, we only consider the emissions related to the production phase of food products. Existing literature shows that this stage accounts for the majority of GHG emissions—approximately 70% (Crippa et al., 2021; Esteve-Llorens et al., 2020; FAO, 2023). Other life cycle stages, including transportation and household-related activities, are excluded from this analysis due to their relatively minor contributions and the limited variability anticipated within the scope of this study.

2.3.1.3. Data collection and impact assessment. We included 92 food categories, divided into 179 subcategories depending on agricultural production methods. These items were merged into 13 food groups. GHG emissions associated with these 179 subcategories were gathered from a total of 193 studies (see **SM**). The literature review included all those studies that quantify GHG emissions – CO_2, CH_4, and N_2O - of Spanish food production, from single-product studies to more comprehensive studies (Aguilera, 2020).

Certain food items are more extensively documented in the literature than others. This is the case for tomatoes (16 observations), pork (14 observations), and beef (7 observations) (see **SM**). Since many of these values originate from studies conducted in specific regions, they have been cross-referenced with data from the agricultural census in Spain in some cases, while in others, a median value has been used. Yet, other products are still missing from the LCA literature based in Spain. The open-access dataset Su-Eatable Life (Petersson et al., 2021) and Agribalyse (2023) were used to complement our dataset for missing products, mainly UPF – such as sweets, sauces, and canned food – tropical items – for instance, pineapple and coffee – and general items consumed in lower proportions – algae or margarine, to name a few (see **SM**). Considering the latter, we ended up with a total dataset of 387 CFs expressed in $kgCO_2eq$.

The CF was calculated as:

$$CF = \sum (Qfi\ x\ GWPfi)$$

Where Q_{fi} is the quantity consumed of each food item and GWP_{fi} is the Global Warming Potential for each food item.

We used the same database to calculate the CF for both the Spanish households' consumption (including the four SES) and the three guidelines. This exercise allowed the contextualization of the guidelines to the Spanish territory, feeding the scenario of shifts towards more sustainable and healthy diets.

3. Results

3.1. Average Spanish household consumption and dietary recommendations

The total intake for the Average Spanish household consumption is 1174 g/person/day, which is lower than the three reference diets (Table 1). However, the distribution of food groups is substantially different (Fig. 1 and SM). On one hand, the Spanish population consumes at home less than the recommended amount of vegetables, grains, and plant-based proteins (Fig. 1d) and, in smaller amounts, for dairy and fruits. The average consumption also shows a substantial deficit in pulses and nuts, with a combined intake of 18 g/person/day; this remains far behind the 51 g/person/day for the MD and 125 g/person/day of the PHD (Table 1). On the other hand, overconsumption is noticeable for food groups such as red meat, especially for pork meat, which is seven times higher than the recommendations (Table 1). Spanish households also exceed three times in the consumption of ready-to-eat and non-recommended food, the latter included in the food group “others”, which encompasses mostly processed items and sweets (Table 1).

The Average Spanish household consumption shows the lowest energy intake (1641 kcal per person daily) compared with the three reference diets (Table 1), due to the omission of the food eaten outside (see Section 4.1). Aligned with the weight intake, we observe lower calories obtained from grains, pulses, nuts, and dairy, but a greater caloric intake derived from pork and non-recommended items (see “other” in Fig. 2) that increase the energy intake due to the high content of empty calories of sugar and sweets-rich products.

In contrast to the weight and energy intake, the nitrogen shows that the values for the Spanish household consumption are in line with the PHD and the MD, i.e. 4.60-4.61 kgN/person/year, while they remain higher than the PHD, namely 4.48 kgN/person/year (Table 1). Although the difference does not seem relevant, results show that 52-61% of nitrogen in the reference diets originates from grains, fish, or pulses, while the nitrogen intake in the Spanish households is mostly associated with pork, dairy, and fish consumption (51%) (Fig. 3).

3.2. Carbon footprint

The CF estimated for the reference diets is 1.79 $kgCO_2eq$/person/day for the MD, 1.19 $kgCO_2eq$/person/day for the PHD, and 1.88 $kgCO_2eq$/person/day for the SG (Fig. 4). With the lowest values in terms of climate change impacts, the PHD (in Fig. 4a) was the diet with the minor footprint, followed by the MD and the SG.

The low emissions of the PHD are connected with the total weight consumed in this diet, as observed in Section 3.1, which proposes to maximise the energy and protein intakes with a lower amount of food. Another interesting point is the ratio of intake to CF of each food group. Beef and red meat, for example, accounts for 8% of the entire CF of the PHD, with only 7 g/person/day, showing the highest ratio of intake to the total CF. In absolute terms, dairy foods and grains present the highest accumulated footprints, accounting for 28 and 26% of the total, respectively. They are followed by beef, fish and shellfish (6%), and oil, sugars and vegetables, with 5% of the CF each. The rest of the food

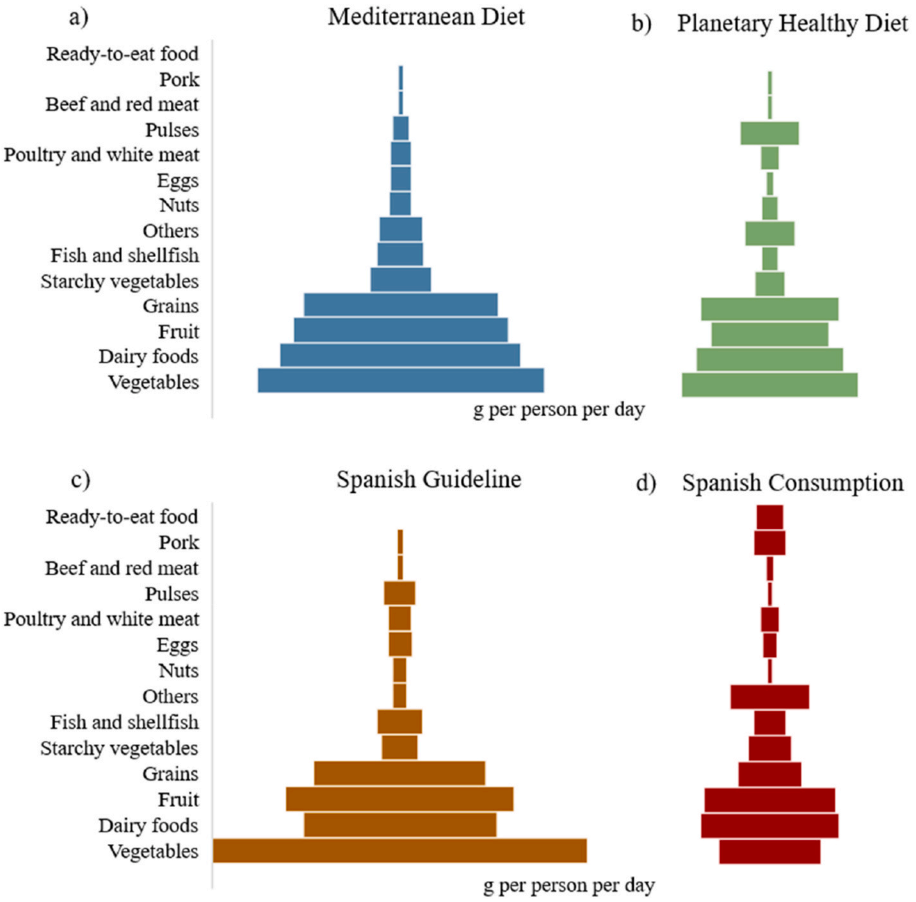

Fig. 1. Weight intake, organised in terms of daily intake for each food group, from the lowest to the highest. The data is represented using the framework of the Pyramid Diet for the **a.** Mediterranean diet; **b.** Planetary healthy diet; **c.** Spanish guideline; **d.** Spanish household consumption.

categories are responsible for less than 4% each (Fig. 4 and Table 1). The lowest ratio intake-CF is given by the pulses, which are recognised as vital for the shift towards healthier and more sustainable diets by the EAT-Lancet (Willett et al., 2019).

Most of the emissions of the MD (Fig. 4b) are associated with dairy food, especially milk and yoghurt, together estimated at 24% of the total CF, and cheese, also responsible for another 23%. The MD is also rich in grains and fish – 12% and 11% of the total footprint, respectively - and beef and red meat, eggs and vegetables, with 5% each. The low intake of pulses and their low emission factors in the MD make its footprint less than 0.1%.

The SG (in Fig. 4c) is aligned with the MD in terms of dairy food-related footprint, which accounts for 41% of the total CF, followed by grains (23%), eggs, fish, and vegetables (6% each), and finally beef and other red meat, which account for 6% of the total CF.

The average Spanish household consumption has a CF of 2.28 kgCO$_2$eq/person/day (Fig. 4d). Despite that, this value is higher than that of the three reference diets. The distribution of the CF for food groups shows significant divergences from the recommended diets: While in the reference diets, more than half of the emissions come from dairy foods and grains, 56% of the real consumption at home comes from dairy, pork, and red meat. Moreover, the accumulated share of GHG emissions from animal origin is higher than 73%, underestimated by the exclusion of the animal-based ingredients in ready-to-eat food and “others”. The four categories with the greatest share of emissions are covered by animal-based products, i.e. dairy foods (26%), fresh and processed pork (20%) and beef and red meat (10%), and finally fish and shellfish (9%) (Fig. 4d).

We observed that the food groups with exceeded consumption, such as processed goods, ready-to-eat items, and fresh and processed pork, show the highest ratio of intake-footprint. In other words, lowering the amount of these categories would have greater repercussions on the CF than reducing other goods.

3.3. *Socioeconomic group analysis*

The average weight intake increases to 1422 g/person/day for the H-MH SES and drops below 1188 g/person/day for the other groups (Fig. 5a). The H-MH SES is the only group with a total intake higher than the average and higher than the PHD weight intake. Observing MAPA Databases on the Food Consumption outside of the household, it is also the group with the highest consumption. Generally, the highest weight intake comes from dairy foods and fruit for every SES, while plant-based proteins occupy the lowest spots (Fig. 5a).

The differences in the weight, energy, and nitrogen intake of food consumed between SES (Fig. 5) lie in the total quantity rather than in the type of food. In other words, the relative distribution of food categories remains consistent across all SES, while the absolute quantity of food consumed varies, generally increasing for higher SES. This results in an overconsumption of pork meat and non-recommended foodstuffs (as “others” in Fig. 5a), higher for high SES (Table 2, see **SM**). This is consequently the group that contributes the most to nitrogen and energy intake, respectively.

Concerning energy intake (Fig. 5b), consumers in higher SES show a robust intake (1887 kcal/person/day) that decreases as the SES become lower (1555 kcal/person/day for the lowest SES). No SES exceeds the total caloric intake recommended by the three guidelines.

The patterns observed for weight and energy intake are repeated in the intake of nitrogen; H-MH SES consume 5.47 kgN/person/year, while for M, M-L, and L SES, the values are 4.65, 4.51, and 4.23 kgN/person/

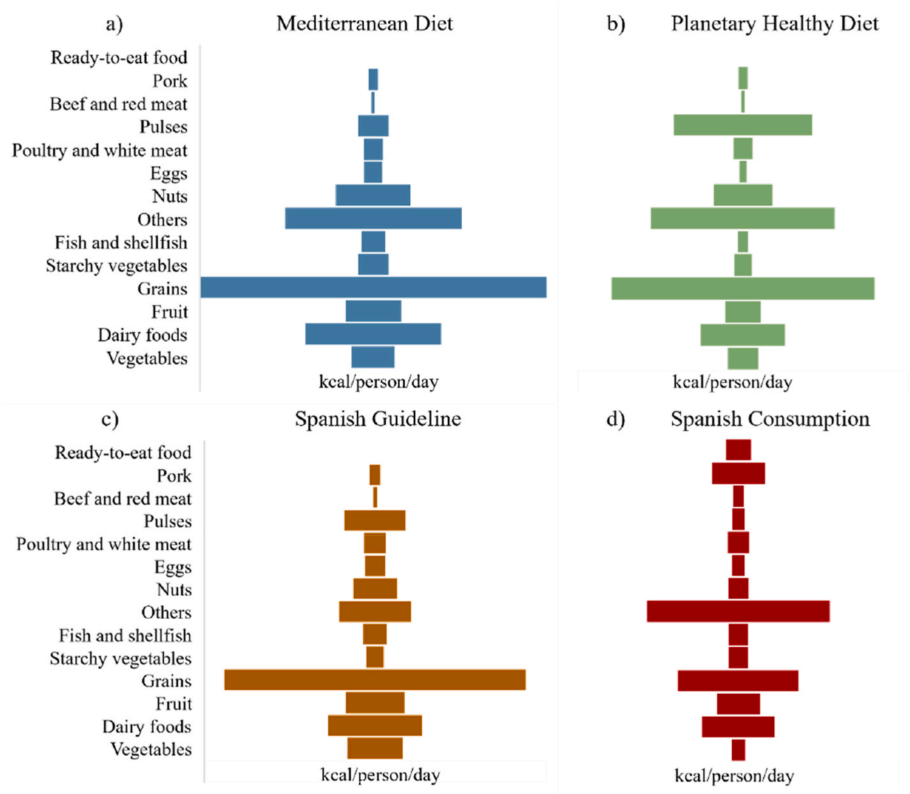

Fig. 2. Energy intake, organised in terms of daily intake for each food group, keeping the list of the weight intake in Fig. 1. The data is represented using the framework of the Pyramid Diet for the **a.** Mediterranean diet; **b.** Planetary healthy diet; **c.** Spanish guideline; **d.** Spanish household consumption.

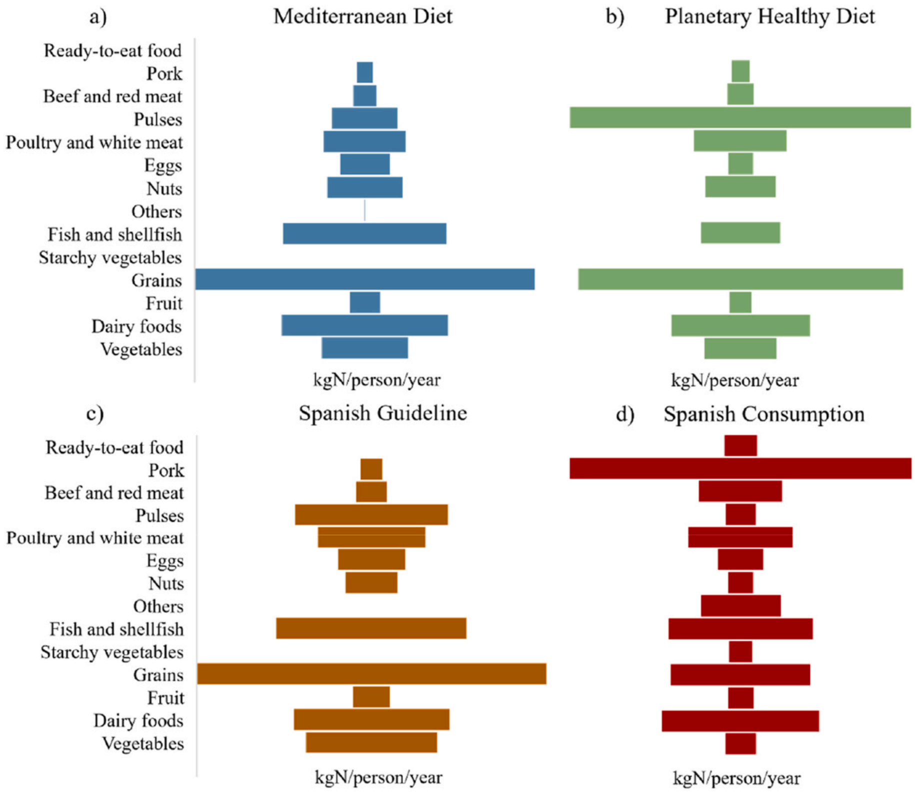

Fig. 3. Nitrogen intake, organised in terms of daily intake for each food group, keeping the list of the weight intake in Fig. 1a. The data is represented using the framework of the Pyramid Diet for the **a.** Mediterranean diet; **b.** Planetary healthy diet; **c.** Spanish guideline; **d.** Spanish household consumption.

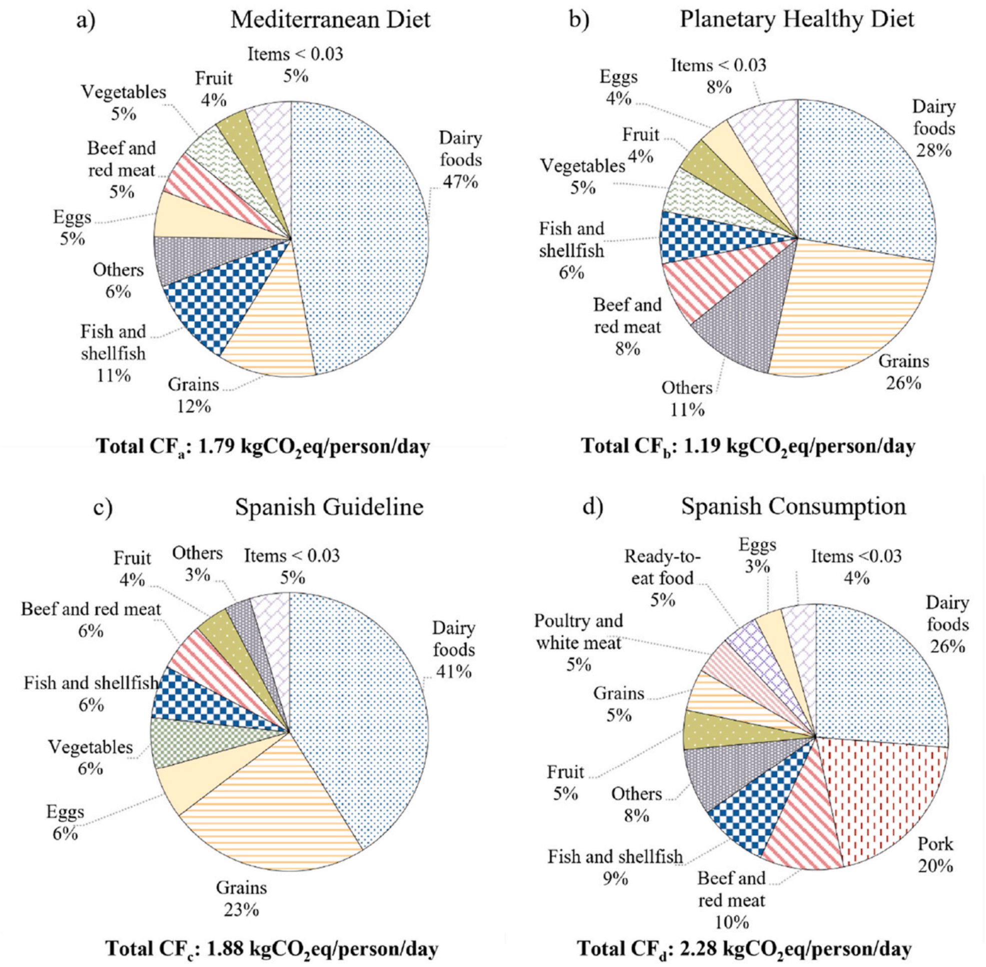

Fig. 4. Share of CF per diet and total CF per diet ($CF_{a,b,c,d}$). **4a**. Share of CF for Planetary healthy diet by food groups; **4b**. Share of CF for the Mediterranean diet by food groups; **4c.** Share of CF for the Spanish guideline by food groups. **4d**. CF of the Average Spanish household consumption by food groups. "Items <0.03" include the sum of all the items that contribute less than 0.03 $kgCO_2eq$/person/day. Absolute data in SM.

year, respectively. The H-MH and M SES nitrogen intakes are higher than the reference diets, while the ML SES is lower than the SG but higher than the MD and PHD. Finally, the L SES shows a deficit in nitrogen intake compared with the three reference diets.

The distribution in food groups also varies from the recommendations (Fig. 5c). The biggest share of nitrogen intake is from pulses in the PHD and from grains in the SG and MD. The three diets also present lower intakes of nitrogen from pork (1-2%) and beef and other red meat (2%). No SES aligns with these values, showing deficits in nitrogen from grains, pulses and vegetables, and excesses in pork (26-27%), beef and other red meat (7%). As for energy and weight, there is also an excess of non-recommended foodstuffs, which accounts for 6% of the total intake for all SES.

Special attention must be paid to non-recommended food. In every group, this category is the highest, covering between 21% and 25% of the total energy intake, and includes mostly UPFs. As mentioned above, UPFs are transversal to several food groups and include baked goods, dairy and non-dairy-based sweets, processed meat and fish, meat substitutes, ready-to-eat food, frozen processed potatoes, and dressings and sauces. The results are concerning for every SES (Fig. 6), showing a picture where UPF occupies the highest ranks of food consumption.

When analysing the CF of each SES, two aspects arise: on one hand, the proportions of each food category are similar among all SES (Fig. 5d). Dairy is the category with the highest footprint, although it is still in line with the guidelines; pork shows the second-highest CF, followed by non-recommended items and ready-to-eat foodstuffs. White meat and fish are slightly higher than the reference diets, and legumes, nuts, and vegetables are always below. The most significant difference between the reference diets and the consumption is, for all SES, the CF of grains, which accounts for 5% of the total footprints instead of 12-26% of the reference diets. This underconsumption is partially compensated for when considering food consumed outside of the home (see Section 4.3).

On the other hand, some aspects become more relevant when analysing the absolute terms. As for consumption, the footprint is higher for higher SES (Fig. 5d and Table 2). The high and middle-high group is associated with the highest CF per FU (2.69 $kgCO_2eq$), followed by the middle SES (2.29 $kgCO_2eq$), the middle-low SES (2.21 $kgCO_2eq$), and the low SES (2.05 $kgCO_2eq$).

4. Discussion

In this section, we compare the Spanish household consumption with three reference diets, considering four SES and estimating their CF.

4.1. Average Spanish household consumption and dietary recommendations

Weight, energy, and nitrogen intakes in the average Spanish household reveal some imbalances in both the total consumption and in food categories. Low total consumption in weight and energy can be explained by two main factors: Firstly, data omits the food eaten outside

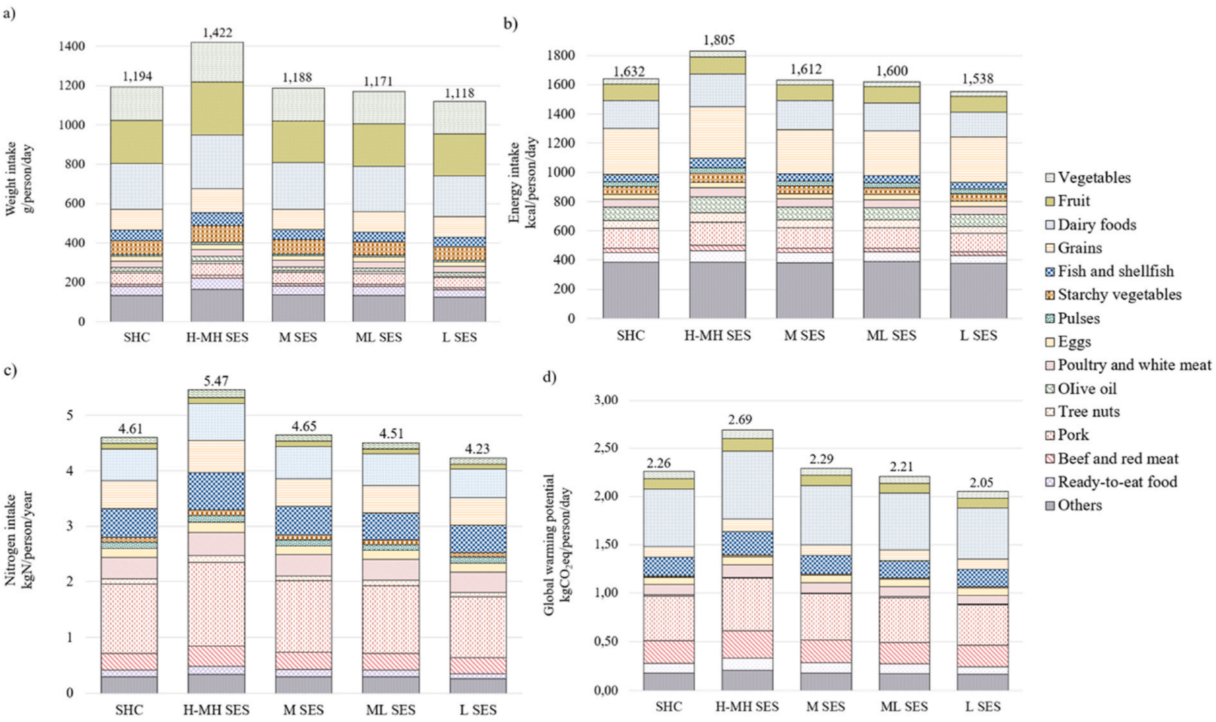

Fig. 5. Intakes and emissions by SES: high and middle-high (H-MH), medium (M), middle-low (ML), and low (L). **5a.** Weight intake for Spanish consumption by SES. **5b.** Energy intake for Spanish consumption by SES. **5c.** Nitrogen intake for Spanish consumption by SES. **5d.** Carbon footprint for Spanish consumption by SES.

Table 2
Differences in weight between the reference diets and the Spanish household consumption, divided into SES: high and middle-high (H-MH), medium (M), middle-low (ML), and low (L) SES.

Food Group	Reference Diets			Spanish household consumption			
	MD	PHD	SG	H-MH SES	M SES	ML SES	L SES
	kgCO$_2$eq person^{-1} day^{-1}	kgCO$_2$eq person^{-1} day^{-1}	kgCO$_2$eq person^{-1} day^{-1}	kgCO$_2$eq person^{-1} day^{-1}	kgCO$_2$eq person^{-1} day^{-1}	kgCO$_2$eq person^{-1} day^{-1}	kgCO$_2$eq person^{-1} day^{-1}
	[%]	[%]	[%]	[%]	[%]	[%]	[%]
Dairy foods	0,84 [47]	0,33 [28]	0,77 [41]	0,70 [26]	0,61 [27]	0,59 [27]	0,53 [26]
Grains	0,21 [12]	0,31 [26]	0,44 [23]	0,13 [5]	0,11 [5]	0,11 [5]	0,11 [5]
Fish and shellfish	0,19 [11]	0,07 [6]	0,11 [6]	0,25[e] [9]	0,19[e] [8]	0,18[e] [8]	0,18[e] [9]
Eggs	0,10 [6]	0,04 [3]	0,11 [6]	0,09 [3]	0,07 [3]	0,07 [3]	0,08 [4]
Beef and red meat	0,09 [5]	0,09 [8]	0,11 [6]	0,28[e] [10]	0,23[e] [10]	0,22[e] [10]	0,22[e] [11]
Vegetables	0,09 [5]	0,06 [5]	0,11 [6]	0,09 [3]	0,07 [3]	0,07 [3]	0,07 [3]
Fruit	0,07 [4]	0,05 [4]	0,07 [4]	0,13 [5]	0,11 [5]	0,10 [5]	0,10 [5]
Pulses	0,01 [1]	0,02 [2]	0,01 [1]	0,00 [0]	0,00 [0]	0,00 [0]	0,00 [0]
Pork	0,03 [2]	0,03 [3]	0,03 [2]	0,54[e] [20]	0,48[e] [21]	0,46[e] [21]	0,41[e] [20]
Others	0,13[a] [7]	0,19[b] [16]	0,12[c] [7]	0,48[e],[d] [18]	0,42[e],[d] [18]	0,41[e],[d] [19]	0,35[e],[d] [17]
Total	**1,79**	**1,19**	**1,88**	**2,69**	**2,29**	**2,21**	**2,05**
Tot UPF	**Minimised**	**Minimised**	**Minimised**	**0,99[e] [37]**	**0,87[e] [38]**	**0,83[e] [38]**	**0,73[e] [36]**

The category "Others" includes different items, depending on the diet.

[a] Sugar equivalent and vegetable oil.

[b] Oil, lard or tallow, and added sugars.

[c] Olive oil.

[d] Snack and olives, honey, bakery items, cookies, breakfast cornflakes, chocolate, cocoa and surrogates, sugar, olive and non-olive oil, margarine, vinegar, broth and juices, coffee and infusions, sauces, seaweeds, spices and condiments, salt, sweet diaries (like smoothies and whipped cream), and butter.

[e] These values include both fresh and processed foodstuffs. UPF includes all items in Fig. 6.

the household. The latter stems from the fact that the databases for food consumption inside and outside of the home have different degrees of detail and are thus hardly comparable. Cerrillo et al. (2023) estimated this gap at the food group level and found that this underestimation could reach up to 50% for grains and meat. Other estimations suggest 1651 g/person/day and 3307 kcal/person/day (Aguilera et al., 2025).

All studies show red meat intake exceeds recommendations, raising concerns (Boldo et al., 2018; Franco et al., 2010). While guidelines recognise the cultural value of processed meat, they advise limiting it due to health and environmental impacts (Springmann et al., 2018; Walker et al., 2019; Willett et al., 2019). Yet, its consumption has increased from 21% of total meat in 2002 to 27% in 2022. This is

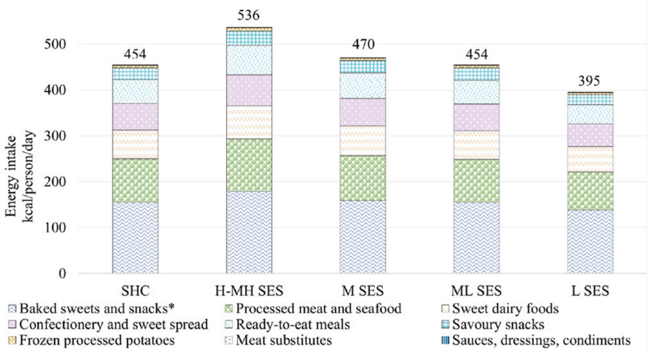

Fig. 6. Energy intake of UPF for the Spanish household consumption (SHC) and by SES: high and middle-high (H-MH), medium (M), middle-low (ML), and low (L) socioeconomic status. * includes baked goods, breakfast cereals, sweet biscuits, snack bars, and dried fruit snacks.

reflected in nitrogen intake, which is the only intake that exceeds recommendations. Moreover, while around 50% of nitrogen intake should come from grains, pulses, dairy foods and shellfish, in the SHC, pork is the top source.

Secondly, Spanish diets are energy-dense in high red meat and sweets. These foods provide more calories per gram than fruits and vegetables, meaning high caloric intake can occur even with lower food weight. Our data show a rise since 2002 ready-to-eat food and non-recommended items, aligning with global trends, especially in expanding and high-income economies such as Spain (Ge et al., 2024).

The rise in UPF consumption displaces nutrient-rich foods and limits dietary improvement (Fanzo and Miachon, 2023). The WHO advises that no more than 10% of the total energy should come from sugars (WHO & FAO, 2024). In 2022, sweets provided 289 kcal/person/day, 18% of the average SHC. Non - recommended foodstuff increased from 120 g/person/day to 167 g/person/day over the last 20 years. To meet WHO and the three recommendations, this trend should be inverted, reducing added sugars to make space for more vegetables and plant-based proteins, promoting healthier and more sustainable diets.

4.2. Carbon footprint

The estimated footprints from our model are lower than those in the literature (Table 2). CFs range from 1.95 $kgCO_2eq$/person/day for the PHD (Cambeses-Franco et al., 2022) to 2.30 and 2.21 $kgCO_2eq$/person/day for the MD (Cambeses-Franco et al., 2022; Castaldi et al., 2022). Animal-based products have the highest contribution to the total CF. For these products, Cambeses-Franco et al. (2022) use data from van Oort and Andrew (2016) for beef production in Norway, while Castaldi et al. (2022) consider global beef values. Our study uses Spain-specific data from different production systems, which are more refined and cover different production systems (see **SM**). Yet, more than half of the CF for the Spanish consumption comes from animal-based products, and some of them still exceed the CF of the recommendations. Other food groups (white meat, fruit, dairy, olive oil, grains, and starchy vegetables) remain within recommended CF levels. Pulses, nuts, eggs, and vegetables show even lower emissions than reference diets, so increasing their consumption would raise CF only slightly while improving diet quality.

Another relevant CF input comes from UPFs, which account for 37% of the total CF of the average Spanish consumption. UPFs include items such as ready-to-eat foods, which contribute 5% of the total CF, bakery and pastries (4%), and processed pork meats, which account for 17%. Pig farming is associated with high water use and nutrient pollution (Fanzo and Miachon, 2023). Processed pork, which has higher emissions compared to fresh pork, makes up 47% of the total pork intake. Overconsumption of these products harms both the health and the environment. These findings align with existing literature emphasising the need to transition towards plant-based diets (González-García et al., 2020; Klapp et al., 2025; Springmann, 2018) and the reduction of UPF intake (Minetto Gellert Paris et al., 2024; Pérez-Domínguez et al., 2021; Vieux et al., 2018).

4.3. Socioeconomic analysis

Higher SES generally eat more of most foods, except white meat, which shows minimal variation across SES and recommendations. They also eat more outside of home compared with other SES (MAPA, 2022a, p. 429). Middle and middle-low SES align with the guidelines for eggs and olive oil, the higher follow recommendations for vegetables, fruit, dairy food, grains, and fish. Lower SES is closer – but still overconsumes –pork, ready-to-eat food, and non-recommended foodstuffs. Our findings also reveal large gaps in fruit, vegetable, and dairy intake between the highest and lowest SES key foods for preventing non-communicable diseases (Afshin et al., 2019). Moreover, households with higher SES present more energy intakes related to UPFs in both absolute terms - 536 kcal/person/day - and relative terms – covering 29% of the total energy intake, in contrast with 26% for the lowest SES. Higher SES also perform poorly in nitrogen intake, given their overconsumption of protein-rich foodstuffs. These results show a pattern that is reproduced in other countries, where higher SES are associated with greater consumption of meat and UPFs (Ge et al., 2024; Global Diet Quality Project, 2022, p. 17; Khandpur et al., 2020; Romero Ferreiro et al., 2022), although global evidence is mixed (Dicken et al., 2024). The reasons beneath these patterns require further investigation into food and market psychology.

Nonetheless, our study suggests that a higher job status and education do not necessarily lead to healthier diets. While high and middle-high SES increase their consumption of fruits, vegetables, and whole grains, they also paradoxically consume more UPF, leading to negative consequences for both personal well-being and the climate. As countries grow wealthier, sales of ultra-processed and animal-sourced foods rise (Baker et al., 2020). Consumers with higher education tend to buy healthier foods but also more products rich in sugar, fat, salt, and processed meat (Global Diet Quality Project, 2022). This paradox is linked to better access to fresh foods and cooking technologies, which also facilitate ready-to-eat meals (Baker et al., 2020). Dietary patterns are shaped not only by income but also by social, cultural, and environmental factors. The latter highlights the complexity of the relationship between socioeconomic status, food choices, and their broader impacts.

A similar trend is observed for the estimated CF for each SES: higher groups consume more high-emitting foods, especially processed pork. While the Kuznets curve suggests dietary impacts should decline with rising income (Stern, 2017), recent evidence shows that meat consumption only drops at the top 90–95% of income distribution (Frontuto et al., 2024), a too-high percentage to drive change (Rivers Cole and McCoskey, 2013). This suggests that shifting toward healthier, lower-impact diets requires systemic policy support that goes beyond economic growth (Godfray et al., 2018; Marques et al., 2018; Vranken et al., 2014).

4.4. Policy implications

To promote healthy and sustainable diets, policymaking instruments should be implemented throughout different governance levels, focusing on targeted interventions. In general terms, legume and vegetable consumption should increase three to fourfold. This would have positive outcomes, especially for lower SES and vulnerable populations. Simultaneously, UPF should be reduced for all SES, preventing current trends and promoting and encouraging the consumption of fresh, minimally processed, plant-based foods. UPF, especially processed pork, is a major contributor to dietary GHG emissions, so these dietary changes would also reduce CF. Small targeted shifts toward more fruits and vegetables and less energy-dense foods are more effective for health and environmental impacts (Perignon et al., 2016; Springmann, 2018;

Stylianou et al., 2021). For the latter, agri-food corporations play a central role in switching towards a better-quality food with lower emissions (Clapp et al., 2025).

While healthy diets are a universal goal, pathways vary due to different starting points, especially when taking into account vulnerable groups. Sociodemographic factors influence cooking habits, food choices, and affordability (Hirvonen et al., 2020). There is evidence that factors as being a woman, being older, having high SES and not working overtime are more associated with home-cooked meals, while being a man is associated with a higher consumption outside (González-García et al., 2020; Mills et al., 2018). Moreover, lower SES correlates with greater fast and convenience foods, as this food is more accessible in low-income areas (Block et al., 2004; Kruger et al., 2014; Macdonald et al., 2007; Wilkinson, 2024). Taking into account how socioeconomic factors shape food consumption, policies should differ. For higher SES, food transition should focus on reducing UPF consumption at home, promoting plant-based options. For lower SES and groups in conditions of vulnerability, interventions should improve food environments, ensuring access to healthy and affordable food while limiting the presence of unhealthy food campaigns.

Finally, dietary shifts must be paired with mitigation in production methods (Gerten et al., 2020; Preinfalk et al., 2024; Springmann, 2018). Strategies include pasture feeding, reducing methane and soy meal use, integrating connections between livestock and crops, reducing manure emissions, and optimising fertiliser use. Though some methods (e.g., organic farming) may raise GHG intensity, they support environmental and nutritional benefits (Penuelas et al., 2020; Popa et al., 2019). A holistic approach beyond carbon emissions is essential (Harrison et al., 2021).

Beyond mitigation strategies, considering adaptation measures would reduce the risks to food security (European Environment Agency, 2024). Recent decades have brought attention to the social dimensions of global changes. Scholars stress the role of governance and institutions that enable transformation, emphasising social learning and community engagement (Käyhkö et al., 2020; Moragues-Faus et al., 2024; Puigdueta et al., 2021; Schneider et al., 2025). A justice-based approach is also needed to address negative social, economic, and environmental effects (Conti et al., 2025; Lonkila et al., 2024). At the same time, there is a growing discourse advocating for a more systemic, post-growth transformation (Guerrero Lara et al., 2023; McGreevy et al., 2022).

5. Conclusions

Food household consumption in Spain is marked by excessive intake of UPF and insufficient consumption of pulses and vegetables. These trends vary by SES: overconsumption is greater in affluent groups; underconsumption is more common in lower SES, leading to dietary inequality and differing CF.

Transitioning to recommended diets requires targeted policymaking, which should involve increasing plant-based foods (vegetables, fruits, legumes) and reducing UPF and some meat-based products. This would lower the emissions, improve food security, and help address dietary inequalities among lower-income groups since, notably, foods consumed in excess are those with the highest climate impact. Achieving this requires a substantial rise in legume and vegetable intake, especially among populations in vulnerable conditions.

However, the paths to achieve recommended diets must account for socioeconomic differences. Factors such as education, cooking time, takeaway habits, and the availability of healthy food options vary significantly across SES. Policies must support those who face greater barriers, include affordability, and consider the gender burden of food responsibilities.

In conclusion, our study shows that Spanish food consumption is not in line with healthy and sustainable standards, with excessive intake of harmful, high-emitting foods and insufficient consumption of beneficial ones. Targeted strategies are needed to reduce ultra-processed and animal-based product intake and promote plant-based, low-impact diets with a focus on social equity.

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CRediT authorship contribution statement

Chiara De Tomassi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft. **Luis Lassaletta:** Conceptualization, Methodology, Supervision, Validation, Visualization, Writing – review & editing. **Víctor Martínez-Cano:** Investigation, Validation, Visualization, Writing – review & editing. **Neus Escobar:** Methodology, Validation, Writing – review & editing. **María José Sanz:** Funding acquisition, Project administration, Supervision, Writing – review & editing. **Inmaculada Batalla:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clrc.2026.100424.

Data availability

Data is to be found in the supplementary material

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