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Impact of current, National Dietary Guidelines and alternative diets on greenhouse gas emissions in Argentina

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ABSTRACT

Diets have become an increasingly important driver of environmental pressures due to greenhouse gas emissions (GHGE), land use and other indicators of environmental impact associated with food production. In the present study we analyse the GHGE and the potential climate change mitigation through dietary changes in a country with high beef consumption, to contribute to the debate on what constitutes a healthy and sustainable diet. Data collected in the National Survey of Household Income and Expenditure 2012/2013 was used to estimate the composition of the current diet in Argentina, and four dietary scenarios were developed following the nutritional recommendations of the National Dietary Guidelines (NDG). We found that the GHGE related to the current Argentinian diet are very high (5.48 ± 1.71 kg CO_2-eq/person/day), with beef production contributing to the largest share of emissions (71%). The NDG suggest a 50% reduction of total daily intake of meats compared to current consumption, which, if adopted, would reduce GHGE in 28%, to 3.95 ± 0.96. Further reductions in GHGE appear possible while maintaining a healthy and balanced diet. The scenarios with non-ruminant meats and lacto-ovo vegetarian lead to similar GHGE, 2.11 ± 0.41 and 1.73 ± 0.37 kg CO_2-eq/day/person, respectively; and the vegan diet results in the lowest, 1.47 ± 0.34 kg CO_2-eq/day/person. Indicators for nutrient efficiencies were also developed. All nutrient efficiencies decreased in diets with bovine meat with respect to the non-ruminant, vegetarian and vegan ones. The results of this study therefore indicate that a set of dietary changes would significantly contribute to lower GHGE. Argentina's NDG should include the environmental impacts of food consumption with the aim of raising consumer awareness.

1. Introduction

Diet and nutrition are major determinants for maintaining health and preventing non-communicable diseases in modern societies (Katz and Meller, 2014). In the last 50 years, there has been a shift in food consumption patterns towards higher food energy density, with an increased participation of more resource-intensive foods, in particular animal-source foods (Imamura et al., 2015; González et al., 2011).

Besides the impact on public health associated with this trend (Popkin et al., 2012), dietary shifts have become an increasingly important driver of environmental pressures (Godfray and Garnett, 2014), a process that is likely to continue even if the rate of population growth slows down (van Vuuren and Carter, 2014). Food production requires a large share of available natural resources, such as land, fresh water, agricultural inputs and energy, and emits pollutants to the biosphere (CO_2, CH_4, NO_x, SO_4^{2-} and PO_3^{3-}), altering global biogeochemical processes (Westhoek et al., 2016; Tuomisto et al., 2017).

It has been estimated that the global surface temperature should not rise more than 2 °C above pre-industrial level to avoid dangerous climatic changes (IPCC, 2014). On the other hand, the share of the food system accounts for approximately one third of total greenhouse gas emissions (GHGE) worldwide (Vermeulen et al., 2012), of which up to 80% are associated with animal-source foods production (Tubiello et al., 2015). Therefore, a sharp decrease in GHGE in the agricultural sector has been suggested (Wollenberg et al., 2016), particularly those related to the livestock sector (Herrero et al., 2016; Röös et al., 2017). In spite of this, projections indicate an increase in animal-source foods production and consumption in the next decades, particularly in developing countries (Alexandratos and Bruinsma, 2012); hence an increase in GHGE in the food sector is also expected (Tubiello et al., 2015; Davis et al., 2016). Technological improvements in animal husbandry and in agricultural practices are still possible, though it would not be enough to decrease the GHGE to achieve the required levels (Bryngelsson et al., 2016; Röös et al., 2017).

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Recent studies have shown that diets with high proportion of animal source foods are associated with larger GHGE and several other environmental burdens, as land and water use and eutrophication potential (Gephart et al., 2016; Alexander et al., 2016; Behrens et al., 2017). Thus, a growing body of evidence suggest that dietary change towards less meat and dairy, in addition to food waste reduction and technical improvements in the agricultural sector, seems to have a large potential to mitigate climate change and comply with the 2°C goal (Hedenus et al., 2014; Bajzelj et al., 2014; Hallström et al., 2015; Röös et al., 2017). Previous studies on diet choices and GHGE were performed for countries with low to medium levels of beef consumption, which has been shown to be the food with the highest GHGE (De Vries et al., 2015), and so there is a gap of knowledge on how much GHGE could be reduced by diet changes in countries with high beef consumption. Argentina is a developing country with a long tradition on beef consumption and at present closely rivals Uruguay for the most beef consumption per capita worldwide (OECD, 2017). The daily amounts ingested exceed by far the recommendations for prevention of cancer and other non-communicable diseases (WCRF and AICR, 2007; Larson and Orsini, 2014; Bouvard et al., 2015), which led the Ministry of Health in Argentina to recommend a healthier diet (National Dietary Guidelines, NDG) with a significant reduction of total meat consumption and an increase in the amount of vegetables, fruits and whole grains (Ministry of Health, 2016).

Using Argentina as a case study, the aim of the present work is to analyse the current GHGE and the potential climate change mitigation through dietary changes in a country with high beef consumption, to contribute to the debate on what constitutes a healthy and sustainable diet. We analysed the composition of the current diet in Argentina and estimated the GHGE associated. Four additional dietary scenarios were developed following the nutritional recommendations of the NDG to be compared. Indicators of nutrient delivery efficiency as a function of GHG emitted were also defined and quantified for protein, carbohydrate, fat and food energy. These indicators give an assessment of the climate impacts of whole diets based on the nutritional content of foods.

2. Materials and methods

2.1. Dietary and nutritional data

The composition of the current diet (CD) was estimated using The Food Consumption Atlas, a tool developed by the National Institute for Agricultural Research (INTA) to facilitate the visualization and analysis of the data collected in the National Survey of Household Income and Expenditure 2012/2013 (NSHIE), carried out by the Institute of Statistics and Censuses (Brescia and Rabaglio, 2015). The NSHIE 2012/2013 was performed in households of urban settlements of more than 5,000 inhabitants, comprising 86.7% of the total population of the country and 99% of the urban population (INDEC, 2017). The rural population, around 14% of the total, was not considered. The information in the Food Consumption Atlas was freely downloaded and includes the monthly consumption of more than 300 types of foods and drinks of all the population represented in the NSHIE. This food items are expressed in kilograms or litres consumed per month at national scale, so the amounts were adapted as grams/person/day or millilitre/person/day using the total consumption data and population represented in the survey. Although NSHIE does not report real consumption but purchase, it is a good proxy to estimate food consumption for the general population (Sununtnasuk and Fiedler, 2017). Food wastage was not considered due to lack of data for Argentina. We did not attempt to use food wastage estimates from other countries due to different social and cultural characteristics, which might lead to unknown uncertainties.

The food composition database from the United States Department of Agriculture (USDA, 2017) was used to assess energy, protein, carbohydrate and fat content in foods. We use this database instead of an Argentinean source because it has all food items required to perform the analyses. To organize the assessment, all food items were classified in 18 categories (see Table 1). Dairy products were unified as "milk equivalent" using conversion factors detailed in Supplementary materials (Table 1) and processed meats and cold meats were allocated into the categories of meat according to their ingredients (for instance, meat in salami are assumed to be 60% pork and 30% bovine, while 10% comprises water and additives).

Finally, the CD was standardized to 2000 kcal/person/day to be compared. Table 1 shows the results of the food, energy and macronutrients composition of CD in Argentina.

Table 1
Food, energy and macronutrient diet composition in grams per person per day.

Food type	Current diet	MDP scenario	NRM scenario	LOV scenario	VG scenario
Beef	135	71.3	0	0	0
Pork	14.2	7.5	15.5	0	0
Poultry	85.7	45.2	107	0	0
Lamb	1.3	0.7	0	0	0
Fish and seafood	7.8	4.1	7.1	0	0
Dairy (milk equivalent)	335	524	520	513	0
Eggs	16.1	25.2	23.5	23.1	0
Legumes and pulses	4	16.1	14.6	115	233
Rice	23.2	41.1	25.4	37.7	57.3
Cereals and pasta	66.8	88	65.6	80.7	170
Baked products	144	120	119	110	126
Fruits	85.4	298	304	286	373
Vegetables	144	406	408	414	629
Starchy vegetables	87.4	73	64	66.9	127
Nuts	0.1	0.1	0.1	19.8	34.7
Oils and fats	23.7	16.1	14.1	22.7	34.5
Energy and macronutrients					
Grams/day	1290	1859	1996	1799	1954
Kcal/day	2000	2000	2000	2000	2000
g/protein/day	85	79	83	69	61
% of kcal	17%	16%	17%	14%	12%
g/fat/day	85	67	70	64	51
% of kcal	38%	30%	32%	29%	23%
g/carbohydrate/day	224	270	259	287	324
% of kcal	45%	54%	52%	57%	65%

2.2. Dietary scenarios

To compare the current diet with alternatives, four scenarios have been proposed: (1) Model Dietary Plan based on the National Dietary Guidelines, named MDP scenario; (2) diet with no-ruminant meats, named NRM scenario; (3) lacto-ovo vegetarian, named LOV scenario; and (4) vegan diet, named VG scenario. All dietary scenarios were also standardized to 2000 kcal/person/day and modelled following the NDG from the Ministry of Health (2016), which was designed by consensus among local experts following the energy consumption and macronutrients suggested by the World Health Organization and Food and Agriculture Organization (WHO/FAO, 2003; WHO/FAO/UNU, 2007; Burlingame et al., 2009), and for vitamins and minerals by the Food and Nutrition Board of the Institute of Medicine (Otten et al., 2006). For the aims of this comparative study, the items in the salt and spices, soft drinks, alcoholic drinks, sweet and sugary foods categories were excluded, assuming them rather constant across the scenarios.

Daily intake of meats recommended by the NDG is 130–150 g/person/day for all meats combined (Ministry of Health, 2016), in contrast with the CD which includes 244 g/person/day. Therefore, MDP and NRM scenarios are modelled to NDG recommendations, which contains almost half of the weight of meats in relation to the current diet. Since the NDGs do not specify which meats to reduce but reducing the total amount, in the MDP scenario the proportions of meat types were maintained as in CD, while in the NRM scenario beef and lamb were replaced by poultry, pork and fish. At present, there are no studies on food patterns of vegetarians in Argentina, thus LOV and VG scenarios were designed following the nutritional recommendations of the NDG (Ministry of Health, 2016) combined with studies on food consumption and nutrient intakes by vegetarians in other countries (Orlich et al., 2014; Clarys et al., 2014; Bradbury et al., 2017). Table 1 shows the composition of the diet scenarios described. For more details about scenarios see Supplementary material.

2.3. Data for greenhouse gas emissions for food production

GHGE are obtained from Life Cycle Inventory (LCI) studies, in which all stages in the producing and manufacturing processes are analysed. At present there is no data on GHGE for the variety of foods produced in Argentina and thus we will use sources that have reviewed data from several studies worldwide. This assumption is reasonable as we consider common foods consumed by the majority of people, as demonstrated in the surveys analysed, and commercial farming and animal production are rather standardized worldwide, in cases with the same companies providing farms with similar technological packages in different countries and locations. We have used three main sources, Clune et al. (2017), Notarnicola et al. (2017), and Tilman and Clark (2014). The criteria to select these works were the large number of cases analysed and the clarity of the system boundary, from the manufacture of agricultural inputs to the farm gate. Therefore, the stages of processing foods, refrigeration, retailing distribution and preparation of meals are excluded, except for baked products, for which the study from Notarnicola et al. (2017) gives a large number of cases up to the final consumption point. Hence, the GHGE obtained here for the various diet scenarios could be underestimated; however, the same criteria was applied across all diets to guarantee the value of the comparison.

As seen in Table 2 in Supplementary material, animal source foods in general result in larger GHGE per unit weight, which is more significant in ruminant meats. In previous works, it has been demonstrated that the differences in GHGE (as well as in energy use) between plant and animal origin foods become even larger per unit of protein produced (González et al., 2011). There are exceptions for vegetables grown in heated greenhouses or transported by airplane (Carlsson-Kanyama and González, 2009); however, these cases do not apply to Argentina.

Uncertainties in the composition of the current diet were not assessed due to lack of information, and the modelled diets have no uncertainties by definition, so GHGE are the variables with uncertainties in the present work, as shown in Table 2 of Supplementary material. To account for the total uncertainty in each diet, we performed a propagation analysis of uncertainties according to IPCC (2006). This is done combining uncertainties in GHGE (Table 2 in Supplementary material) with food intakes (Table 1).

3. Results and discussion

3.1. GHGE for the current diet and four dietary scenarios

Table 2 summarizes the results of the GHGE for the different food types of the current diet and dietary scenarios.

The CD in Argentina resulted in the higher emissions of the diets analysed (5.48 ± 1.71 kg CO_2-eq/person/day), of which bovine meat has a share of 71% of the total, followed by dairy with 8.5%, poultry with 6.4% share, and baked products and oils and fats with 3% and 2.2% respectively. Even though all plant foods consumed comprise 45% of the weight and 33% of the protein, the emissions associated are 10% of the total. On the other hand, foods from animal origin account for 45% of the weight, 67% of the protein and 90% of GHGE. This result is related to both the high amount of beef consumed and the fact that beef results in the largest emissions per kg of foods (Clune et al., 2017). Traditionally, consumers in Argentina have preference for beef over lamb and pork, not only due to cultural or gastronomical reasons but due to lower sale prices for beef against other meat options, with the exception of poultry. In the last 50 years, beef consumption in Argentina has decreased steadily, although it is still the most consumed meat and of great relevance in the current diet (Table 1). Poultry is at present the meat with lowest retail price and second in consumer preference, experiencing a sharp rise in consumption reaching 36.5 kg/year/person in 2016 from only 9 kg/year/person in 1990 (OECD, 2017). The very low current consumption of legumes, fruits and vegetables is highly noticeable given that Argentina is a major producer and exporter of these products and their availability in the local market.

The GHGE in the Argentinian CD are between 33% and 120% higher than diets studied for other countries, where the same boundary conditions at farm gate were assumed. For instance, Fazeni et al. (2011) investigated the emissions for the Austrian diet, which includes 150 g/day of all meats and resulted in 2.47 kg CO_2-eq/person/day emissions. Based on the Dutch National Food Consumption Survey from 1998, van Dooren et al. (2014) estimated the GHGE in 4.1 kg CO_2-eq/person/day for a diet with 102 g/day of total meats, but the study does not present the emissions for each food item in the diet, meaning that the comparison can be done only on the total amount. A very recent work investigated the Chinese average diet by using data from Tilman and Clark (2014), and found emissions of 3.07 kg CO_2-eq/person/day for women and 3.50 kg CO_2-eq/person/day for men (Song et al., 2017). However, the GHGE for animal products given by Tilman and Clark (2014) are higher than those used here from Clune et al. (2017). For instance, emissions from beef are considered 42 kg CO_2-eq/kg of product in the former but 28.7 kg CO_2-eq/kg of product in the later. For the case of Argentina, the world average emission given by Clune et al. (2017) may underestimate the real emissions from beef production (Rearte and Pordomingo, 2014).

The MDP scenario resulted in a reduction of 28% in GHGs with respect to the CD (3.95 ± 0.96 kg CO_2-eq/person/day. This trend is also in agreement with studies which compare diets and their respective emissions in other countries (Hallström et al., 2015). This scenario presents lower emissions from animal sources, in spite of the fact that dairy and eggs increase GHGE by 55% compared to the current diet. In the MDP scenario the GHGE from plant foods account for 21% of the total, while contributing 57% of the weight and 46% of the protein in the diet. Even after the reduction in bovine meat intake, this sole item leads to 52% of the GHGE in the MDP scenario. The reduction in beef consumption in the MDP scenario with respect to the current diet is significant; however, the 71 g per day of bone-free beef consumed implies a yearly consumption of 26 kg/person, which is still above the average beef consumption per capita in Brazil, USA and in the European Union (OECD, 2017). Also, this amount of beef is at the upper limit of recommended red-meat consumption in order to prevent cancer (WCRF and AICR, 2007) and with the addition of pork, even the MDP scenario results in red meat consumption above the recommended amount for cancer prevention.

The NRM scenario sums up a total GHGE of 2.11 ± 0.41 kg CO_2eq/person/day, which is a reduction of 62% compared to the CD and 47% compared to the MDP scenario. It is interesting to note that in NRM scenario the percentage of animal protein in total protein (57%) is still high, lower than the 66% found in the CD scenario. However, GHGE from animal protein sources have been sharply reduced from 4.91 kg CO_2-eq/person/day to 1.37 kg CO_2-eq/person/day respectively. In MDP scenario, the main contributor to GHGE is dairy, followed by poultry. The portion of animal foods in the MDP scenario account for 34% of the weight, 57% of the protein and 65% of the total GHGE. Other studies found that replacing meat from ruminants with meat from monogastric animals (poultry and pork) could reduce emissions between 20% and 35% (Hallström et al., 2015). Yet, in the present comparison we find

Table 2
Daily GHGE for current diet and the 4 dietary scenarios. The values are expressed in gCO_2-eq/person/day.

Food type	Current diet	MDP scenario	NRM scenario	LOV scenario	VG scenario
Beef	3880	2049	0	0	0
Pork	82.8	43.7	90.8	0	0
Poultry	353	186	442	0	0
Lamb	36.5	19.3	0	0	0
Fish and seafood	34.3	18.1	31.4	0	0
Dairy (milk equivalent)	465	729	723	713	0
Eggs	54.5	85.3	79.8	78.3	0
Legumes and pulses	3.6	15	13.2	103	210
Rice	61.6	109	67.6	100	152
Cereals and pasta	92.1	121	90.6	111	235
Baked products	166	139	137	127	145
Fruits	42.7	149	152	143	186
Vegetables	67.7	191	192	194	296
Starchy vegetables	17.5	14.6	12.8	13.4	25.5
Nuts	0.14	0.15	0.13	28	49
Oils and fats	123	84	73	118	179
Total	5481 ± 1707	3953 ± 968	2106 ± 412	1730 ± 372	1478 ± 340

that the reduction in GHGs could reach 53% when comparing CD with MDP and NRM scenarios, both including the same amount of total meats of 130 g/day.

Finally, the vegetarian scenarios led to the lowest levels of emissions, with 1.73 ± 0.37 and 1.47 ± 0.34 kg CO_2-eq/person/day for LOV and VG scenarios respectively, with reductions of 69% and 73% compared to the current diet. The values found here for LOV and VG scenarios were similar to those found in previous works (Hallström et al., 2015; Aleksandrowicz et al., 2016, Perignon et al., 2017). In LOV scenario, GHGE were found almost equally distributed between animal and plant foods, with dairy and eggs sharing 46% of the total. Fig. 1 shows the total emissions of the diets studied, and the colour bars depict the relevance of each food group in total emissions, for which the uncertainties are also shown.

With the data provided here and the methodology to assess GHGE, it is possible to estimate emissions for further compositions of foods in diets. For instance, in NRM scenario the main contributor to GHGE was dairy, then, what would be the result if dairy would be reduced and legumes and vegetables increased to nutritionally balance in NRM scenario? This could lead to a further non-ruminant meat diet with GHGE even lower than that for lacto-ovo vegetarians or vegan diets. In any case, the production of poultry and pork is involved in other environmental burdens whose details are out of the scope of the present work; however, it is known that the burdens are much larger than those for plant food production (González et al., 2011). For instance, when the use of energy resources is assessed, NRM scenario requires almost double the amount of energy as LOV scenario, although the GHGE are rather similar (González et al, 2011). Another drawback is the use of antibiotics in animal feed, which is very common in poultry and pork production, with potential negative effects to public health (Marshall and Levy, 2011).

3.2. Nutrient efficiency for dietary scenarios

The diet scenarios proposed here have all the macronutrient values required to maintain health and prevent chronic disease according to the NDG from the Ministry of Health (2016). The amounts of

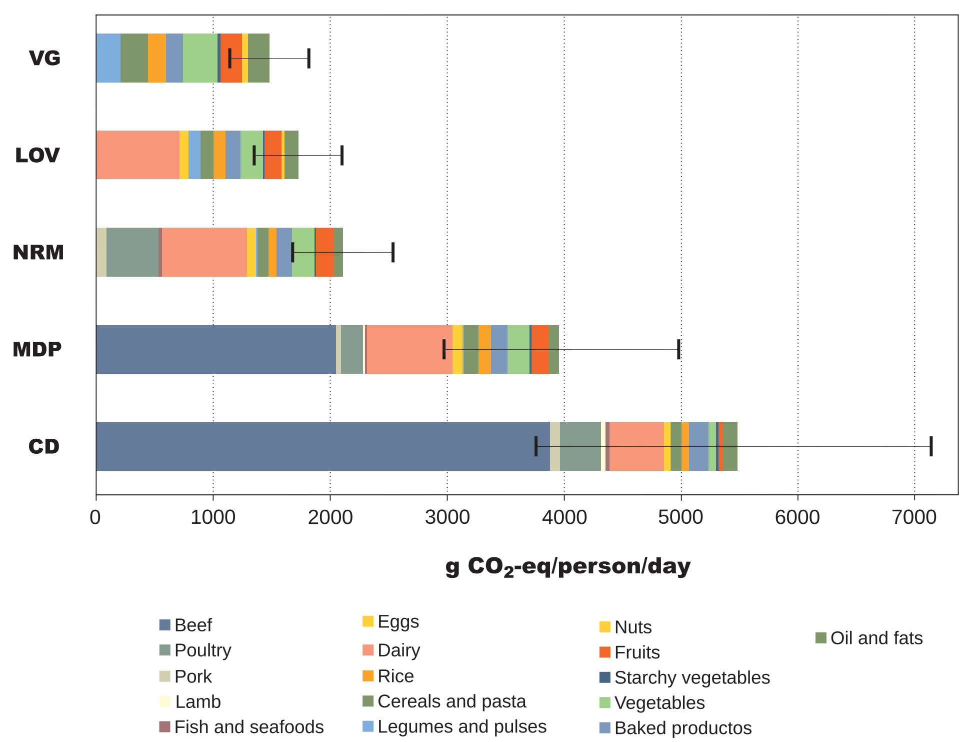

Fig. 1. GHGE for the current diet and four dietary scenarios, with their respective uncertainties.

macronutrients consumed per day for each diet are given in Table 1 and the GHGE in Table 2. The assessment of GHGE for each diet shown in Table 2 is based on per gram of food ingested daily regardless of the nutritional value, and therefore it is interesting to study nutritional indicators associated directly with GHGE (van Dooren et al., 2017). Let us define the GHGE efficiency of a nutrient as the ratio between the amount of the particular nutrient obtained from a diet and the associated GHGE, as it reads in Eq. (1):

$$Eff_{N,D} = M_{N,D}/GHGE_D \quad (1)$$

where N is the corresponding macronutrient considered (either protein or fat or carbohydrate or total calories); D is the particular diet scenario considered; $Eff_{N,D}$ is the GHGE efficiency to obtain nutrient N *in the particular diet* D; $M_{N,D}$ is the mass of nutrient N ingested daily in diet D; and $GHGE_D$ is the daily GHGE found for diet scenario D. Hence, the unit of measure for the nutrient efficiency is grams of nutrient obtained from the diet for each kg of CO_2-eq. Note that the GHGE efficiencies result in units that are independent of the daily intake, and thus represent a general feature of the diet. In a previous work, we have obtained protein efficiencies for individual food items (González et al., 2011); the value of the present analysis is that the efficiencies here are associated with whole diets. Table 3 depicts the protein, fat, carbohydrate and food energy efficiencies for the CD and the four scenarios investigated. The ratio of animal to plant protein is also shown as a variable to characterize a diet and will be used below for a further linear regression analysis. Protein ratios equal to one mean that the particular diet consumes the same amount of animal as plant protein.

The current Argentinean diet has the largest percentage of animal protein, which almost doubles the plant protein intake, and results in the lowest efficiencies for all the nutrient indicators. For protein, only 15.6 g of protein are consumed for each kg CO_2-eq emitted, while in NRM, LOV and VG scenarios the efficiency reaches around 40 g protein per kg CO_2-eq. The nutrient GHG efficiencies improve as the diet reduces meats from ruminants. Note that scenarios NRM, LOV and VG result in similar protein and fat efficiencies, though the nature of the protein and fats are different for each diet. The comparison of NRM scenario with MDP scenario shows interesting features: both diets have large amounts of protein from animal sources, however, the NRM protein efficiency is much larger than in MDP. All nutrient efficiencies are larger for the non-ruminant meat diet than for the MDP one, showing the definite influence of bovine meat in GHGE.

We have plotted the nutrient efficiencies from Table 3 as a function of the ratio of animal to plant protein, and shown them in Fig. A1 in Appendix A. Linear regressions were obtained and data points are well interpolated by linear functions with linear determination coefficients between 0.76 and 0.94. In the cases of carbohydrates and food energy the p-value are < 0.05, then the linear fits can be interpreted as a negative correlation of the efficiencies vs. the animal/plant protein ratio. However, for protein and fat the p-value is slightly over 0.05 and the correlation therefore could not be established definitively. It is reasonable to argue that only five data points may not define a correlation; however, note that in all cases the determination coefficients are high and the p-values low. Future analysis with more diets with different compositions could define whether the preliminary correlations observed would hold.

Table 3
Nutrient GHGE efficiencies and ratio of animal to plant protein for diet scenarios.

	Current diet	MDP	NRM	LOV	VG
Ratio of animal to plant protein	1.94	1.17	1.31	0.37	0.0
Protein Efficiency (g prot/kg CO_2-eq)	15.6	20	39.4	40	41.2
Carbohydrate Efficiency (g carb/kg CO_2-eq)	40.8	68.3	123	166	219
Fat Efficiency (g fat/kg CO_2-eq)	15.5	17.0	33.3	37	34.7
Kcal Efficiency (kcal/kg CO_2-eq)	365	506	950	1156	1353

3.3. Policy implications

The perceived health, social and environmental concerns associated with high levels of meat consumption have stimulated calls to reduce the quantity of meat we eat and created an on-going global debate among policy makers, practitioners and academics (IOM, 2014; Hallström et al., 2015). The present study confirmed the notion that there are major synergies between choosing healthier and more sustainable diets and food patterns (Perignon et al., 2017; Behrens et al., 2017; Hallström et al., 2017). Such findings are relevant to consumers' choices as well as advisory bodies. We believe that an extension of the present NDG towards guidelines that include environmental effects and sustainability issues is not only feasible but also desirable. For instance, several countries with moderate to high red meat consumption have already generated dietary guidelines to promote the need for moderating red meat in consumer diets to substantially reduce the global pressure on public health, the environment and society, like Sweden, Qatar, Germany, USA, Australia, UK, France, Netherlands, Brazil and Estonia (Fischer and Garnett, 2016).

The results of our study shows that by adopting a diet according to the NDG in Argentina (scenario MDP), the GHGE associated would be substantially reduced, achieving total GHGE per person and day as those found in sustainable diets of other studies (Aleksandrowicz et al., 2016; Perignon et al., 2017). Reduction of around 28% in GHGE appear possible while maintaining a healthy and balanced diet which does not deviate too greatly from the current Argentinean average diet. The results of this study therefore indicate that a set of dietary changes in line with recommendations from the Ministry of Health would be beneficial not only for the health status of the population, but also for the climate.

In this work we have not dealt with other categories of environmental burdens, but a potential reduction in the consumption of animal products and particularly bovine meat would probably reduce significantly the whole ecological footprint of diets. For instance, it has been demonstrated that beef production is also associated with larger land and energy use, deforestation and biodiversity loss (González et al., 2011; De Vries et al., 2015; Machovina et al., 2015). A recent work made by Baumann et al. (2017) found that land use change between 1985 and 2013 in the Argentinian Great Chaco (the most extensive dry forest ecosystem in South America) emitted a total of 466 Tg of CO_2. Of this total, the land use change from forests to pastures is responsible for the 68% of total emissions (317 Tg of CO_2). Therefore, including carbon emissions from land-use change would increase the carbon footprint from bovine meat produced in Argentina (Persson et al., 2014).

In spite of the analysis above, beef is an important food in the Argentinean diet, it is associated with traditional cultural values and has a great acceptance and positive image in the public (Ruby et al., 2016). The recommendation to reduce meat consumption following the National Health Guidelines (or lower) would most likely be rejected by the general public, which poses a challenge for policy makers and health professionals. However, there are actions that can be carried out.

Policies systematically promoting the access to information for the public and raising awareness seem to have better acceptance in the general public. Some scholars suggested that performing campaigns to inform consumers can be an effective approach to increasing consumer awareness, encouraging changes in meat consumption, and supporting the acceptance of further meat reduction policies (Dagevos and Voordouw, 2013; Kiff et al., 2016). Many studies have shown that consumers are willing to change food habits if they are confronted with clear information on the environmental impacts of their diets (Pohjolainen et al., 2016; Hunter and Röös, 2016). In this sense, NDG are an example of government-led information campaigns and are an important policy tool for providing nutritional advice (Story et al., 2008). At present, the Argentinean NDG focuses on ensuring an adequate intake of nutrients, indirectly discouraging the consumption of total meats. This trend is also observed among other countries worldwide. A good first step would be that the health institutions in

Argentina shall include environmental information regarding foods to help consumers make dietary choices according to environmental impacts, as well as other health impacts of diets rich in red meat. Messages that emphasize the positive public and individual health implications of a less meat-rich diet are likely to have considerably more acceptance than those that centre on environmental impacts alone (Röös et al., 2014). Guidelines for sustainable and healthy diets could provide an effective means of supporting dietary change at national and institutional level, but would need to be accompanied by awareness raising campaigns and outreach programs to ensure that the principles of healthy eating are fully understood and to avoid unintended rebound effects. Nevertheless, in Argentina public understanding of livestock's role in climate change is low and the risk of confusion is high, so it is necessary to elaborate simple and clear messages about the need to reduce meat consumption for healthy and sustainable levels (De Boer et al., 2016).

Although raising awareness is unlikely to have a remarkable impact on individual behaviour in the short term, it may make the public more supportive and accepting policy intervention. Previous works have shown a diversity of tools to foster reduced meat consumption among their population, like food labelling, advertising regulation, meat substitutes promotion, ban or tax on unhealthy or unsustainable foods, change in default food options in public institutions, public information campaigns, etc. (Grunert et al., 2014; Röös et al., 2014; Apostolidis and McLeay, 2016; Kiff et al., 2016). Although there are very few recent precedents for government intervention to discourage meat and dairy consumption, many of these policy approaches have been widely adopted to influence diets and behaviour in other ways. Efforts to dissuade the public from consuming sugar, trans fats, tobacco, alcohol and other unhealthy products can offer a valuable learning opportunity, particularly around the use of health-focused messaging to change habits. However, there is a need to adapt diet changes to actual social scenarios, to avoid that policies would lead to negative effects in the public and business sectors (Dagevos and Voordouw, 2013).

For example, product-specific taxes have been used by a number of governments to remove incentives for the consumption of certain unhealthy products (Edjabou and Smed, 2013; Penney et al., 2015) and these cases point to the potential for influencing meat consumption habits through taxes. The effectiveness of taxes and other financial incentives as interventions for reducing meat consumption has been debated in the academic literature (Säll and Gren, 2015). If people do not understand the idea behind policies, taxation to meat products may face opposition from meat producers, politicians and consumers (Edjabou and Smed, 2013). Furthermore, higher food prices may have a negative impact on the food security of the lower income households/families (Green et al., 2013). This is certainly true at present in the case of Argentina, in which 30% of the population is under poverty level, but still can afford to buy meats at low prices in local markets. A possible way to overcome this difficulty would be to tax certain foods but excluding low incomes (Nordström and Thunström, 2011). In any case, poverty adds a lot of complexity to policy development. For instance, recently, a law was passed in Argentina to return food Value Added Tax to the lowest income sectors for a number of basic food items, including meats. This shows that solving urgent social problems may act against reducing GHGE through reduction in the consumption of animal-based foods. However, beef consumption in Argentina is subsidized since the Value Added Tax on beef is half that of other meats (10.5% vs. 21%). In addition, at present the government intends to do the same with pork, generating a discrepancy between agro-food and public health policies.

In any case, the achievement of sustainable and healthy diets is more complex than only reducing meat consumption (Auestad and Fulgoni III, 2015). As we show in the present work, an increase in vegetables and fruit consumption is also necessary to achieve a healthy diet in Argentina (as well as in most countries worldwide) (Imamura et al., 2015). In this sense, subsidies for production of fruits and vegetables or actions oriented to increase the availability of these foods could be appropriate to reduce prices and encourage their consumption (Powell et al., 2013). However, it is interesting to note that this would increase the environmental impacts associated with the conventional production of fruits and vegetables (Feliciano, 2016). On the other hand, there are other concerns regarding reduction in meat consumption, as the abandonment of pastures and loss of jobs. Destination of abandoned pastures may be the transformation to croplands or an opportunity to perform ecosystem restoration and conservation. Land use change from pasture to cropland is more feasible in suitable lands for agriculture, reducing the pressure on the remaining natural ecosystems but increasing the environmental impact per unit of area compared to extensive livestock systems (Foley et al., 2011); while transformation from pasture to natural or semi-natural ecosystems are more likely to occur on marginal agricultural lands with low productivity, were the risks of soil erosion and soil carbon/nutrient depletion is higher (Smith et al., 2016). This last scenario may be more desirable in a context of climate change mitigation due to the carbon sequestration potential of forest and scrublands (Conti et al., 2014; Baumann et al., 2017).

In any case, holistic approaches that consider the complexity of the food system are needed and governments must lead the action, because without government intervention at national and international level, populations are unlikely to reduce their consumption of animal products and there would be insufficient incentive for business to risk on new plant-based products (Wellesley et al., 2015).

3.4. Limitations of the study

Some limitations of the present study should be addressed. First, there is a lack of data on GHGE from food production in Argentina. Even though at present food production has similar standards worldwide and the averages from literature reviews used here seem to be confident, regional soil and climate characteristics, as well as energy carriers, might influence GHGE (Arrieta et al., 2018). Therefore, future efforts are needed to investigate the emissions of food produced in Argentina, specifically animal sourced foods, which have more complexity in their production. Also, GHGE is not the only criteria to be estimated for the purposes of assessing the environmental consequences of consumer diets and other criteria such as water and land use or biodiversity loss, must also be considered.

Second, the values used here do not consider several steps in the life cycles of the food products, such as transportation to rental distribution and from stores to the homes of consumers, or cooking foods at home. Third, the 2000 kcal/day diet could not be representative of certain groups of the general population, so it could be underestimating the real needs of foods, energy and macronutrients for some groups (as pregnant women, children and elderly people). Thus, this analysis does not have the purpose of making dietary recommendations of any kind and should be understood as a study of the potential changes on GHGE through dietary modifications in Argentina.

Fourth, the data source of food consumption belongs to the NSHE, which gives information on food bought (apparent consumption) and due to processing and wastage do not represent the real food consumed. However, adjusting the diet at 2000 kcal/day we reduce the probabilities of overestimating the food consumption, and thus the GHGE. This can be verified when the composition of the current diet analysed here is compared with other similar studies made in Argentina (Bertollo et al., 2015).

Fifth, due to lack of data on dietary patterns among vegetarians in Argentina, scenarios LOV and VG were elaborated using assumptions of food consumptions and studies made in other countries. So, even though the vegetarian diets modelled are realistic, they might not represent the real food consumption among vegetarians in Argentina.

All of these limitations open the scope for further research. The high complexity of a multivariate analysis of food systems, consumer preferences, health and the environment leads inevitable to research with limitations. In spite of this, the results obtained here are in line with several previous works for other countries, adding a case study with particular characteristics to the debates on possible reduction of GHGE by diet changes.

4. Conclusions

We have analysed in detail the composition and GHGE of the current diet in Argentina, a country with a long tradition in high meats consumption. Based on this diet, four other scenarios were modelled according to nutritional recommendations of the National Dietary Guidelines (NDG) which differs widely from the current one, mainly in the intake recommendation of meats, vegetables and fruits. These dietary scenarios present different proportions of animal sourced food and were: (1) based on the Model Dietary Plan (MDP) from the NDG; (2) a non-ruminant meat diet; (3) a lacto-ovo vegetarian diet; and (4) a vegan diet. The current diet resulted in very high GHGE (5.48 ± 1.71 kg CO_2-eq/person/day), while the scenarios based on NDG leads to a reduction between 28% and 73%. It is relevant to note that not only the choice of meat or non-meat but the relative composition and characteristics of the diet led to large differences in GHG burdens, being beef the main factor in the differences. The non-ruminant diet does not have relevant differences of GHGE in relation to the non-meat diets. For instance, in the non-ruminant diet the main contribution to GHGE are both dairy and meats (pork and poultry), thus a reduction in dairy followed by an increase in legumes and nuts (to balance protein and fat) but keeping daily intake of meats unchanged could lead to emissions even lower than a lacto-ovo vegetarian diet. The method and data presented here allow the reader to design further scenarios than those investigated here.

Indicators for nutrient efficiencies were defined to assess the amount of protein, carbohydrate, fat and caloric energy obtained in each diet per kg of CO_2-eq emitted. These efficiencies were plotted as a function of the ratio between the amounts of animal protein and plant protein in diets. We have found that all nutrient efficiencies decreased in diets with bovine meat with respect to the non-ruminant, the LOV and the VG ones, and that the scenario with non-ruminant meats results in similar nutrient efficiencies than those of the LOV. This analysis is relevant as it increases the knowledge on food delivery efficiencies in whole diets.

The information presented here reinforces the idea that NDGs are a valuable tool not only to improve public health but also the environment, and could be useful for public health, food and environmental policy makers. Recognizing the environmental and health impacts of beef rich diets, a good first step to moving forward would be to include environmental information regarding foods in the NDGs, in order to help consumers make dietary choices, especially in countries with high beef consumption. For the public, this information would also help to elucidate the link between foods, environment and health, and enable people to take actions that could contribute to climate change mitigation.

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Appendix A

See Fig. A1.

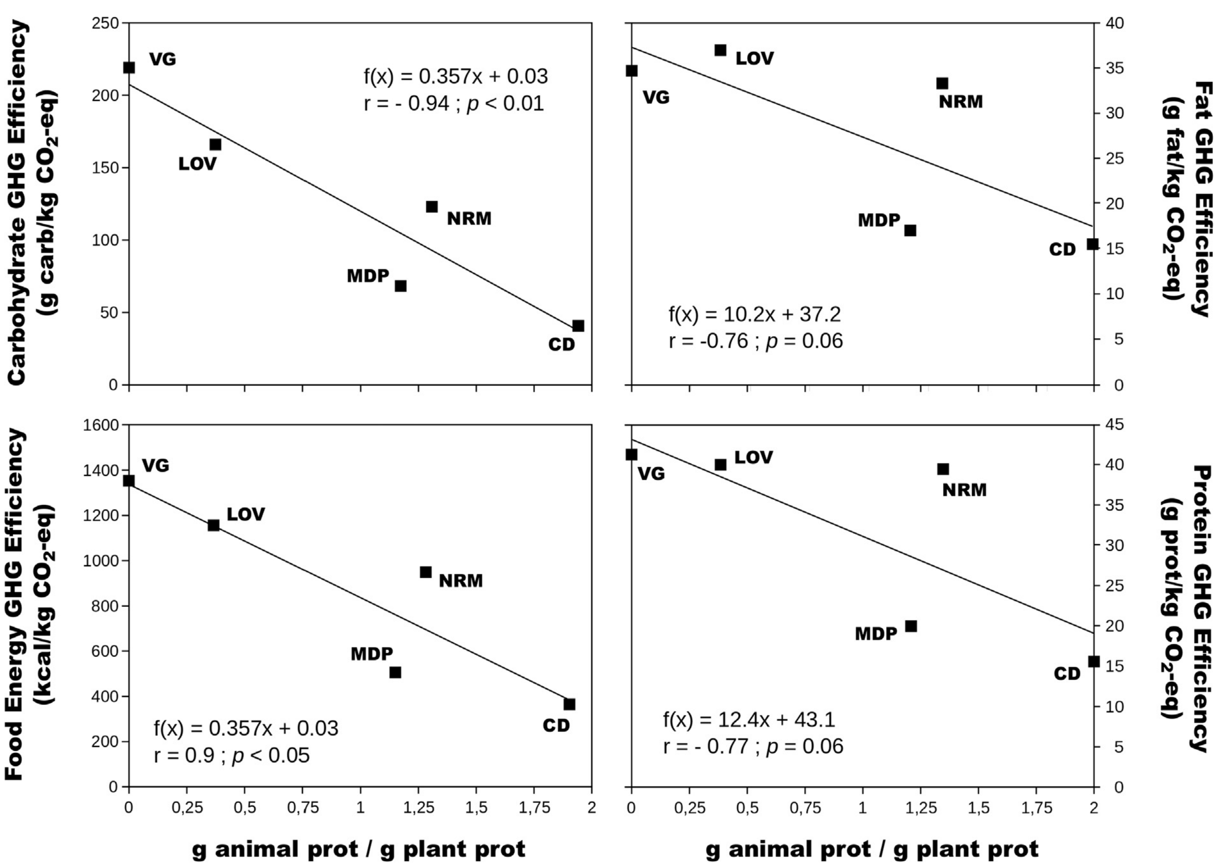

Fig. A1. Carbohydrate, fat, food energy and protein efficiencies per unit of GHGE vs. the ratio animal to plant protein, for the five diets studied. CD: current diet; MDP: model dietary plan; NRM: non-ruminant diet; LOV: lacto-ovo vegetarian; VG: vegan diet.

Appendix B. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.foodpol.2018.05.003.

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