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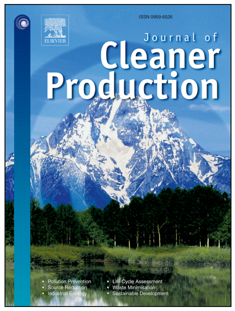

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The Spanish Dietary Guidelines: a potential tool to reduce greenhouse gas emissions of current dietary patterns

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Highlights

- The nutritional quality of the average diet is lower than the NDG-based diet
- The average diet, with a daily intake of 2,665 kcal, emits 1.6 kg CO_2eq per year
- Diet's GHG emissions can decrease 17% by following Spanish dietary recommendations
- 42% less GHG emissions is achieved when considering diets' nutritional qualities
- Cutting down consumers' losses can further decrease the diet's GHG emissions by 10%

Keywords

Greenhouse gas emissions, LCA, diet, climate change, impact reduction, nutrition

Abstract

This study assesses the Greenhouse Gas (GHG) emissions and the nutritional quality of the current food consumption and losses of an average Spanish adult citizen, and compares them with two alternative diets: one following the Spanish dietary guidelines (The NAOS Strategy; NAOS), and another one based on the Mediterranean (MED) diet. The diet-related GHG emissions of current eating patterns would be reduced by 17% and 11%, when shifting to the NAOS and MED diets, respectively, and even more (42% and 35%) when diets' nutritional qualities are considered within the functional unit. In addition, food losses contribute 20% to diet's emissions. Our results suggest that national dietary guidelines (NDGs) can be a good policy tool, not only to lead to a healthier condition, but also to promote a shift towards a lower-carbon diets. Finally, it is recommended that life cycle-based indicators are added within the

NDGs, to better communicate the environmental impacts of dietary choices, and ultimately enhance knowledge and awareness of consumers.

1. Introduction

The dietary habits of the Spanish population have moved from a traditional Mediterranean diet to a more so-called “Western diet”, with a higher intake of animal products and a lower consumption of plant-based products than recommended (Varela-Moreiras et al., 2010). These dietary patterns have been associated with health problems (FEN, 2013), specially obesity and overweight (Ruiz et al., 2015), which relates to a higher risk of chronic diseases and a reduction of life expectancy (Walls et al., 2012). To decrease this trend, since 2005, the Spanish Ministry of Health and Consumer Affairs has launched the Strategy for Nutrition, Physical Activity and Prevention of Obesity (NAOS, in Spanish) to promote healthy diets and proper physical activity. Among other initiatives, a key objective of the NAOS Strategy is to develop nutritional dietary guidelines, being the last version published in 2010 (Tur-Marí et al., 2010).

Besides health issues, a growing attention has been recently given to the influence of dietary choices on greenhouse gas (GHG) emissions. At the global scale, changes of dietary patterns towards a higher consumption of meat and processed food, can increase the current GHG emissions related to food production by 80% in 2050 (Tilman and Clark, 2014). In contrast, dietary shifts of current average diets to a more plant-based eating patterns can potentially reduce the GHG emissions up to 50% (Hallström et al., 2015), as well as result in health benefits, such as reducing diet-related mortality (Springmann et al., 2016). In addition, food losses, defined by FAO (2014) as “*the amount of food intended for human consumption that, for any reason, is not destined to its main purpose*”, also contribute to these emissions. Heller and Keoleian (2015) reported that food losses contributed to 28% of the total GHG emissions of an average US diet, and Eberle and Fels (2016) estimated that 1.1 kg of the GHG emitted per kg of food consumed in Germany was caused by food losses. Facing this climatic burden of food losses, Notarnicola et al. (2017a) highlighted the need to include them when accounting for environmental impacts of food consumption.

In this regard, this study estimates the GHG emissions and the nutritional quality of the current food consumption and losses of an average Spanish adult citizen (MAPAMA, 2017a), and compare them to two diets; one based on the nutritional guidelines from the NAOS Strategy (Tur-Marí et al., 2010), and another one based on the Mediterranean pyramid from Bach-Faig et al. (2011). This study follows the life cycle assessment (LCA) approach, a methodology that has been widely utilized to estimate environmental burdens of food production (as reviewed by Clune et al., 2017), food packaging (Albrecht et al., 2013; Jara Laso et al., 2017; Navarro et al., 2017a) and, recently, food consumption (Hallström et al., 2015).

2. Methods – LCA Approach

2.1. Functional Unit and Scope of the study

In order to fulfil the goal of this study, a common functional unit applied to the three compared diets needed to be defined. The chosen functional unit was a food basket with the representative food products consumed in- and out-of-home by a Spanish adult in a year, ensuring the daily average recommended energy intake of 2383 kcal (EFSA, 2017).

This food basket was divided into 6 food categories (animal-, plant-based products, beverages, dairy products, sweets and ready meals) with their representative items, a total of 48 food products and 6 type of beverages. Several products were grouped into a wider food product. For example, most dairy products were considered as yoghurt; and pastry products were grouped as biscuits. Only about 2% of the products, such as honey and sauces, were not considered due to lack of LCA data.

The system boundaries of this study are from cradle-to-consumer, and, therefore, the stages of food production (cropping, farming, and fisheries), industrial processing, manufacturing, packaging, retailing and consumption (Figure 1) were considered, as well as the food losses along the whole food supply chain.

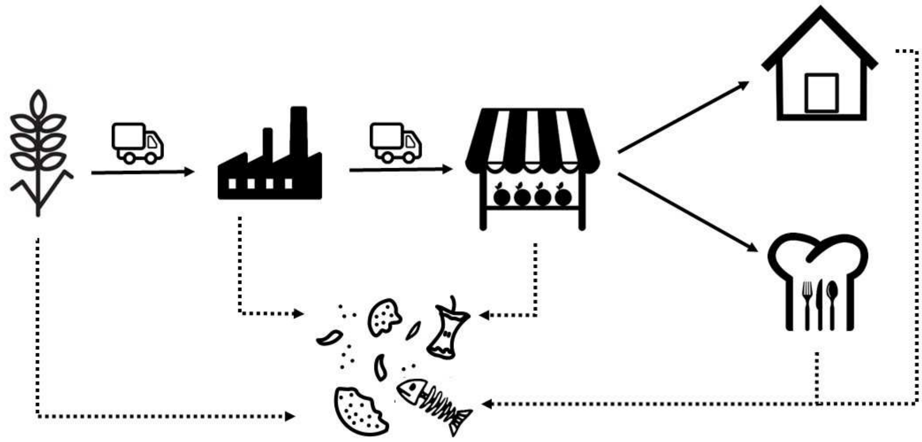

Fig. 1: Overview of the life cycle stages considered in the current study

2.2. Developing the food baskets

2.2.1. Current Spanish food consumption: in-home and out-of-home

The food basket for an average Spanish adult was based on the in- and out-of-home food consumption surveys carried out by the Spanish Ministry of Agriculture and Fishery, Food and Environment. These surveys followed different methodologies. For the annual home food consumption survey, around 10 thousand households recorded daily all food products and beverages consumed, by using a bar code reader of food items. Averages between 2006 and 2016 (MAPAMA, 2017b) were considered as the current in-home consumption of an adult Spanish citizen. In the case of the out-of-home food consumption survey, 7000 Spanish citizens documented the products consumed away from home during two weeks every trimester. However, no detailed data at the food product or category level was available for all the years considered in this study. Hence, the out-of-home consumption was based on the data from 2006, 2007 (MAPAMA, 2008, 2007) for food products, and from 2016 (MAPAMA, 2017a) for beverages.

Finally, the annual food consumption for an average Spanish adult citizen summed up about 790 kg of food products and beverages, which supplied a daily energy intake of 2,665 kcal.

2.2.2. Recommended Diets: the NAOS Strategy & the Mediterranean diet

The NAOS food basket follows the recommendations of the Spanish national dietary guidelines, known as the NAOS Strategy (Tur-Marí et al., 2010). Besides suggesting physical activity, they promote fruit and vegetable consumption (minimum three and two servings per day, respectively), as well as legumes, cereals-based products, such as rice, bread or pasta, and dairy products (between 2 and 4 servings per day). The Mediterranean food basket is based on the Mediterranean diet and food lifestyle pyramid elaborated by Bach-Faig et al. (2011). Similarly to the NAOS Strategy, the Mediterranean guidelines suggest that the highest energy intake should be supplied by plant-based products, while animal products, sugars and fats should be consumed moderately or occasionally.

Both guidelines provide some detailed recommendations on the quantity and frequency (daily, weekly and occasionally) of food intake. Based on them, and the recommended average servings of the NAOS Strategy, a weekly food intake was assumed for both diets (Table 1). For those products that should be occasionally consumed, such as pastry, red and processed meat or wine, the maximum number of servings per week were based on Bach-Faig et al. (2011). To determine the amount of each food product, the same weighing factors as in the current consumption of each product per food category was considered.

Table 1:
Weekly intake per food category for the NAOS (Tur-Marí et al., 2010) and the Mediterranean (Bach-Faig et al., 2011) diets. Serving's weights are taken from the NAOS Guidelines.

Food category	Food product		Servings per week		Weight per serving (g serving^{-1})
			NAOS	MED	
Animal-based products	Eggs		1.3	3	112.5
	Fish & seafood		3.5	2	137.5
	Meat	Processed	1	1	30
		Red	1	1	112.5
		White	2.2	2	112.5
Dairy products	Cheese		1.9	1.3	50-102.5
	Yoghurt		4.6	3	225
	Milk		14.5	9.7	232
Plant-based products	Cereals	Bread	29.1	17.5	50
		Pasta	2.8	1.7	70
		Rice	3	1.8	70
	Fruit		21.0	21	160
	Legumes		2.5	2	70
	Olives		5	10.5	25
	Potatoes		12.5	3	175
	Vegetables		14	28	175
	Vegetable fats		28	28	10
Beverages	Soft drinks		2	2	200
	Water		56	56	200
	Wine & Beer		12.2	12.2	10
Sweets			2	2	30

2.2.3. Energy-adjusted food baskets

The three dietary patterns described above were adjusted to the average recommended daily energy intake (2,383 kcal). For this adjustment, the corresponding (caloric) energy contribution of each food category per diet (Table 2) was kept. The final energy-adjusted ES, NAOS and MED food baskets weighted about 700, 890 and 1020 kg, respectively, and their composition per food categories are illustrated in Figure 2.

Table 2:
Energy Contribution (%) of all food categories per dietary pattern

Food category			**ES**	**NAOS**	**MED**
Animal-based products	Eggs		1.8	1.1	3.7
	Meat	Red	10.0	2.2	2.8
		White	4.3	2.6	2.8
	Fish		5.9	4.2	3.1
Dairy products			12.0	18.7	16.1
Plant-based products	Cereals		14.4	26.4	18.2
	Fruit		6.4	10.7	15.0
	Legumes		1.6	3.6	3.7
	Vegetables		5.0	13.1	12.3
	Vegetable fats		18.7	14.3	18.3
Sweets			12.3	1.7	2.1
Ready meals			2.2	0.0	0.0
Beverages			5.4	1.4	1.9

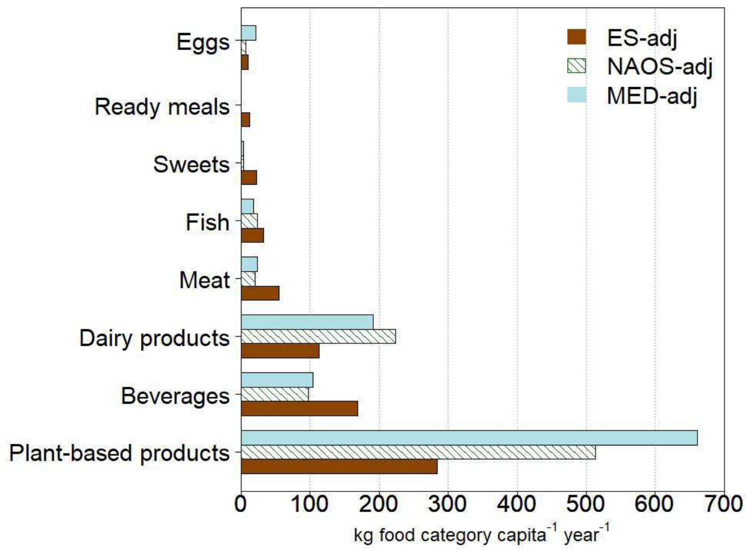

Fig. 2: Mass Composition of the food products (kg food capita^{-1} year^{-1}) for the three energy-adjusted food baskets.

2.3. Data collection & assumptions

To perform the LCA of these three food baskets, first, the life cycle inventories (LCI) of all food products & beverages were gathered by an extensive literature review. Data on GHG emissions included emissions of CO_2, CH_4, NH_3 and N_2O.

The methodology to build up this extensive LCI followed the next steps. After evaluating the Spanish food sector and based on the FAO database, a list of combinations of food products and the origin of their raw materials was gathered. Next, LCA data for all these food products by country combinations was searched. When no data or low quality data was available, data from similar countries or products were used as proxies. The methodology of gathering data has been as consistent as possible. However, to build up an inventory that can represent the Spanish food sector has been a challenge. The number of LCAs of Spanish food products has increased, but a big data gap still exists. For instance, there is currently no available Spanish LCI data on bakery products, bananas or poultry. Therefore, expert knowledge was required to fill in these data gaps with the best estimations or available proxies. Table 3 summarizes all the sources used for the LCIs per food product.

Assumptions were needed for certain LC stages. For example, when no data of packaging was available, data from Notarnicola et al. (2017a) was used. In the case of logistics, international and national transports were considered. In the case of the national one, transport by truck to wholesalers and retailers are assumed to be 400 km and 100 km, respectively, similar assumption as Castañé and Antón (2017). For refrigerated trucks, 20% of extra diesel is assumed being consumed. The retail phase considers the electricity to store and display food products. This electricity depends on the type of product and the storing status, which can be at ambient temperature, cooling or freezing conditions. As done by Milà i Fontanals et al. (2007), it is assumed 2 days storage for products stored at ambient or chilled conditions, and 15 days under freezing conditions.

Table 3
Sources of the life cycle inventories of all food products considered in the food baskets

Food category	Food product		Main sources of LCI data
Animal-based products	Eggs		Berggren (2013)
	Fish	Mussels	Aquaculture (Iribarren et al., 2011b) and mussel purification and canning (Iribarren et al., 2010)
		Shrimps & Prawns	Ziegler et al. (2009)
		Atlantic Mackerel	Vázquez-Rowe et al. (2010)
		European hake	Vázquez-Rowe et al. (2011)
		European pilchard	Vázquez-Rowe et al. (2014)
		Salmon	Silvenius and Grönroos (2003)
		Tuna	Iribarren et al. (2011c)(Vázquez-Rowe et al., 2010), canning (Hospido et al., 2006)
		Octopus	Vázquez-Rowe et al. (2012)
		Canned anchovy	Laso et al. (2017)
	Meat	Beef	Beef system production (Nguyen et al., 2010), slaughterhouse (Mogensen et al., 2016)
		Chicken	González-García et al. (2014)
		Pork	Pig systems and slaughterhouse (Noya et al., 2017b)
Dairy products	Butter		Nilsson et al. (2010)
	Cheese		Mozzarella (Palmieri et al., 2017); Hard Cheese (González-García et al., 2013a); Semi-hard cheese (van Middelaar et al., 2011)
	Milk		Spain (Iribarren et al., 2011a), Germany (Dalgaard et al., 2016), and Portugal (Castanheira et al., 2010)
	Yoghurt		González-García et al. (2013b)
Plant-based products	Cereals	Bread	Bread production (Notarnicola et al., 2017b) and consumption (Espinoza-Orias et al., 2011)
		Pasta	Pasta manufacturing (Heidari et al., 2017), and boiling (Ruini et al., 2013)
		Rice	Cultivation in Spain (Aguilera et al., 2015), Brazil (Coltro et al., 2017), India (Gathorne-Hardy et al., 2016) and Thailand (Ramsden et al., 2017)
	Fruits	Apples	Cultivation in Spain (Vinyes et al., 2017) and Italy (Longo et al., 2017), post-harvest processes (Longo et al., 2017)
		Bananas	Cultivation and transport from Costa Rica (Luske, 2010) and Ecuador (Iriarte et al., 2014)
		Citrus	Oranges cultivation (Ribal et al., 2017)
		Olives	Olives production (Russo et al., 2016)
	Legumes		Aguilera et al. (2015)
	Vegetables	Tomatoes	Tomato cultivation (Torrellas et al., 2012)
		Lettuce	In open field cultivation and in greenhouse (Canals et al., 2008)
		Vegetables	Aguilera et al. (2015)
		Processed vegetables	Del Borghi et al. (2014)
	Vegetable fats	Margarine	Nilsson et al. (2010)
		Olive oil	Tsarouhas et al. (2015)
		Sunflower oil	Nucci et al. (2014)
Beverages	Beer		Amienyo and Azapagic (2016)
	Coffee		Cultivation (Noponen et al., 2012), coffee production (Humbert et al., 2009), consumption (Hassard et al., 2014)
	Juice		Jungluth (2013)
	Soft drinks		Amienyo et al. (2013)
	Water		Garfí et al. (2016)
	Wine		Navarro et al. (2017b)

Sweets	Biscuits	Noya et al. (2017)
	Breakfast cereals	Jeswani et al. (2015)
	Chocolate	Cacao production (Ntiamoah and Afrane, 2008); Dark chocolate (Recanati et al., 2018)
	Sugar	Dalgaard et al. (2016)
Ready meals		Calderón et al. (2010)

There are four main processes to consider in the consumption phase: (1) how consumers get their food products from retailers, and how they (2) store, (3) cook, and (4) waste their food. Based on MAPAMA (2017), 77.5% of food products are bought at big retailers, while 22.5% at small ones. In the case of the transport of products to consumers' homes, all products were assumed to be bought at the same time and, therefore, the emissions of fuel consumption are distributed equally among products. Data within these life cycle stages need to be assumed, since little information is available about how Spanish people get their food products. For car and bus transport, the methodology by Milà i Fontanals et al. (2007) was used, resulting in 3.3 km and 0.015 km per kg of food transported by car and by bus, respectively.

Regarding home storage, it is based on data from the LCA Food Database (Nielsen et al., 2003). The energy use factors by Foster et al. (2006) were used to estimate the energy needed for cooking: 0.8 MJ, 3.5 MJ, 7.5 MJ and 9 MJ used for microwaving, boiling, frying and roasting 1 kg of food product, respectively.

Food losses along the whole supply chains are based on Garcia-Herrero et al. (Under review).

2.4. Allocation procedures

Regarding allocation criteria for processes that have several by-products, the allocations chosen in the reviewed studies were applied. Industry processes with multiple co-products, for instance, the production of soy meal or rapeseed oil, have been economically allocated. However, a few products with very low by-product price, such as fish meal and oil, have been allocated by mass (Silvenius and Grönroos, 2003). Economic allocation of environmental burdens of crop productions was chosen; therefore, no burden was allocated to straw, or other similar residues. Fishery activities need allocation procedures since more than one fish type is captured by the fleets. Following the literature, some species were allocated by mass (Atlantic mackerel, European hake and octopus), or by the economic value (shrimps & prawns, European pilchard and Tuna). In the case of mussels culture and salmon, no allocation was considered (Iribarren et al., 2011b; Silvenius and Grönroos, 2003).

2.5. The nutritional quality

The Nutrient Rich Diet 9.3 score (NRD 9.3; Van Kernebeek et al., 2014) was used to assess the nutritional quality of the three food baskets. This index is based on the Nutrient Rich Food 9.3 (NRF9.3) score (Drewnowski, 2009), which is widely accepted and validated against the Healthy Eating Index (Fulgoni et al., 2009). The NRD 9.3 is calculated as the Total Nutrient Rich 9 (TNR9) minus the Total Nutrient Limiting 3 (TNL3) sub-scores (Eq.1). The TNR9 is the sum of percentages of the yearly recommended values (RV) of 9 nutrients to encourage (protein, fibre, Vitamins A, C and E, and minerals Ca, Fe, Mg and K) in the edible portion of all products in the food basket (Eq.2). Yearly RV values (Table 4) were based on Daily Recommended Values (RDV) from EFSA (2017). In order to avoid crediting overconsumption of nutrients, their intakes were capped (Drewnowski, 2009). Hence, when a certain nutrient intake was higher than its RV, the intake was applied to its RV. The TNL3 is the sum of percentages of maximum recommended values (MRV) of three nutrients (added sugar, saturated fat and sodium) to be limited in the edible portion of all products in the food basket.

$$NRD9.3 = TNR9 - TNL3 \qquad [Eq.1]$$

$$TNR9 = \sum_{i=1}^{i=9} \frac{nutrient_{i,capped}}{RV_i} \qquad [Eq.2]$$

$$TNL3 = \sum_{i=1}^{i=3} \frac{nutrient_i}{MV_i} \qquad [Eq.3]$$

Table 4
Yearly recommended values (RVs) based on EFSA (2017), and maximum values (MVS) based on the healthy diet defined by the WHO (2015)

Nutrients	Unit	RVs	MVs
Protein	kg year^{-1}	19.3	-
Dietary fibre	kg year^{-1}	9.1	-
K	kg year^{-1}	1.3	-
Ca	kg year^{-1}	0.3	-
Fe	kg year^{-1}	0.0	-
Mg	kg year^{-1}	0.1	-
Vit. A	g year^{-1}	0.3	-
Vit. C	g year^{-1}	0.0	-
Vit. E	g year^{-1}	4.4	-
Saturated fat	kg year^{-1}	-	8.5
Added sugar	kg year^{-1}	-	21.3
Na	kg year^{-1}	-	0.9

In this study, the NRD9.3 was relative to the daily recommended energy intake. The nutritional contents of all the food products within the basket were retrieved from the Spanish Food Composition Database (BEDCA).

Finally, since the NRD9.3 is based on the edible parts of food products, GHG emissions were converted to GHG emissions of edible products, using the conversion factors shown in Table 5. After this conversion, the food baskets' GHG emissions were adjusted to their NRD9.3.

Table 5
Conversion factors to convert mass of food to mass of edible food.
Source: Gustavsson et al. (2013)

Food product	Conversion factor
Beef	0.8
Chicken	0.7
Egg	0.9
Fish	0.6
Fruits and vegetables	0.8
Milk	1
Pork	0.7
Rice	1

2.6. Variability analysis

Variability in LCI data of food products is expected due to differences in production systems, as well as, in modelling approaches, such as the system boundaries or allocation factors applied. To show this variability, the meta-analysis of GHG emissions of fresh products from Clune et al. (2017) was used. From their extensive database, mean, median, upper (Q3) and lower quartiles (Q1) emissions of the fresh food products, considered within the food baskets, were calculated. Since Clune's data were estimated from cradle-to-Regional Distribution Centre, emissions from the consumption phase were added. Finally, as they suggest, the Q1 and Q3 quartiles were used for the data range for the fresh products.

3. Results

3.1. Food baskets' emissions

The current consumption pattern of an average Spanish adult citizen, which supplies 2,665 kcal per day, emits annually about 1.6 t CO_2 eq (1.4 – 2.0 t CO_2 eq). When adjusted to a food basket that ensures the average recommended energy intake, it emits about 1.4 t CO_2 eq per year (Figure 3a). Animal-based products are the largest contributors (Meat: 33%; Fish: 22% and Dairy products: 17%), followed by vegetables (5%), cereal-based products and beverages (5%) (Figure 3b).

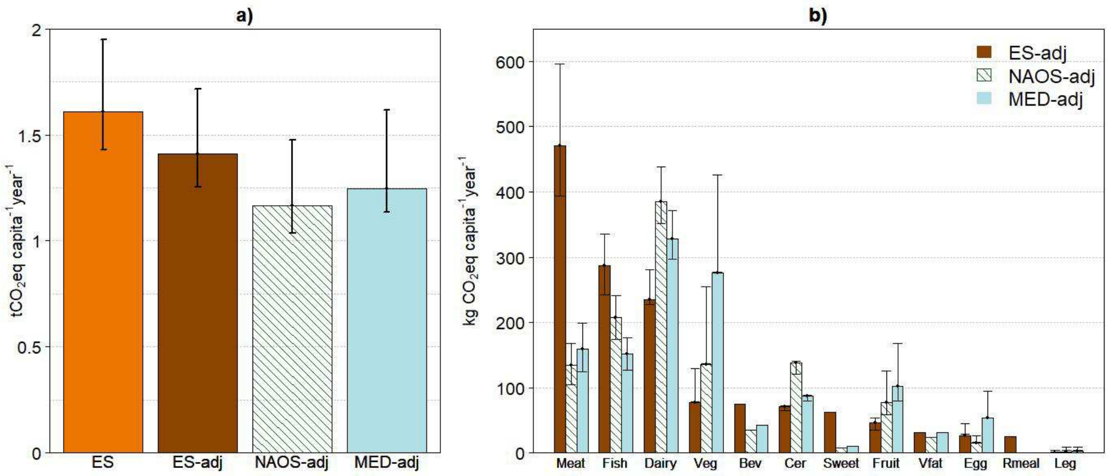

Fig. 3: (a) Total annual GHG emissions ($tCO_2eq\ capita^{-1}year^{-1}$) of the current consumption (ES) at daily 2,665 kcal intake, and the three energy-adjusted food baskets. (b) Total annual GHG emissions for all food sub-categories for the three adjusted food baskets. Veg: Vegetables; Bev: beverages; Cer: cereals-based products, Vfat: vegetable fats; Rmeal: ready meals; Leg: legumes.

The NAOS and the MED food baskets emit 1.2 and 1.3 tCO_2 eq, respectively. Their lower emissions result from the decline of meat consumption (Figure 2), which has the largest GHG emissions per mass (Figure 4), and the increase of plant-based and dairy products (milk and yoghurt) with lower emissions. The main contributors for both alternative food baskets are the dairy products (33% and 26% for NAOS and MED, respectively), followed by fish (18%; 12%), vegetables (12%; 22%) and meat (12%; 13%).

In terms of the life cycle processes, the primary production phases are the most emitting ones, contributing to 72-73% of the total emissions, followed by the manufacturing stage (Table 6).

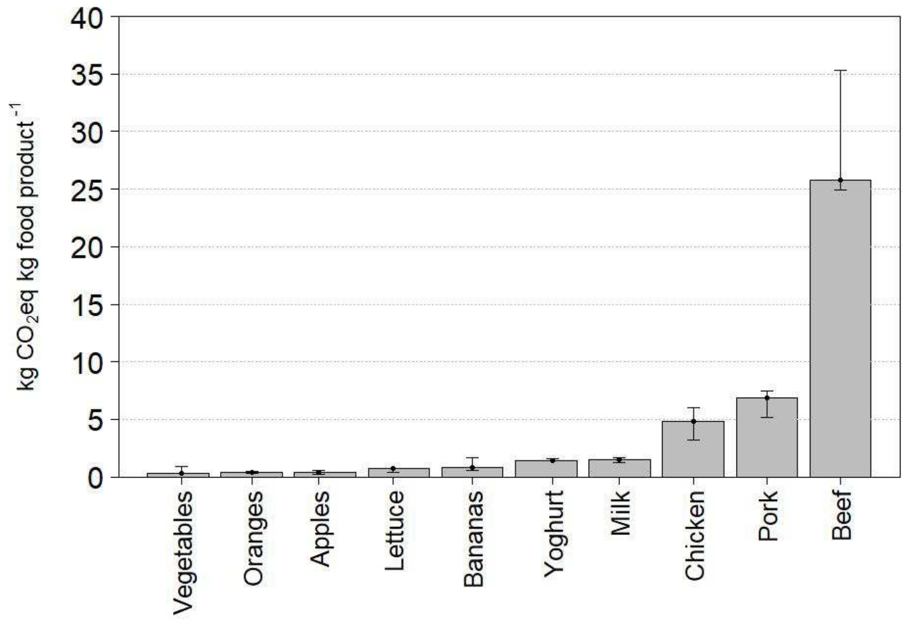

Fig. 4: GHG emissions of several animal- and plant-based products (kg CO_2 eq kg product^{-1}) from cradle-to-consumer

Table 6
Contribution (%) of all life cycle stages to the food baskets-related GHG emissions

LC Stages	ES (%)	NAOS (%)	MED (%)
Cropping	23	28	27
Farming	33	24	23
Fish farming	1	1	1
Fisheries	17	15	10
Manufacturing	10	12	16
Packaging	6	7	9
Wholesale & retail	6	8	8
Consumption	5	6	6

Regarding the nutritional quality, the Spanish adjusted food basket has the lowest nutritional score (465) due to low intake of fibres, potassium, calcium, magnesium and Vitamin A, and higher consumption of all three limiting nutrients. The nutritional scores of the NAOS and the Mediterranean diets are 621 and 581. However, both exceed the saturated fat recommended level, mainly due to the high intake of dairy products and vegetable oils. When GHG emissions of the three food baskets are adjusted by their nutritional score, the alternative food baskets further reduce the emissions compared to current consumption: 42% and 35% for the NAOS and Mediterranean diets, respectively.

3.2. Food losses

The food basket with the largest annual food losses is the Mediterranean (Figure 5a). This is due to the larger intake of fruit and vegetables (Figure 2), which are more perishable than animal products and have larger losses along the supply chain (Figure 5b). In contrast, the Spanish adjusted food basket generates the lowest total amount of food losses, but a larger amount of meat losses. For all food baskets, primary production, and especially the cropping stage, is the largest contributor, followed by the consumption stage (Table 7).

The GHG emissions associated to these food losses along the whole food supply chain are about 0.3 t CO_2eq capita^{-1} year^{-1} for the three adjusted food baskets, and about 50% of these emissions take place at the consumption phase.

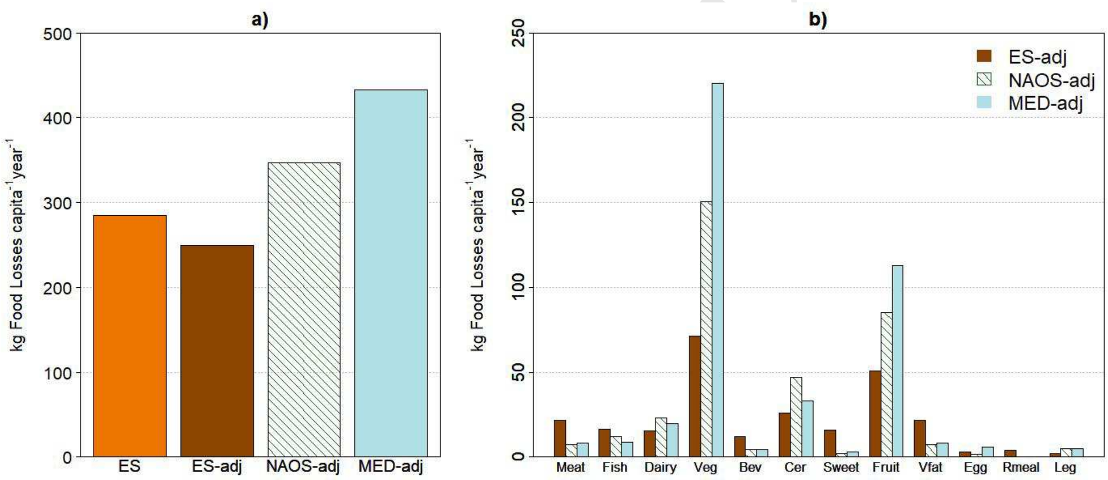

Fig. 5: (a) Total annual food losses (kg FL capita^{-1} year^{-1}) of the current consumption at 2,665 kcal and the three energy-adjusted food baskets. (b) Total annual food losses per food sub-category of the three adjusted food baskets.

Table 7
Contribution (%) of life cycle stages to food losses generation by weight for the three energy-adjusted food baskets

LC Stages	ES (%)	NAOS (%)	MED (%)
Primary production	45	41	43
Manufacturing	11	11	10
Packaging	2	2	3
Wholesale & retail	11	13	13
Consumption	31	32	32

4. Discussion

The CO_2 emissions reported in this study (Figure 3) are found within the value range of previously published ones (summarized in Table 8), and match with the general understanding that a more plant-based diet reduces GHG emissions. However, comparison among studies must be carefully done, mainly due to differences in the functional unit and system boundaries. For example, a functional unit could be mass-based: the total amount of food products (kg) yearly consumed or recommended per capita, without considering any nutritional value of the diet. Based on this approach, if the current energy intake (2,665 kcal) was reduced to the recommended value, by decreasing the amount of food consumed, the reduction of GHG emissions would be about 12.5%, and even higher if changes in dietary patterns were applied.

However, for diets, Heller et al. (2013) suggest that "*the ideal functional unit basis for diet comparisons should be nutritionally based*" to make fair comparisons among diets. A common approach to include the nutritional value within the assessment, is defining a functional unit based on the intake of a certain nutrient, and adjust all comparative diets to those that provide the similar intake of that specific nutrient. A common nutritional-based functional unit is the energy content of diets (Table 8), and evaluate the iso-caloric shift of diet scenarios (Hallström et al., 2015). This study, besides the caloric-adjustment, the overall nutritional quality of the diets was considered by applying the nutritional score NRD9.3 (Van Kernebeek et al., 2014). Dividing the GHG emissions of the three energy-adjusted food baskets by their nutritional score, the relative differences of GHG emissions between the current and the alternative food baskets increase, due to the lower nutritional quality of the current eating pattern.

Another aspect to consider when comparing studies is the inclusion of food losses within the assessment. Within this study, food losses accounted for 21% of the GHG emissions of the food baskets, and half of them take place at the consumption phase. These values are within the range of other studies. Heller and Keoleian (2015) reported that food losses contributed to 28% of the emissions of the average US diet, and Veeramani et al. (2017) estimated a 8% decline of diet's emissions in Ontario when reducing food losses at the consumer level. Therefore, addressing food losses at this stage, by enhancing consumers' awareness, can potentially reduce diet's emissions.

In the last years, a clear message has been given about both health and environmental benefits of changing dietary habits to less meat consumption (Hallström et al., 2015). However, the challenge is how to make the change in consumer's behaviour or consumption more realistic. Besides health and environmental reasons, there are two other key factors to be considered: cost and culture. Westhoek et al. (2014), for instance, highlighted that governments and food businesses should act together to encourage this change. In this regard, governments' policies to promote change may use the National Dietary Guidelines (NDGs) as a policy tool within which sustainability and health issues can be integrated to promote citizens' awareness and overcome cultural or economic barriers.

The Spanish Dietary Guidelines, the NAOS Strategy, aim to provide the best information to Spanish consumers on best healthy choices in food consumption as well as in lifestyle; however, no environmental benefits of those recommendations are considered. The current study shows that a diet based on the NAOS Strategy can potentially reduce GHG emissions, being comparable to the Mediterranean diet. Therefore, it is recommendable to add a climate assessment within the guidelines in order to give extra valuable information on the environmental performance to guide-users.

In contrast to other NDGs, such as the French (Anses, 2016), Nordic (NNR, 2012) and the American (USDHHS and USDA, 2015), the NAOS Strategy does not provide any guideline on the energy (caloric) needs for the Spanish population. Adding this to the NAOS Strategy is essential to communicate food requirements to consumers, but also to call attention to food overconsumption. A current average Spanish adult consumes daily about 2,665 kcal, 12% higher than the average recommended by EFSA (2017). Besides health effects, this overconsumption of calories has a climate impact, since larger caloric intakes are related to higher GHG emissions (Vieux et al., 2012; Walker et al., 2018).

Furthermore, the type and amount of food products recommended in the NDGs are highly relevant when willing to shift towards healthier but also lower-carbon diets. For example, Heller and Keoleian (2015) reported that an iso-caloric diet shift to the American recommended diet would increase 12% current diet-associated emissions (see Table 8), and only 1% decrease when the current energy intake was reduced by 20%. They related this to the high recommended consumption of dairy products, and the low GHG emissions associated to solid fats and added sugars, which represented a significant part of the diets' caloric reduction. Van de Kamp et al. (2018) also highlighted the low decline of GHG emissions when following the Dutch dietary guidelines, and they showed that higher reductions were possible when extra measures, such as excluding meat consumption or selecting food products with low climate burdens, were adopted (Table 8).

An important limitation of our study is data availability. First, national statistical data on the out-of-home consumption at the food product level is limited, and, consequently, assumptions had to be taken. In addition, LCA data for representative Spanish food products is scarce, especially at the manufacturing level. For food production, more LCA data is available, but data gaps remain for common food products such as eggs, pastry or dairy products. Data on consumer food handling is also needed, especially due to the significant contribution of the consumption stage to food losses, accounting for 10% of diet-related GHG emissions. Finally, how citizens will adhere to the Spanish recommendation guidelines will depend in many factors such as cultural or societal. Further research with more information on individual dietary choices and willingness (preferences) to change eating patterns may improve the current assessment of the impact of adherence to the recommended guidelines.

Table 8
Summary of GHG emissions of different diet scenarios in published scientific articles

Functional Unit	Article	Country	System boundaries	Food Losses	Out-of-home consumption***	Include beverages	Dietary Scenarios	Energy-adjustment (kcal)	GHG emissions t CO_2eq capita^{-1} year^{-1}
Mass-based	Muñoz et al. (2010)	ES	Cradle to wastewater	No	Yes	Yes	CONSUMPTION	-	2.0
	Eberle and Fels (2016)	DE	Cradle to Consumer	Yes	Yes	No	CONSUMPTION	-	2.8
	Notarnicola et al. (2017a)	EU-27	Cradle to Grave	Yes	No	Yes	CONSUMPTION	-	1.4
	Hoolohan et al. (2013)	UK	Cradle to Retailer	Yes	-	Yes	CONSUMPTION	-	3.2
	Ritchie et al. (2018)	GLO	Cradle to Farm gate	No	No	No	NDG – WHO	-	1.2
		AU					NDG – AU		1.5
		CA					NDG – CA		1.4
		DE					NDG – DE		1.3
		IN					NDG – IN		0.7
		US					NDG – US		1.6
Energy-based	Sáez-Almendros et al. (2013)	ES	Cradle to Retailer	No	-	Wine	CONSUMPTION	2000	2.2*
							MEDITERRANEAN		1.1*
	Meier and Christen (2013)	DE	Cradle to Retailer	Yes	-	Non alcoholic	CONSUMPTION	2000	2.1
							OVO-LACTEO VEGETARIAN		1.6
							VEGAN		1.0
	Van Dooren et al., (2014)	NL	Cradle to Gate	No	-	-	CONSUMPTION – WOMEN	2000	1.5
							NDG - WOMEN		1.3
	van de Kamp et al. (2017)	NL	Cradle to Consumer	No	No	Non-alcoholic	CONSUMPTION-MEN	2000	1.7
							NDG – MEN		1.5
							NDG – NO MEAT - MEN		1.0
							NDG – NO MEAT – LOW C - MEN		0.8
							CONSUMPTION- WOMEN		1.6
							NDG –WOMEN		1.7
							NDG –NO MEAT - WOMEN		1.1
							NDG –NO MEAT-LOWC-WOMEN		1.0
	Scarborough et al. (2014)	UK	Cradle to Retailer	No	-	Yes	FISH DIETS	2000	1.4
							MEAT		2.1
							VEGAN		1.1
							VEGETARIAN		1.4

Castañé and Antón (2017)	ES	Cradle to Consumer	No	-	Yes	MEDITERRANEAN	2000	1.1
						VEGAN		0.7
Veeramani et al. (2017)	CA	Cradle to Consumer	Yes	No	Yes	CONSUMPTION – VEGAN	2300	1.0
						CONSUMPTION – VEGETARIAN		1.1
						CONSUMPTION – FISH		1.4
						CONSUMPTION – NO PORK		3. 2
						CONSUMPTION – OMNIVOROUS		2.3
Current study	ES	Cradle to Consumer	Yes	Yes	Yes	CONSUMPTION	2383	1.6
						NDG - NAOS		1.2
						MEDITERRANEAN		1.3
Heller and Keoleian (2015)	US	Cradle to Consumer	No	No	No	CONSUMPTION	2534	1.8
						NDG		2.0

* divided by 32738615 adults (>19 years old) in 2007. Data from the National Institute of Statistics. ** representing 58% of the total consumption per capita.***For those papers that consider national food consumption

5. Conclusions & final recommendations

This study shows that, besides being nutritious, a diet based on the Spanish dietary guidelines can reduce the GHG emissions of current eating patterns, due to its promotion of plant-based products, and the reduction of meat consumption. We firmly recommend that life cycle-based indicators are added to these guidelines to provide information on the environmental performance of the recommended diet, in addition to other indicators dealing with other areas of sustainability. This will enhance consumers' knowledge and awareness on the impacts of their food choices, and potentially lead them to shift their dietary habits to more sustainable ones. Additionally, a strong emphasis needs to be placed on reducing food losses, especially at the consumption stage, which can reduce diets-related GHG emissions.

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