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Linking environmental sustainability and nutritional quality of the Atlantic diet recommendations and real consumption habits in Galicia (NW Spain)

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Abstract

Today's society is increasingly aware of food consumption patterns. Under the perspective that real consumption trends are often not in line with healthy recommendations, this research focuses on the study of the environmental and nutritional sustainability of two types of food consumption habits present in the northern Atlantic area of Spain (Galicia). The main objective is, therefore to detect the existing deviations between the current Galician diet (GD) and the traditional and increasingly relevant Recommended Atlantic Diet (RAD), allowing verifying whether current consumption patterns ensure an optimal and sustainable nutritional profile.. In this sense, the carbon footprint from a Life Cycle Assessment perspective has been estimated as environmental indicator of both dietary patterns and, the nutritional quality has been determined by the Nutrient Rich Diet 9.3 index and the Health gain score. The carbon footprint of both dietary models is moderately high compared to recommended diets such as the Mediterranean one. Comparing the two scenarios, the associated greenhouse gas emissions are about 15% higher for GD than for RAD, mainly due to the higher intake of beef and dairy products. On the other hand, nutritional quality is comparatively higher for RAD than for GD, associated with higher consumption of vegetables and fruits. An additional objective of this work has been to consider a sensitivity analysis to determine the effect of replacing beef with alternative sources.

Having in mind this study, it can be concluded that the real consumption pattern in Galicia is far from the recommended one, with worse environmental and nutritional quality. The promotion of social awareness policies to guide consumers in the choice a healthier and more environmentally sustainable dietary pattern should be advisable for regional decision-makers as

well as for those who wish to promote adherence to the Atlantic diet in other regions and countries.

Keywords: Atlantic diet; consumption patterns; GHG emissions; LCA; nutritional quality; sustainability.

1. Introduction

There is a crucial need to make a change in the present unsustainable trends in food production and consumption. According to the literature (Garnett, 2011; Tukker and Jansen, 2006; Vringer et al., 2010), one third of human impact on climate change is related to the food production chain and consumption patterns. For this reason, consideration of more environmental friendly dietary patterns may be a good option to help climate change mitigation. In order to understand the concept of sustainable diets, it is required to take into account the definition of the Food and Agriculture Organization of the United Nations - FAO (FAO, 2010). According to this organization, sustainable diets are those with low environmental impacts, that contribute both to food and nutritional security as well as to healthy life for present and future generations. In this regard, it is also advised food that comes from agricultural production systems with low environmental impact, such as less limited dependence on food of animal origin, short distance production and consumption networks, and minimal food processing and refining, among others (FAO, 2010).

Food consumption trends have a significant influence on environmental impact (Garnett, 2011; Irz et al., 2016; Sonesson et al., 2005). Nevertheless, numerous studies have been conducted in recent years to assess the environmental profile of the human diet (Castañé and Antón, 2017; Coelho et al., 2016; Pernollet et al., 2017; van de Kamp et al., 2018) since dietary habits have shifted from traditional to the so-called “Western diet” based on the intake of animal based products in portions greater than recommended. As a result, the amount of GHG associated with a dietary choice varies significantly depending on the different products that makes it up (Carlsson-Kanyama and González, 2009; Committee on Climate Change, 2010; Scarborough et al., 2014), and largely depends on the efficiency of the production chain.On the road to healthier and more environmentally friendly dietary patterns (Van Dooren et al., 2014) governments from countries such as Sweden (Livsmedelsverket, 2009), United Kingdom (Reddy et al., 2009), Germany (Gerlach et al., 2013) and Finland (Steering Group, 2010) have strengthened their efforts to set up committees to advise society on more sustainable dietary patterns. Among the recommended diets, the well-known Mediterranean diet, traditionally present in Mediterranean countries (Spain, Italy, Greece, Croatia, Maghreb, Cyprus and Portugal), receives special attention. It is considered a healthy diet by global organizations such as the World Health Organization (WHO, 2012) and FAO (FAO, 2010). The Mediterranean diet is related to a low incidence of chronic diseases due mainly to the high intake of vegetables, fruits and whole grains (Cencic and Chingwaru, 2010) and to the low intake of animal fats, with the moderate use of olive oil as a source of healthy fatty acids (Charro et al., 2006).

It is interesting to note how countries outside the traditional area of the Mediterranean diet have begun to promote the Mediterranean diet style (van Dooren and Aiking, 2016; Wilson et al., 2013), as well as to create new dietary choices following that philosophy (e.g. the New Nordic diet) to achieve healthier consumption patterns (De Boer et al., 2014; Donati et al., 2016; Hoek et al., 2017; Saxe et al., 2012; van Dooren and Aiking, 2016). In line with the Mediterranean style, the Atlantic diet (Tojo and Leis, 2009) represents a dietary pattern traditionally associated with the northwest of the Iberian Peninsula including Galicia (Spain) and northern Portugal. The Atlantic diet has been recently considered a world reference for a healthy diet (Vaz Velho et al., 2016), as it maintains the basic characteristics of the Mediterranean diet while promoting the intake of fresh local and seasonal products, avoiding complex cooking methods. This diet also includes plant-based foods, seafood, legumes and nuts, with moderate consumption of animal products (i.e. pork and beef, milk and dairy products, and eggs), a significant intake of potatoes (higher than in Mediterranean countries), preferential use of olive oil for seasoning and cooking, and high consumption of mineral water. Therefore the optimal intake of polyunsaturated fatty acids, complex sugars, vitamins, fiber, minerals and functional components is guaranteed (Tojo and Leis, 2009; Vaz Velho et al., 2016). In this sense, the consumption of a balanced diet as in the aforementioned diets is beneficial for the prevention of numerous chronic diseases (Cencic and Chingwaru, 2010). For instance, the consumption of fruits, vegetables, nuts and fish is related with the low incidence of cancers, neurodegenerative and cardiovascular diseases and Type II diabetes (Bach-Faig et al., 2011). Furthermore, consumption of fruits and vegetables is also related to protective effects against cell oxidation (Charanjit Kaur and Harish C. Kapoor, 2001; Wang et al., 1996).

Numerous studies available in the literature report that there are outstanding differences between the dietary recommendations established by health administrations and actual food consumption patterns (Sáez-Almendros et al., 2013). While the Atlantic diet recommends a high consumption of fresh produce such as vegetables and fruits, data on actual consumption habits indicate that this is not being met as it should be (Sáez-Almendros et al., 2013). Thus, there is a significant gap between recommended dietary patterns and actual food consumption trends, which implies an intensification of resources in the production chain. Current patterns of actual consumption are associated with increased intake of processed food and other resource-intensive products, such as those of animal origin or processed foods (Cencic and Chingwaru, 2010; Tilman and Clark, 2014; Tukker et al., 2011).

Therefore, the main goal of this study is to compare, from a sustainability perspective, the recommendations of the traditional Atlantic diet with the real consumption trends, considering Galicia as case study, as well as to provide an answer to the question whether current consumption patterns ensure an optimal nutritional profile. Finally, the level of concurrence between both dietary patterns was also determined by taking into account both the carbon footprint (CF), from an LCA approach associated with food production, as well as the nutritional quality. Regarding the latter, two different indexes have been proposed for analysis to improve robustness and consistency of results: The Nutrient Rich Diet 9.3 score, which takes into account the intake of certain valuable and harmful nutrients (Van Kernebeek et al., 2014) and the health gain score, which follows a similar approach for food groups (Van Dooren et al., 2014). Furthermore, from a practical point of view, the study will allow to identify the weak spots of the GD from both a nutritional and environmental point of view and will serve as a guide for decision-makers to promote a consumption pattern in pursuit of the traditional diet.

2. Materials and methods

The comparative assessment of sustainability between two different dietary patterns related to the recommended Atlantic diet and the actual consumption pattern has been carried out by estimating the CF as a representative environmental indicator, as well as by means of two nutritional quality indexes. A detailed description of both perspectives is presented below.

2.1. Carbon footprint methodology

2.1.1. Description

In this study, the environmental sustainability of the two different dietary patterns in terms of their CF (i.e., GHG emissions) has been determined from a Life Cycle Assessment (LCA) approach, which systematically assesses the environmental burdens of each type of diet at all stages of its life cycle (ISO 14040, 2006). The carbon footprint is selected as an environmental indicator due to its great relevance and widespread use in related studies of dietary patterns (Aleksandrowicz et al., 2016; Batlle-Bayer et al., 2019; González-García et al., 2018; Ritchie et al., 2018; Springmann et al., 2018). In this case, the CF has been estimated considering the stages of production and transport to retailer, as detailed below.

2.1.2. Functional unit

The selected functional unit to report the results corresponds to the daily amount of food eaten per person, that is, the individual daily diet. This functional unit allows the comparison between the scenarios proposed, as well as with other related studies available in the literature on environmental assessment of different types of daily diets (Castañé and Antón, 2017; Pernollet et al., 2017; Werner et al., 2014) regardless of daily energy intake (i.e. kcal per capita and day).

2.1.3. Scope of the dietary scenarios

The scope of the CF study for both scenarios considered a cradle-to-mouth perspective. Thus, the systems analyzed included the stages of food production (i.e., production of the foodstuffs included in each daily diet) and transport activities (i.e. the distribution of the products from the factory, farm or port to the corresponding retailers and from retailers to households). Therefore, storing at retailers and consumption stage at the households, which should include operations such as food preparation at home, refrigeration and final waste disposal, were disregarded. The rationale behind their exclusion from the scope of the study is that these consumer activities should have a similar impact in both dietary scenarios, considered for the same region (Heller et al., 2013). Moreover, other studies (Berlin and Sund, 2010) established that the consumption stage could contribute up to 10% of the total life cycle GHG emissions when estimated considering the food consumed in a typical menu. However, with regard to the estimation of GHG emissions from food cooking in or outside households, it should be necessary to have real information on the menus and the cooking method (i.e., boiling, frying, baking, …) considered information that is not available for the GD scenario. Thus and taking in mind the mentioned studies, the exclusion of the consumption stage (i.e., food preparation) from the analysis could be justified. In addition, the exclusion of the stages mentioned also allows the results of this study to be compared with other relevant ones available in the literature (Castañé and Antón, 2017; Risku Norja et al., 2009; Sáez-Almendros et al., 2013; Saxe et al., 2012; Van Dooren et al., 2014).

Food losses along the chain considered in both scenarios have been calculated based on García-Herrero et al. (2018), especially regarding the distribution to retailer and consumption stages (Garcia-Herrero et al., 2018). This estimation is based on the losses reported by FAO for European countries (FAO, 2011). Bearing in mind that there is not detailed information on the loss percentage for pre-cooked food – an important item in the current diet, the highest percentage reported by García-Herrero et al. (2018) for processed food (5%) has been assumed for this type of foodstuff as the worst case. With regard to the foodstuffs production stage, information on losses has been included in the corresponding background processes due to the consideration of the cradle-to-gate approach of the references consulted.

2.1.4. Description of dietary patterns

Galicia (NW Spain) has been historically characterized as the cradle of a wide selection of high quality food products, appellation of origin and organic farming with prestige beyond its borders (Xunta de Galicia, 2005). All these concepts are included within the Atlantic diet model, fulfilling its basic characteristics such as abundance of seasonal, local and fresh products, high intake of plant-based products and seafood, as well as a moderate intake of animal-origin foodstuffs (Vaz Velho et al., 2016). Nevertheless, the current dietary choices of the Galician region may not be at all in line with these recommendations and with traditional patterns, which seem to vary in proportion and quantity of certain categories of foodstuffs. The spread of the occidental culture and the globalization of food consumption and production are behind these alternative choices; however, this trend is also observed in other dietary patterns such as the Mediterranean diet (Da Silva et al., 2009).

Recommended Atlantic Diet – RAD scenario

This scenario corresponds to the Atlantic diet recommendations defined by the Health Department of the Xunta de Galicia (2013). The 7 daily-menus reported by Esteve-Llorens et al. (2019) have been taken into consideration (See SM Table 2 to 8) (Esteve-Llorens et al., 2019). This study includes 67 foodstuffs grouped into 11 different categories (i.e., fruits, vegetables, legumes, grains, nuts, dairy products, eggs, meat, fish, sweets and oils/fats), all of which are recommended ingredients in the Atlantic food pyramid (Tojo and Leis, 2009) as well as in the traditional Galician gastronomy (Xunta de Galicia, 2013). In this scenario it has been assumed that the recommended servings according to the Atlantic diet pyramid (Tojo and Leis, 2009) are applied to the entire population even though they are aimed at the adult population. Therefore, the average daily intake of each food group ($g \cdot day^{-1}$) has been considered for evaluation to facilitate the resulting comparison with the other scenarios proposed for analysis. **Table 1** summarizes the daily intake of each food category per capita.

Galician Diet – GD scenario

The second scenario considered for analysis is based on the actual consumption patterns of the Galician diet. The available surveys from the Galician Ministry of Health (SERGAS, 2007) have been analyzed to gather dietary information. The consulted study reports Galician eating habits in 2007 (last year updated) and it is based on data from 3,148 participants, both urban and rural residents. The nutritional analysis included 129 food-items according to the surveys (SERGAS, 2007). As a result, in addition to the food categories indicated in the RAD scenario, an additional group of industrially processed foods has been included in the GD scenario which appears in the current consumption trends but is not included in the Atlantic dietary philosophy due to its low nutritional quality. The surveys were based on a dietary plan of 24 hours, conducted in two different seasons (Spring-Summer and Fall-Winter) to cover seasonal differences in the intake of some foodstuffs (e.g. broccoli, asparagus, peach, fig); in addition, a food consumption questionnaire was also carried out, supported by photographs of food servings to calculate the size of the portions eaten. The reported global food-items intakes (See SM Table 9) have allowed the estimation of the apparent food consumption per capita a whole day ($g \cdot person^{-1} \cdot day^{-1}$) as shown in **Table 1**. Nevertheless, the aforementioned SERGAS survey (2007) only provides an average figure of the food consumed per person per day. Thus variations between the different individuals surveyed cannot be appreciated. It is therefore important to take potential uncertainty into account when discussing the results.

Table 1. Daily amount (g) of each food category in the Recommended Atlantic Diet (RAD) and Galician Diet (GD) scenarios.

Food category	RAD ($g \cdot person^{-1} \cdot day^{-1}$)	GD ($g \cdot person^{-1} \cdot day^{-1}$)
Fruits	1024	439
Vegetables	633	581
Legumes	29.3	20.1
Grains	291	319
Nuts	33	5.0
Dairy	419	472
Eggs	23.7	26.2
Meat	91.9	213
Seafood	195.7	182
Processed food	0.00	88.1
Sweets	11.7	15.5
Oil/fats	29.9	23.6
TOTAL	2753	**2387**

2.1.5. Inventory data for carbon footprint estimation

After an extensive literature review, a total of 139 food products from 42 LCA studies (see Supplementary material) have been included in the inventory data set to determine the CF scores of both diet scenarios, all of which have been analyzed from a cradle-to-gate perspective. In addition, these foodstuffs have been grouped into 12 representative food categories: fruits, vegetables, legumes, grains, nuts, dairy, eggs, meat, fish, processed food, sweets and oil/fats (Aguilera et al., 2015; Clune et al., 2017; González-García et al., 2013; Gunady et al., 2012; Iribarren et al., 2011; Nielsen et al., 2013; Notarnicola et al., 2017; Noya et al., 2017; Volpe et al., 2015), attending to the Atlantic diet pyramid and other relevant studies in literature (Castañé and Antón, 2017). In order to apply a similar scope for both dietary scenarios, some assumptions have been made. In this sense, most of the foodstuffs LCA studies cover a cradle-to-gate perspective; however, when the CF of a food product includes transportation from retailer to households, food preparation or waste disposal, stages that have not been included in this study, the related GHG emissions have been discarded, by subtracting the corresponding percentage, according to specific LCA study indications. In addition, due to their minor contribution on the daily diets (Castañé and Antón, 2017; Van Kernebeek et al., 2014), food condiments, soft drinks, infusions, coffee and alcoholic beverages have been left out of the scope of the study.

On the other hand, certain products have been assimilated to others with similar production process and/or comparable nutritional characteristics due to the lack of data for the estimation of their environmental profiles. This is the case of chard (assimilated as lettuce), curd (as yogurt), semi-cured and cured cheese (as Galician cheese), leek (as onion), nectarine (as peach) and clams, oysters and scallops (as mussels).

In terms of distribution, Euro 5 diesel freight lorries (>32 tons) have been chosen for transport activities from the factory/farm gate to retailers for Spanish products. Thus, distribution distances of 60 km and 400 km (on average) have been set for the foodstuffs supply from inside and outside Galicia, respectively, for all products included in the study. In this sense, it is assumed that the vast majority of the products are manufactured in Spanish territory, except certain foodstuffs that are imported such as pineapple, coffee, cod or salmon. In these cases, an average distance by ship and lorry from their country of origin to Galicia has been estimated. Regarding the transport from retailers to households, assumptions from Esteve-Llorens et al., (2019) have been considered. Concerning the estimation of the CF of transport activities, the Intergovernmental Panel on Climate Change (IPCC) characterization factors have been applied to quantify the equivalent CO_2 emissions to be added to those of the food production phase. Inventory data taken from the Ecoinvent ® v3.2 database (Wernet et al., 2016) have been considered for road and sea transport.

2.2. Nutritional quality estimation

As previously mentioned, the nutritional quality of a diet is as important as its environmental impact, whether or not it is considered a sustainable diet, and it is also an important concept in our time, when the growing trend towards a healthy lifestyle includes the consumption of nutrient-rich foods instead of high-calorie products (FAO, 2010). In this sense, the nutritional quality of both dietary scenarios (RAD and GD) has been analyzed from an average daily menu perspective rather than from a single meal evaluation, which would not provide sufficient representative information on consumer habits (Van Kernebeek et al., 2014). In this case, the concept of daily menu is based on the average amount of each food-item consumed per person in a day.

In this study, two different nutritional indexes have been proposed for analysis, as they could be considered complementary. Firstly, the Nutrient Rich Diet 9.3 (NRD9.3) index proposed by Van Kernebeek et al. (2014) was calculated (see Equation 1). This score considers the daily intake of nine nutrients to encourage (protein, fiber, calcium, iron, magnesium, potassium, vitamin A, vitamin E and vitamin C) and three nutrients to limit (total sugar, saturated fats and sodium) (Castañé and Antón, 2017; Van Kernebeek et al., 2014). Consequently, the greater the amount of nutrients ingested to encourage and the smaller the amount of nutrients to limit, the higher the NRD 9.3 index is. Nevertheless, when the 9 nutrients to encourage exceed the Recommended Daily Value (RDV), they are capped to this former value, in order to avoid overestimation caused by overconsumption.

$$NRD9.3 = \left(\sum_{i=1}^{i=9} \frac{nutrient_{\,i\,capped}}{RDV_i} - \sum_{k=1}^{k=3} \frac{nutrient_{\,k}}{RDV_k}\right) * 100 \qquad (1)$$

On the other hand, a health gain score has also been proposed for estimation, which is based on certain parameters other than the nutrients mentioned above (see Equation 2). This health index has been developed by Van Dooren et al. (2014) taking into account the complexity of determining the health benefits of diets (Van Dooren et al., 2014). To this end, the health parameters established by different health organizations such as WHO[1], World Cancer Research Fund (WCRF)[2] or Dutch Health Council (DHC)[3] were taken into account.

$$Health\ gain = \left(\frac{g\ veg}{200} + \frac{g\ fruit}{200} + \frac{g\ fiber}{30} + \frac{30}{en\,\%\ total\ fat} + \frac{10}{en\,\%\ free\ sugar} + \frac{6}{g\ salt} + \frac{2000}{kcal\ energy}\right) * \frac{100}{7} \qquad (2)$$

The following parameters have been considered for the estimation: the daily intake of two food groups (i.e., vegetables and fruits), the daily percentage of energy obtained from total fatty

[1] http://www.who.int/ (accessed June, 2018)
[2] https://www.wcrf.org/ (accessed June, 2018)
[3] https://www.gezondheidsraad.nl/en/home (accessed June, 2018)

acids and free sugars, the daily intake of sodium and fiber and the total daily energy intake (kcal·day^{-1}). Therefore, the amounts of vegetables, fruits and fiber consumed are beneficial elements to encourage. Furthermore, it is not recommended to exceed the reference values for the daily percentage of energy intake obtained from total fatty acids and free sugars and the daily intake of sodium. Moreover, to contextualize the health gain score obtained for the RAD and GD scenarios, the recommended reference values of the mentioned parameters reported by the WHO (WHO, 2003) have been considered. Additionally, the complete nutritional composition of the foodstuffs has been obtained from the Spanish Food Composition Database (AECOSAN, 2018).

Finally, the estimated indexes for both dietary scenarios will be compared with other results (for these scores) available in the literature (van Dooren and Aiking, 2016; Van Kernebeek et al., 2014) to rank their position in terms of nutritional quality.

3. Results and discussion

3.1. Carbon footprint assessment

The estimated CF for RAD and GD is 4.53 kg CO_2 eq ·person^{-1}·day^{-1} and 5.22 kg CO_2 eq person^{-1}·day^{-1} respectively. The main factor responsible for the total GHG emissions is the foodstuffs production stage regardless of the scenario (i.e. 4.07 kg CO_2 eq ·person^{-1}·day^{-1} and 4.80 kg CO_2 eq·person^{-1}·day^{-1} for RAD and GD, respectively). The food production stage includes all the background processes related to agricultural and farming activities, as well as the corresponding industrial preparation activities if necessary (e.g., slaughterhouse, refrigeration and packaging). Consequently, it can be observed that transport activities are responsible for around 10% of total GHG emissions in both scenarios, specifically, ~0.4 kg CO_2 eq·person^{-1}·day^{-1}. The rationale behind this fact is that, in the case of food patterns from the same geographical area, the foodstuffs come from the same sources in most cases and are transported over similar distances.

Figure 1 shows the individual CF per scenario for the food production phase, including the distribution by contributing food category. As it can be observed, livestock products (i.e. meat and dairy products) are the main contributor to the CF. Not only because they are some of the most consumed foods (**Table 1**) but also because they are the foods with the worst associated environmental profiles (Aleksandrowicz et al., 2016).

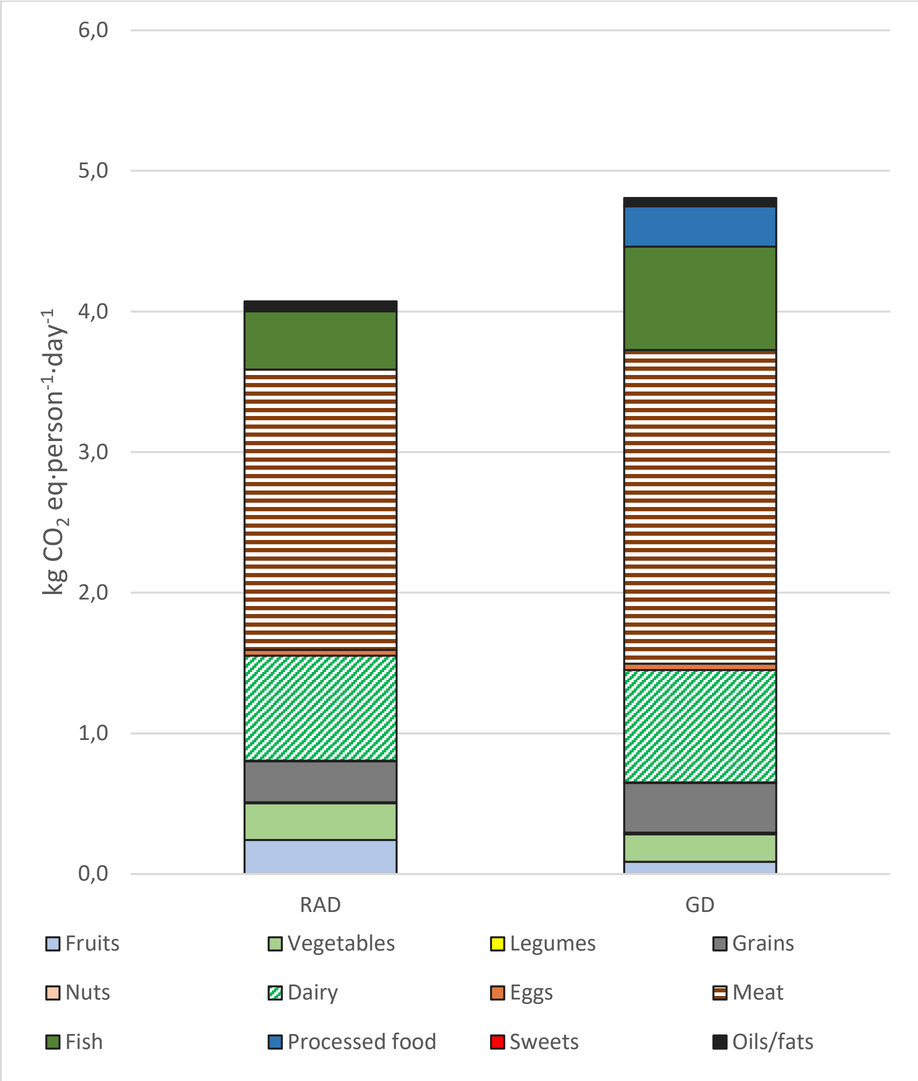

Figure 1. Distribution of food category contributions to the global carbon footprint. Acronyms: RAD – Recommended Atlantic Diet scenario; GD – Galician Diet scenario.

Focusing on meat products, both scenarios have a similar CF (i.e. 1.9 kg CO_2 eq and 2.2 kg CO_2 eq respectively for RAD and GD), despite the fact that the amount of meat ingested is roughly double in the GD compared to RAD as shown in **Table 1**. The rationale behind this result is associated with beef consumption, which is similar in both scenarios (66.9 g and 56.6 g respectively in RAD and GD), being this type of meat the one with the worst associated environmental profile: 28.60 kg CO_2 eq·kg^{-1} according to the average value reported by Clune et al. (2017). The CF associated with this amount of beef is 1.91 kg CO_2 eq and 1.62 kg CO_2 eq per person and day, being responsible for 42% and 31% of total GHG emissions in RAD and GD, respectively.

By comparison, the contribution to the total CF from meat consumption, taking into account other types of meat, is much lower than that from beef and veal. In addition, it can be noted that beef alone accounts for about half of the total CF in RAD, and about a third in the GD.

For all other food products, dairy products also report a remarkable effect on the CF regardless the scenario under study. In RAD, dairy products are responsible for 16% of the total CF. In the case of GD, their contribution is lightly lower (15%). This is a consequence of the notable intake of dairy products in the Galician region as shown in **Table 1**. The production of the seafood consumed is the third largest in terms of GHG emissions in both scenarios (see **Figure 1**). However, in this food category it is necessary to distinguish between RAD and GD. Although the amount of seafood products is similar in both dietary patterns (195 g and 182 g respectively for RAD and GD), the derived CF is almost twice as much in GD as in RAD (0.73 and 0.41 kg CO_2 eq respectively). The rationale behind this surprising result is mainly explained by the consumption of certain species in the GD, with relatively high GHG emission factors (e.g. salmon, hake, flatfish, prawns and canned tuna), which were not considered within the designed menus of RAD. As a result, seafood products account for about 14% of the total CF for the GD, and about 9% for RAD.

Moreover, it is interesting to note the contribution of the processed food category in the case of GD. As mentioned above, this category only appears in GD, as it includes products not recommended by the health authorities due to their low nutritional quality (Xunta de Galicia, 2013). However, they are actually present in the current consumption trends. In this sense, the consumption of processed foods represents around 6% (0.29 kg CO_2 eq) of the total CF in GD, which is a higher ratio than that associated with other ingredients such as vegetables and fruits (≈4% and ≈2% respectively), which are considered basic foods in the diet.

Finally, in terms the contribution to the CF score of food losses along the food supply chain, its relevance to the environmental footprint can be highlighted, since food losses represent around 14% of the total CF for both scenarios (around 0.7 kg CO_2 eq). Therefore, attention should be paid to this hotspot.

3.2 Comparing the nutritional quality of RAD and GD scenarios

Regarding the NRD9.3 index, the results estimated for RAD and GD are 474 and 242, respectively, as shown in **Table 2**. The amount of each nutrient ingested to limit and promote is also depicted in the table, as well as its recommended daily intake value (RDV). It is important to note that when the RDV outcomes fall between two values, an average value has been considered in the estimate.

Table 2. Nutrient Rich Diet 9.3 (NRD9.3) index for both Recommended Atlantic Diet (RAD) and Galician Diet (GD) and Recommended Daily Value (RDV) for each nutrient considered in the index.

Nutrient	Units	RDV	RAD	GD
Protein	g	50	101	133
Fiber	g	25	39.9	36.8
Vit A	µg	700-3000	1448	967
Vit C	mg	60-2000	320	195
Vit E	mg	20-1000	23.0	11.7
Ca	mg	1000-2500	1083	1182
Fe	mg	18-45	33.0	18.5
K	mg	3500	4938	4151
Mg	mg	400	435	364
Saturated fats	g	20	19.3	35.2
Free sugars	g	50	117	101.1
Na	mg	1500-2400	1449	2537
NRD9.3			**474**	**242**

As can be seen, the intake amount of many nutrients is higher than the RDV in both scenarios. On the other hand, comparing the ingestion values corresponding to the nutrients to encourage, their intake is higher for most nutrients in RAD than in GD mainly due to the large consumption of fruits and vegetables (see **Table 1**). However, in terms of protein and calcium, the situation is reversed. The higher intake of protein in GD (2.5 times higher than the RDV) is related to the remarkable consumption of meat, considerably higher than the recommended values (see **Table 1**). The higher intake of dairy products in GD consequently increases the amount of calcium ingested, being 0.2 times higher than the RDV.

When comparing the intake of nutrients to limit, saturated fat, free sugars and sodium are ingested in higher amounts in the GD than in the RAD, which is mainly attributed to the consumption of processed foods (AECOSAN, 2018). In this regard, it is important to mention that in RAD, the intake of all limiting nutrients is below the RDV. In contrast, the intake of saturated fat and sodium in the GD is considerably higher than the recommended values. The intake of added free is much higher than the RDV for the GD, mainly due to the intake of processed foods and sweets. Considering that sodium is the leading cause of death due to an inadequate diet, followed by a low intake of fiber and fruits (Afshin et al., 2019), emphasis is placed on avoiding excessive consumption of this element.

The health gain scores for the RAD and GD scenarios are shown in **Table 3**, as well as the required reference values for each parameter (Equation 2). As previously reported, the health gain score is the result of the ratio between the reference intake values considered for vegetables, fruits, total fatty acids, free sugars, fiber, sodium and energy and those for actual intake in both scenarios.

Table 3. Health gain score results for both Recommended Atlantic Diet (RAD) and Galician Diet (GD) scenarios.

Indicator	Units	Reference value	RAD	GD
Vegetables	g	200	462	424
Fruit	g	200	747	321
Total fatty acids	%	30	31.8	31.9
Free sugars	%	10	22.3	23.5
Fiber	g	30.0	39.9	36.8
Sodium	g	6.0	1.4	3.1
Energy	kcal	2000	2100	2381
Health gain score		**100**	**198**	**115**

As can be seen, the amount of vegetables and fruits consumed in both scenarios is higher than the reference values set by WHO (WHO, 2003). In this sense, it is important to note that the intake of vegetables is more than double the reference quantity regardless of the scenario analyzed, and almost three times higher for the intake of fruits for RAD. Even the quantity of fruit consumed in the GD is 50% higher than the reference value (321 g versus 200 g). The justification for these differences is associated with the high availability of vegetables and fruits in the Atlantic region throughout the year, as well as the cultural culinary tradition of the region. In terms of fiber intake, it can be seen that the amount consumed in both scenarios is also above the reference value (30 g), an increase of 33% and 23% respectively for RAD and GD. As beneficial parameters, a higher intake of vegetables, fruits and fiber leads to better nutritional quality and, consequently, a higher health gain score. Taking into account the percentage of energy obtained from total fatty acids and free sugars, it should be mentioned that the proportions are above the reference value. While it is only 2% higher for total fatty acids, the percentage of energy from sugars far exceeds the recommended value, which is evidenced by a clear negative effect on the final health gain score. However, it is important to point out that the high intake of free sugars is directly related to high fruit consumption. On the other hand, the daily intake of sodium is lower than the recommended dose (6 g), at values around 75% and 50% lower in RAD and DG, respectively.

Energy intake in both scenarios varies slightly from the 2,000 kcal set by WHO (WHO, 2012). An increase in calorie intake is not considered advisable and has a negative impact on the health benefit score. With all these data reported, the health gain score has been estimated for both scenarios according to Equation 2.

The values obtained for both scenarios are 198 points and 115 points respectively for RAD and GD (**Table 3**). Despite this outstanding difference, both scores are above the WHO benchmark (i.e. 100 points). Comparing the RAD and DG scores, it can be seen that the reason for the large difference in health gain scores is directly associated with fruit intake, as no notable differences in the remaining parameters can be identified. Otherwise, this practice also influences the fact that the health gain values in GD are above the reference value, mainly due to higher consumption of vegetables and fruits. Furthermore, it should be borne in mind that due to non-excessive energy intake (**Table 3**), the Health Score is not affected by this factor which on the contrary, would significantly penalize the nutritional quality.

3.3. Benchmarking environmental and health gain scores

Taking into account the results obtained in terms of nutritional and CF indexes, it is necessary to establish a relationship between them and those of the different studies available in the literature (Van Dooren et al., 2014; van Dooren and Aiking, 2016). The health gain score for RAD (198) is above the values found in the literature for other well-positioned dietary options from environmental and health approaches such as the Mediterranean (MD), vegan (VD), vegetarian (VGD) and semi-vegetarian (SVGD) diets as can be seen in **Figure 2**. On the other hand, the health gain score achieved for GD (114) is above the reference value (100) as mentioned above, and is consistent with those identified for other dietary patterns (**Figure 2**), and even better than VGD or SVGD.

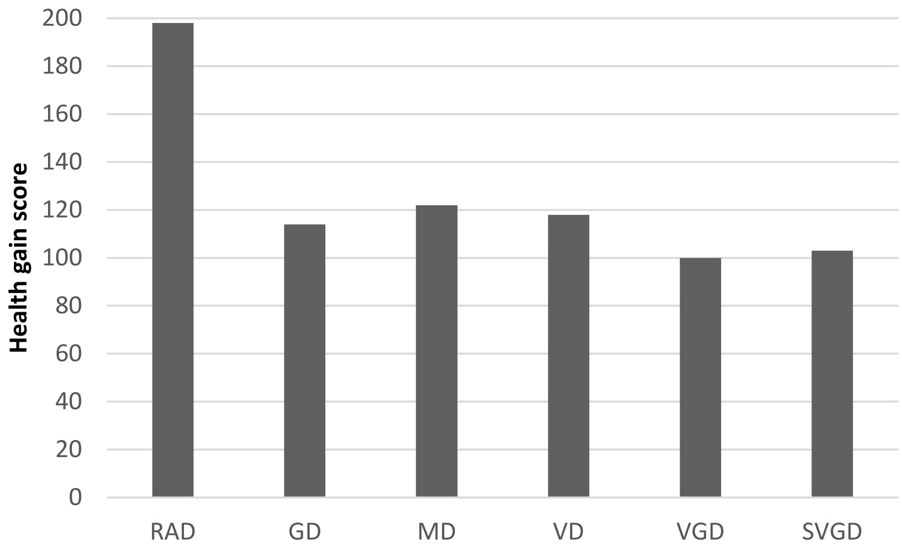

Figure 2. Comparison in terms of Health gain score of RAD and GD with alternative healthy diets available in literature. Acronyms: MD - Mediterranean diet; VD - Vegan diet; VGD - Vegetarian diet; SVGD - Semi-Vegetarian diet.

In order to establish a relationship between the nutritional quality and the CF, **Table 4** details the NRD9.3 and CF scores of both scenarios under study and the studies available in the literature; the health gain score has not been included in this table due to lack of information to perform the estimation of this index for these diets. Regarding the NRD9.3 values, RAD and GD obtain a score in line with those of these diets that use the same RDV (Castañé and Antón, 2017). As it can be seen in **Table 4**, the RAD score reports a higher nutritional quality than others in the literature. On the other hand, the nutritional score for GD is lower than most of the values cited (e.g., Mediterranean and Healthy diets). Nevertheless, it is necessary to keep in mind that this is a scenario based on real consumption trends and it is not a one based on recommendations such as the other studies mentioned in the literature (Castañé and Antón, 2017; Pathak et al., 2010; Risku Norja et al., 2009; Saxe et al., 2012; Van Dooren et al., 2014). It means that certain type of foods of lower nutritional quality, such as processed food and sweets, are included.

Table 4. Summary of NRD9.3 and Carbon Footprint (CF) indexes regarding RAD (Recommended Atlantic diet), GD (Galician diet) and other diets available in literature.

	NRD9.3	**CF (kg CO_2 eq·person^{-1}·day^{-1})**
RAD	474	4.53
GD	242	5.22
Mediterranean diet (Castañé and Antón, 2017)	389	2.86
Vegan diet (Castañé and Antón, 2017)	469	1.86
Mediterranean diet (Sáez-Almendros et al., 2013)	-*	2.19
Spanish current diet (Sáez-Almendros et al., 2013)	-*	4.39
Vegan diet (Castañé and Antón, 2017)	469	1.86
Vegetarian diet (Pathak et al., 2010)	424	0.58
Healthy diet (Risku-Norja et al., 2009)	382	3.84
Vegan diet (Risku-Norja et al., 2009)	442	2.47
Vegetarian diet (Van Dooren et al., 2014)	-*	3.2
Danish dietary pattern (Saxe et al., 2012)	112	5.52

*nutritional information not available.

Taking into account the CF for RAD and GD, and comparing these values with others reported in the literature, our scenarios involve relatively high CF scores (i.e. 4.53 and 5.22 kg CO_2 eq·pers^{-1}·day^{-1} respectively for RAD and GD) mainly due to the huge consumption of beef as mentioned above. In view of the results, it is important to refer to the fact that all the dietary patterns mentioned, except the current Spanish dietary pattern of Sáez-Almendros et al. (2013), the Danish dietary pattern of Saxe et al., (2012) and GD, are diets based on recommendations, generally leading to lower CF outcomes. However, attention should be paid to the system boundaries considered since waste production and distribution to households have been included in our study, these stages being responsible for 24% of total CF. In this sense, food distribution and waste are relevant hotspots that significantly increase the CF value and have not been considered in the abovementioned studies. As can be seen, nutritional quality and CF are not always inversely proportional parameters when comparing diets from different studies; however, there is a trend that links both. In this sense, a higher nutritional quality usually translates into a lower CF, as is also observed for the Mediterranean and vegan diets in Castañé and Antón (2017). Considering these interactions, it is important to stand out that the variation on both the nutritional quality and the CF is always related to the products of animal origin (i.e. meat and dairy).

3.4. Sensitivity analysis of diets sustainability

As mentioned above, beef meat is the main source of GHG emissions for both scenarios under study. For this reason, a sensitivity analysis is proposed to determine the effect of the substitution of this type of meat by other types of foods that imply lower GHG emissions and a similar contribution of protein in both diets, as summarized in **Table 5**, without significantly affecting energy intake (kcal per day).In this sense, six protein-rich foods have been selected: Two alternative types of meat (pork and chicken) have been selected as alternatives to beef, taking into account that they are the second (pork) and third (chicken) most consumed meats in Galicia (SERGAS, 2007); two legumes (lentils and peas) have also selected for analysis taking into account the recommendations from Jungbluth at al. (2016), which advise the consumption of vegetable proteins as opposed to animal proteins (Jungbluth et al., 2016); finally a couple of fish products (hake and tuna) have been considered, considering the priority of fish consumption in the Atlantic diet (Álvarez and Peláez, 2018).

Table 5. Sensitivity analysis of Carbon Footprint (CF) and NRD9.3 results when substituting beef-meat in RAD and GD scenarios by alternative foodstuffs (meat, legumes and fish).

	RAD		**GD**	
Scenario	**CF (kg CO_2 eq·person^{-1}·day^{-1})**	**NRD9.3**	**CF (kg CO_2 eq·person^{-1}·day^{-1})**	**NRD9.3**
Beef-meat	4.53	474	5.22	242
Meat				
Pork	2.81	512	3.79	245
Chicken	2.84	515	3.77	247
Legumes				
Lentils	2.63	513	3.67	269
Peas	2.62	523	3.62	266
Fish				
Hake	3.08	512	3.96	271
Tuna	2.72	515	3.69	272

As regards the simulations carried out for RAD and GD, it is noted that the removal of beef meat in both cases results in a drastic reduction in the CF. In this sense, the highest variation in both the CF and NRD9.3 scores occurs when beef is replaced by legumes, with a reduction in the CF of about 40% and 30% for RAD and GD respectively, and an improvement in the nutritional quality of about 10% in both situations. On the other hand, the consideration of alternative meats reduces the CF by 40% and 30% in RAD and GD respectively, resulting in an improvement of the nutritional quality in both scenarios, around 10% for RAD and 2% for GD. Finally, the alternative of fish products also leads to an improvement in the nutritional quality, in this case the highest one in the GD. Regarding the CF score, it is also reduced in both scenarios although the reduction is lower if hake is considered than tuna, which has a moderately high GHG emission factor. It could therefore be reported that the replacement of beef with alternative food products would be a beneficial measure both environmentally and nutritionally.

Analysis of data quality

In terms of data quality, CF is selected as an environmental indicator. In this regard, the variability of LCA data for each product should be taken into account, e.g., for beef meat the carbon footprint ranges from 9.3 kg CO_2 eq·kg^{-1} for organic farming (Solid Forest, 2011) to

28.73 kg CO_2 eq·kg^{-1} for conventional farming (Clune et al., 2017). Thus, most conservative figures have been taken into account and the results have been carefully discussed. Furthermore, the beef meat has been identified as a hotspot regarding the results for CF, which could be identified as an opportunity by LCA practitioners to improve their production processes (e.g., technological adaptation at the farm level in order to minimize methane emissions from either enteric fermentation or manure management)(Hyland et al., 2017). Moreover, additional environmental indicators, such as water footprint or land occupation, should be taken into consideration to obtain a more complete environmental profile.

Additionally, with regard to the source of actual food consumption figures for the GD scenario, data from a survey conducted in 2007 has been used, as previously mentioned, due to the lack of more updated real representative data. Thus, this survey is the most recent one for Galicia and the most detailed. However, consumption habits evolve and consequently the CF and nutritional quality. Therefore, efforts should be conducted in the design of a food frequency consumption questionnaire to be supplied to the Galician population for the handling of real parameters.

4. Conclusions

The outcomes of this study prove that there is a deviation between actual consumption patterns and diets based on health recommendations, both from an environmental and nutritional point of view. Thus, in the specific case of Galicia, the current dietary pattern obtains much lower scores in nutritional indexes and a higher CF than the recommendations from the traditional Atlantic diet. Therefore, a change in the current trends of food consumption towards the recommendations of the Atlantic pyramid would be beneficial. In this sense, as weak spots in the GD (excessive sodium intake), processed and pre-cooked foods should be left aside, as they are the ones with the worst nutritional quality. However, it has also been proven that both the nutritional and environmental quality of the two studied scenarios can be improved by replacing beef with a more sustainable source of protein, taking as reference the methodology used in this study. In this sense, it is advisable to provide more proteins of vegetable origin than those of animal origin, with legumes being the best possible substitute.

The results can be useful for regional policy makers and sanitary authorities to act on the hotspots that cause the greatest loss of nutritional quality and the resulting increased carbon footprint. In the same way, they can be also extended to other regions or countries interested in promoting adherence to the Atlantic diet.

Further research should be based on the design of new variants for the Atlantic diet, focusing on improving environmental quality without affecting its nutritional quality; the changes should be made by replacing foods with a higher environmental impact with more sustainable ones, included in the traditional foods of the Atlantic diet. In addition, taking into account the concept of sustainable diet, future research should include other relevant environmental impacts that are also significant in studies related to food production, such as the water footprint, and socio-economic indicators related to the affordability of diets.

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