Carbon footprinting of dietary habits: the Meneghina Express project

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ABSTRACT

Meneghina Express is 44 day and 13,000 km long journey from Shanghai to Milan, covered via electric motorcycles as a representation of electric mobility and sustainable food production and consumption. The purpose of this journey was to promote sustainable mobility and also gather knowledge and best practices regarding food production and consumption along the route. In this context, the University of Bari developed a database that allowed the evaluation of the environmental burden related to various foods in terms of carbon footprint. Starting from the databases of the FAO, the carbon footprint of the consumed foods was estimated, drawing up an inventory of their life cycle. The result is a carbon footprint report, thanks to which it is possible to compare the "sustainability" of different foods encountered along the journey, with those of the Mediterranean diet.

Keywords: carbon footprint, diet, sustainable food consumption

1. Introduction

Various studies carried out during the last two decades have demonstrated that most of the human food chains are not sustainable because of their environmental burdens that occur during the various life cycle phases of the food systems. In fact the contribution of the food and drink sector to the total environmental impact deriving from private consumption, according to the European Science and Technology Observatory (ESTO) project on "Environmental Impact of Products" (EIPRO), ranges from 22 to 34% (Tukker et al. 2006). In the UK, food consumption is responsible for 19% of the overall 2008 national greenhouse gas (GHG) production. Similarly, according to the United Nations Food and Agriculture Organization (FAO), the livestock sector is responsible for 14.5% of the overall global GHG emissions (Gerber et al. 2013). In a search, over the last fifteen years, for some indication on more sustainable means for food production and consumption, various sustainability assessment instruments have been used, among which is the Life Cycle Assessment methodology (LCA). This has been predominantly used for the identification of the environmental impacts of food during its life cycle and also as a means of supporting environmental decision making (Notarnicola et al. 2012a).

In view of the above mentioned context the Meneghina Express project, object of the present paper, was developed. It entails a 44 day and 13,000 km long journey from Shanghai to Milan, covered via electric motorcycles as a representation of electric mobility and sustainable food production and consumption. This journey aimed not only at promoting sustainable mobility, showing that even adventurous journeys such as this one from Shanghai to Milan can be carried out by relying on renewable energy, but it also aimed at gathering knowledge and best practices regarding food production and consumption along the route. Since these themes are also among the main ones of the Expo2015 that will be held in Milan, the organizing committee of this exhibition sponsored the initiative.

For such a project, the University of Bari developed a database that enabled the evaluation of the environmental load related to the various types of food consumed during the journey. Currently, at global level for agro-industrial systems, there seems to be a growing interest in *carbon and water footprints* that represent "mono-indicators" that exclude the effects of other important impact categories such as eutrophication and eco/human toxicity. The current project also used the carbon footprint (CF) as means of evaluating the environmental sustainability of the food consumed during the journey; however a more comprehensive approach, that includes other indicators, is more desirable (Notarnicola et al. 2012b) and might be considered in the future. Specifically, starting from the UN Food and Agriculture Organization (FAO) databases, the CF of the single products was estimated thus creating a life cycle inventory of both primary (agricultural and livestock) and transformed products. This task was carried out for each nation crossed during the journey since the energy mix and other production variables imply different CFs for both primary and transformed products of different countries. The next sections of this paper discuss the methodologies and sources used for the construction of the inventory and the main results of the carbon footprint report of the journey.

2. The database for the food carbon footprint calculation

The starting point for the work regarding the calculation of the food CF database, was the analysis of the existing relevant data found in the scientific LCA literature regarding food products (agricultural and transformed ones). Also existing food databases (e.g Ecoinvent, FoodlcaDk and others) were preliminarily consulted together with data from environmental product declarations. Next, in a more specific manner, the FAO databases were used as data sources since they detail, for each country, the type of product and the relative land use, the use of fertilizers, the CO_2 emissions and other greenhouse gases (GHG) both for the agricultural phase and for livestock production (FAOSTAT 2013).

From the above mentioned data the CF for each single food product considered was calculated thus enabling the construction of the database of both primary and transformed products. The calculated CFs are intended as quantities of $CO_{2eq.}$ associated with the production of the specific food type and include other GHG such as CH_4 and N_2O. The phases included in the inventory analysis are the agricultural phase, the production and use of fertilizers and pesticides, the transport of auxiliary products and of the finished ones and the transformation. For livestock products the animal enteric fermentation and the type of manure management were also accounted for. All the results are referred to 1 kg of finished food product. For the conversion of all the GHG emission data to absolute values of $CO_{2eq.}$ the IPCC characterization factors were used (IPCC 2007).

The FAO database contains information on the following: total agriculture, combustion of agricultural residues, cultivated land, residues from cultivation, rice cultivation. All these inventories are calculated according to the *Tier1* approach indicated in the IPCC guidelines for the calculation of the national GHG inventories (IPCC 2006).

The inventories regarding the impacts of livestock, contained in the FAO database, are the following (also calculated according to the *Tier1* approach indicated in chapter 10 Vol.4 (IPCC 2006):

- manure management: the relative emissions are constituted mainly by methane and nitrous oxide deriving from the aerobic and anaerobic decomposition of the manure;
- enteric fermentation: this includes the emissions of methane produced mainly by ruminant digestive systems and in minor amount by those of non ruminant animals.

The CF of each product was calculated specifically for each country crossed during the journey. This is because the energy mix, the production factors and the efficiencies in terms of useful product vary between countries. The computation of the energy mix and its relative association to amounts of $CO_{2eq.}$ was based on the International Energy Agency databases (IEA 2013). As a result, for the non-transformed agricultural products, a database was generated, subdivided per each country, containing CFs of 136 products (not shown here for sake of brevity).

For the CF calculation for the various types of milk originating from different countries the yearly animal production yield illustrated in Table 1 was used.

Differences between intensive and extensive animal farming were also taken into account in the CF calculations. Specifically freely grazing animals are responsible for lower amounts of $CO_{2eq.}$ with respect to those of intensive systems which not only are accountable for emissions from enteric fermentation and manure decomposition but also for the production of fodder. However, intensive farming results less impacting in terms of CFs due to the higher production yields associated to the animals.

Table 2 illustrates the CF of milk form different countries. In some cases the results are particularly divergent. For example the CF of Mongolian milk is ten times higher than that of European milk which averages 1 $kgCO_{2eq.}$/kg. This is due to the extremely low yields in terms of product. Specifically, the FAO database reports a yearly milk yield per Mongolian bovine animal of 479.5 kg which is much lower than the Chinese (3,003.0 kg) or Russian yearly yield (3,857.2 kg). Such a result is well known and documented in literature as reported by Gerber et al. (2011). These results also are in line with the LCA report on GHG emissions from the dairy sector in which large variations in emissions between the different world regions have been estimated, with regional average emissions ranging from 1.3 to 7.5 kg CO_{2eq}. per kg of fat and protein corrected milk (FPCM) [±26 percent]. Livestock systems in the temperate regions, mainly in industrialized countries, were found to have much lower emissions per kg of milk and meat than systems in the arid and humid zones in the developing countries (FAO 2010).

Table 1. Production yield in terms of milk produced (in kg) per animal over a period of one year for each country

	China	Mongolia	Kazakhstan	Russia	Moldavia	Ukraine	Romania	Serbia	Croatia
buffalo	543.3	0	0	0	0	0	0	0	0
camel	200.0	186.4	0	142.9	0	133.3	0	0	0
cow	3,003.0	479.5	1,893.0	3,857.2	3,405.2	4,175.0	3,775.9	2,921	4,246.1
goat	159.5	17.4	42.3	309.3	130.5	498.4	0	0	307.9
sheep	38.2	12.8	89.1	42.7	34.3	86.6	83.6	55.2	145.3

Table 2. The Carbon Footprint of milk for each country (in kg CO_{2eq}/ kg of milk)

	China	Mongolia	Kazakhstan	Russia	Moldavia	Ukraine	Romania	Serbia	Croatia
buffalo	2.23	-	-	-	-	-	-	-	-
camel	5.11	7.00	-	10.30	-	8.66	-	-	-
cow	0.65	9.60	1.22	0.68	0.71	0.51	0.67	0.76	1.02
goat	0.69	7.77	2.90	0.51	1.06	0.25	-	-	0.84
sheep	2.86	10.30	1.37	3.70	4.01	1.43	1.63	2.43	1.78

Global scale analysis has clearly shown that GHG other than CO_2, such as methane and nitrous oxide, are inversely correlated to animal productivity. In other words, compared to animals with low milk yields, animals that produce more milk, will consume more fodder and other foods, will undergo more enteric fermentation and produce more manure that will produce more GHGs. However when scaled to the amount of milk produced the CF is lower for animals with a high productivity. Hence increasing the productivity of livestock represents an effective strategy for the mitigation of the greenhouse effect associated to livestock breeding (Hristov et al. 2013).

Similar results are also obtained for meat production. In fact there appears to be a divergence in results in terms of CF also due to the differences in yields illustrated above.

Overall the database consists of 411 products for which a CF has been calculated. For 188 of these products the indicator was calculated for each country involved in the journey, whilst for the remaining 223 products the data was gathered from literature and existing databases.

3. The carbon footprint report

By using country specific food and energy mix data it was thus possible to evaluate the CF of each type of food eaten during the journey which varied considerably from country to country.

In China the nutrition of the team was based mainly on rice, pasta, eggs, vegetables and fruit with meat and small quantities of dairy products consumed on only two occasions.

In the Mongolian steppe, the nutrition was based mainly on dairy products and meat. In fact Mongols still practice nomadism and have large availabilities of such products. Specifically the nutrition included a type of pasta made from soft wheat, camel and goat milk, butter, sheep meat and a few onions and potatoes (the only vegetables eaten). This is mainly because Mongolia has very little arable land and thus produces few vegetables which are usually imported from China. This makes the Mongolian diet unbalanced, lacking vegetable foods and rich in proteins. This is also dependent on the fact that such a hyper caloric diet is necessary for surviving in a country with very rigid winters. In fact the capital city of Mongolia, Ullanbator, during the winter can reach temperature of -50°C. It thus appears that the climatic factor may be of considerable importance in the comparison between diets.

During the 11 days spent in Kazakhstan the team continued a diet similar to that undertaken in Mongolia, mainly based on meat with a lack of vegetable food. This depended on the route of the journey that involved crossing the northern part of the country through the city of Astana the second coldest capital of the world. In the southern part of the country the climate is milder and locally grown vegetables can be found.

During the 6 days spent crossing Ukraine the nutrition of the team was more continental, similar to that of northern Italy with a few variations based on fish from the Black sea.

A "carbon footprint report" was created in which, for each country, the average CF of the daily diet was calculated based on the food eaten. These values have been compared to those of the Italian Mediterranean diet. Presuming that the energy need during the journey could vary between 2000-2500 kcal per day, the CF of the Mediterranean diet varies from 4.9kg of CO_{2eq} to 6.1kg of CO_{2eq} per day.

Figure 1 reports, for each country, the averaged calculated CF of the daily nutrition. The horizontal line represents the Mediterranean average value.

As already mentioned the worst results are relative to Mongolia due to the high consumption of meat and dairy products. Specifically the team leader during the journey through Mongolia consumed 1.850 kg of vegetable food for a total of 0.54 kg CO_{2eq}., 0.55 kg of milk and other dairy products for a total of 8.64kg CO_{2eq}. and 0.3kg of meat for a total of 2.4 CO_{2eq}. as well as 0.2kg of transformed products for a total of 0.1kg CO_{2eq}.The highest contribution is from the dairy products and there is no major contribution from the electricity mix since most products (apart from butter) are consumed without any transformation. The meat consumption regards sheep and goat meat that typically have lower CF values than beef.

Summarizing, the results are higher than typical Mediterranean values due to the high consumption of milk and dairy products. The higher than average values for such products for Mongolia are due to the extensive nature of cattle breeding in such country. The best results in terms of CF regard China and are due to the high consumption of vegetables. In this particular case the nutrition of the team was biased towards such products due to safety food precautions that partially excluded milk based products from the diet.

The diets from the other countries, shown in figure 1, indicate a sustainability profile, in terms of CF, similar to the Mediterranean one and their largest contribution to the CFs depended on meat consumption.

These results confirm some findings of the extensive literature on diets. Indeed several studies compare different foods or compare various types of diets. A review by Heller et al. (2013) compared 32 LCA studies on diets. The results of all these studies pinpointed some key areas:

- in general, foods of animal origin show a worse environmental performance than those of plant origin;
- consequently vegetarian diets have a better environmental profile than other diets;
- there is a strong regional difference in food habits and production processes.

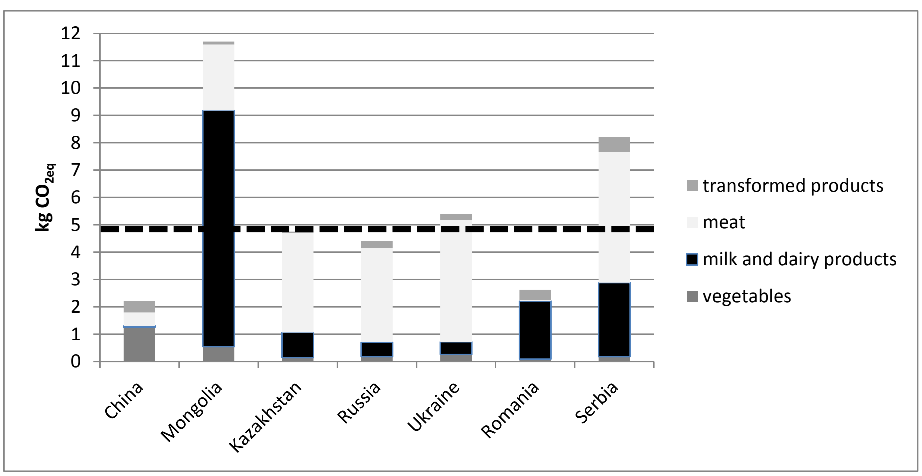

Figure 1. "Carbon footprint report": CF of the daily diet calculated for the various countries

4. Conclusions

The Meneghina Express project, that obtained the Guinness world record for the longest distance travelled on electric motorbikes, represented a good occasion to focus on the environmental sustainability of food and diets. The desired results were reached thanks to the synergy between the exploration team and the University of Bari.

Regarding the creation of the database for the environmental sustainability assessment of food, it should be pointed out that it is a mere carbon footprint; the inclusion of other environmental aspects and impact categories was initially discussed but then excluded due to the lack of sufficiently reliable sources.

Overall the database is made up of the CF of 411 products. For 188 of these the indicator has been calculated for each country crossed during the journey, whilst for the remaining 223 products the data was gathered from literature and existing databases.

For many of the products the CF value varies considerably among countries due to the different production techniques and the their respective efficiencies.

Based on the data collected regarding the team's nutrition during the journey it was possible to generate a "carbon footprint report" of the various diets of the various countries and these have been compared to the Mediterranean diet. The results are of course representative only of this particular experience and do not represent national average values. Overall what emerges is that in the colder countries the diets are hyper caloric, based on meat and dairy product consumption and are less eco-compatible. In China where the nutrition was based mainly on vegetables the resulting CF is lowest hence counterbalancing the effects of the Chinese kWh which is based 79% on coal.

Concluding, food sustainability will continue to remain at the center of attention with the ever growing awareness of consumers, but it also needs technical instruments and reliable sources to find a scientific solution to the many problems connected to such a topic.

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The full proceedings document can be found here:
http://lcacenter.org/lcafood2014/proceedings/LCA_Food_2014_Proceedings.pdf

It should be cited as:

Schenck, R., Huizenga, D. (Eds.), 2014. Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector (LCA Food 2014), 8-10 October 2014, San Francisco, USA. ACLCA, Vashon, WA, USA.

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ISBN: 978-0-9882145-7-6