Food service: climate issues and water demand of meals

Michaela C. Theurl[1,2,*], Stefan Hörtenhuber[1,3], Markut Theresia[1], Thomas Lindenthal[1,3], Axel Wirz[4]

[1] Research Institute of Organic Agriculture (FIBL) Austria, Doblhoffgasse 10/13, A-1010 Vienna, Austria
[2] Alpen Adria University of Klagenfurt, Schottenfeldgasse 29, A-1070 Vienna, Austria
[3] University of Natural Resources and Applied Life Sciences Vienna, Gregor-Mendel-Str. 33, A-1180 Vienna
[4] Research Institute of Organic Agriculture (FIBL) Germany, Kasseler Strasse 1a, D-60486 Frankfurt am Main, Germany
[*] Corresponding author. E-mail: *michaela.theurl@fibl.org*

ABSTRACT

Food service companies are important stakeholders in promoting sustainably produced and healthy foods. We worked in a transdisciplinary team to calculate the greenhouse gas emissions and virtual water demands of vegetarian and non-vegetarian meals in Germany using the LCA method. Partners from different scientific disciplines and the manager of a food service company as out industrial partner collaborated on the study's design and the definition of goal and scope. The result of the study was a management plan for the incremental implementation of short and long-term choices based on environmental sustainability indicators. The major reduction potential rests in shifting eating habits from quantity to quality, specifically to high quality organic meat and in using renewable energy during food preparation. Linking LCA to transdisiplinary approaches is important for the development of environmentally responsible choices considering the food service company's internal preferences and regional infrastructural constraints.

Keywords: food service, sustainable foods, carbon footprint, virtual water demand, LCA

1. Introduction

Individual eating behaviors and attitudes have lasting effects on the development of sustainable lifestyles. Establishing balanced global dietary patterns will be a major challenge in the coming decades as growing affluence is a major driver behind the increasing demand for food (Tilman et al. 2011). There is an increasing tendency towards eating outside the home. Such is the case for school meals, canteen meals and catering companies offering their services at events. In 2012, the turnover of the German food sector was about 68 billion-euro and the trend is rising. Therefore, food service companies are important stakeholders in promoting sustainably produced and healthy foods. In Germany, the contribution of organic products in the food sector is estimated at 300 million-euro per year which is 0.5 % of the total market for organic food products (MKULNV 2010).

Over the past several years, different communication labels such as primaKlima, EMAS or Stop Climate Change were established to certify a climate friendly and sustainable performance of companies and effort were made to develop sustainability standards for restaurants (e.g. Baldwin et al. 2011). At first glance, the definition of system boundaries and functional units are often not recognized. In order to have a tool to transfer knowledge to consumers, especially in the food service sector, it makes more sense to relate environmental impacts to kilocalories than to kilograms of food. Most of the studies aiming to support sustainable decision making focus on the ecological perspective and underestimate the complexity of economic and social aspects (Binder et al. 2012).

In this study, we worked in a transdisciplinary setting in order to extend the research beyond the specialized knowledge of ecological dimensions of food provision. We valued this transdisciplinary approach as a means to fundamentally understand the situation of food service companies and discover solutions using problem-driven research. Despite a long tradition of application to questions of sustainable development, neither trans- nor interdisciplinary research approaches are strictly defined. The two approaches are also often applied simultaneously. In our understanding, a transdisciplinary approach combines and synthesizes scientific systems and societal systems (Hirsch-Hadorn et al. 2006).

Therefore, depending on specific aims, food service companies have several options for environmentally responsible choices regarding their services. We conducted our study using an LCA framework with the goal of identifying leverage points and priorities for reducing climate impacts and the water use for small and medium enterprises.

2. Methods

In our study, we cooperated with a food service company that runs a canteen kitchen and a catering service. Our industry partner has observed a rising demand amongst costumers for quality food and an interest in environmental impact labeling of the company's foods. We worked in a mixed team with partners from different scientific backgrounds, including ecology, economics and nutritional advisers. In order to address problem-driven research questions, the manager of the food service company played an important part in the team, providing practical viewpoints that brought new insights to the scientific partners. Using this transdisciplinary approach, we collaborated with our partners to define specific questions to be answered over the course of the project.

The project's starting workshop provided the platform for intensive discussions with all partners resulting in the definition of the goal and scope of the LCA, as well as the definition of the functional unit. Moreover, the definition of the system boundaries and samples for sensitivity analysis were settled. We first focused on climate impacts as the key indicator of environmental performance of two standard dishes served in the food service canteen. We choose a vegetarian and a non-vegetarian plate. Table 1 gives details on the different ingredients. One of the food service company's typical dishes is couscous with mixed vegetables accompanied with a full-fat sour cream used as a flavoring ingredient. In order to evaluate the differences in environmental impact of beef and pork, we choose typical German meatballs with gravy and potatoes. The meatballs are composed of 50 % pork and 50 % beef meat. We also conducted an analysis of the water demand of both dishes, which we termed virtual water demand. The virtual water demand was calculated in order to evaluate potential tradeoffs between the two indicators.

Table 1. Isocaloric meal ingredients and baseline for the identification of reduction measures

Lunch plate	**Ingredients**	**Energy content [kcal]**	**Contribution [%]**
Vegetarian	Couscous	68	14
	Vegetable mix (corn, pepper etc.)	34	7
	Olive oil	21	4
	Sour cream	378	76
	Total	500	100
Meat	Meatballs	374	75
	Gravy	5	1
	Potatoes	121	24
	Total	500	100

The functional unit was one portion of a typical German vegetarian and non-vegetarian dish offered by the company. Considering the importance of nutrition to the consumers, we used the energy content as functional unit for representing the results. We evaluated two isocaloric diets, one vegetarian and one non-vegetarian dish à 500 kcal from "farm-to-fork" (Baldwin et al. 2011). The meal ingredients are presented in Table 1. GHGE (greenhouse gas emissions) and water use were analyzed from agricultural production and its upstream supply processes (e.g. animal feed, fertilizers) along the supply chain to the serving counter in the canteen regarding food processing steps (such as slaughter), storage, and food preparation in the canteen kitchen (see Figure 1). Primary data from the canteen's most important suppliers and processing companies were collected via questionnaires and in interviews. The catering company provided data and energy use on food preparation and food wastes, as well as cooking and chilling techniques, and the re-heating of the meals in the canteen.

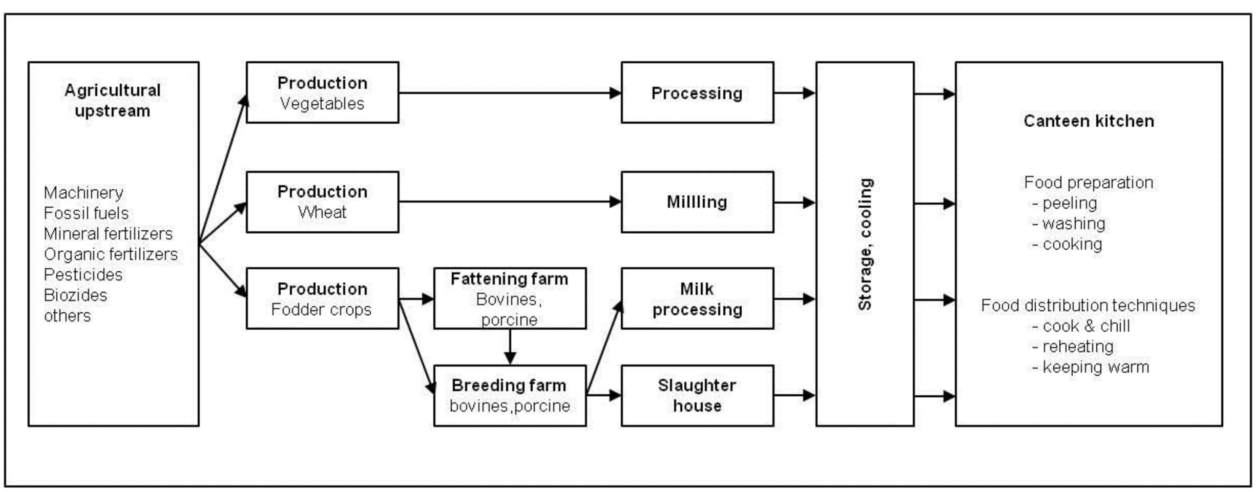

Figure 1. System boundaries for a typical lunch plate offered by the food service

2.1. Analysis of climate effects (GWP) and virtual water demand

This study used the life-cycle-assessment (LCA) method, following the ISO 14040 and 14044 standards (ISO 2006). The calculation of the carbon footprint was carried out using the SimaPro software, as well as the GEMIS 4.42 and ecoinvent v2.2 databases. The carbon footprint was calculated according to IPCC (2006). Primary data on agricultural production systems, specifically regarding yields, fertilizer input, cropping systems and supply chain, was available directly from the food service company's suppliers in Germany. Gaps in the data were filled with data from comparable agricultural production systems in similar climatic conditions in Austrian regions (Hörtenhuber et al. 2011, Lindenthal et al. 2010). Data on regional transport, including the different means of transport (truck size, refrigerated transport) and transport distance were obtained from questionnaires. Data on imported vegetables from South Spain, specifically on agricultural production, processing and means of transport, were obtained from Theurl et al. (2014). Food waste factors, obtained from primary data of the food service company for meat, fresh and frozen vegetables, were considered in the calculations of GHGEs and water use. The calculation of GHGEs is based on a specific, locally-adapted farm model in which methane emissions, as well as direct and indirect N_2O emissions are considered in the calculation of the GWP (Theurl et al. 2014; Lindenthal et al. 2010). Direct and indirect emissions due to land use changes from feedstuffs were also considered in our methods (Hörtenhuber et al. 2011). These farm models are also the basis for the evaluation of water demand. The calculation of the water demand is based on studies from Hoekstra et al. (2011) considering water use in different contexts. First, we considered "blue" water, which is consumed during production processes, including irrigation, cooling and water consumed in cleaning. Secondly, we included "green water" from precipitation and evapotranspiration of different crops and soil types (Asamer et al. 2011). Thirdly, we accounted for a theoretical water fraction called "grey" water that is necessary to dilute or assimilate a certain amount of pollutants in water bodies (see Mekonnen and Hoekstra 2011; Hoekstra et al. 2011, Chenoweth et al. 2013; Hörtenhuber et al. 2014). The virtual water demand is the sum of blue, green and grey water in liter per meal portion (500 kcal), whereas the climate effects defined by the GWP is depicted in kg CO_2eq per meal portion. The baseline for the identification of promising measures that entail a reduction of GHGE and water consumption is the conventional production system for beef and pork meat, as well as vegetables and potatoes. Natural gas for cooking and the average German electricity mix were considered as the baseline in both variants. An incremental plan was established that considered the use of organic livestock-based and vegetarian ingredients and the implementation of renewable energy sources, as well the use of frozen products.

3. Results

Following our transdisciplinary approach, we started with the identification and discussion of the most important questions to be addressed in the LCA. Intensive discussions resulted in the development of an incremental action plan that offers incentives to food service companies in order to implement feasible and ecologically responsible choices based on a baseline. We focused on three key questions:

1. What are the potential net savings from the implementation of green electricity in the canteen?
2. How much is the environmental impact of organic products especially organically produced meat?
3. What is the GHG mitigation potential of regionally produced vegetables versus imported ones?

The results for the GWP and the water demands of the vegetarian conventional (VC), vegetarian organic (VO) and non-vegetarian with conventional ingredients (MC) and the non-vegetarian plate with organic ingredients (MO) are presented in Figure 2. The column on the very left of each variant represents the initial baseline from which the incremental reduction measures of each indicator started. The baseline maximum magnitude is reached by the meat meal resulting in a water demand of 2,000 l and in a GWP of about 1.60 kg CO_2eq per portion. The baseline maximum of the vegetarian plate portion is considerably lower with a demand of 600 l water and 0.7 kg CO_2eq per portion. Farming stages contribute significantly to both indicators, especially for the meat variant.

The results show that the total sum of blue, green and grey water demand of the baseline meat plate is more than 70 % higher than the water consumption of the baseline vegetarian plate resulting in a potential water reduction of approximately 1,200 l per plate portion The virtual water demands are dominated by the water consumption of the agricultural production stages, whereas processing energy and transport have no visible impact on the overall water use for the vegetarian and the non-vegetarian plates. Although couscous contributes to only 14 % to the total energy content of the meal, it is related to a water consumption that is 300 l per portion. A switch to organic meat leads to a reduction of the virtual water demand of 305 l (17 %). Less significant would be a switch to organically produced vegetables where a reduction of 8 % or 50 l per portion could be obtained. According to our method, the water demands of the specific ingredients show wide ranges, the highest being for beef. In general, the overall virtual water demand and the advantages related to organic production systems were found to be related to grey water. Further, the results for livestock products are mainly dependent on the composition and quantity of the animal's diets and the related grey water content of the feedstuffs.

Our methodological approach to climate impacts (in terms of GWP) offered a more detailed picture in relation to potential ecological reduction measures based on the plate portion. The carbon footprint of the baseline is represented on the very left of the right half of Figure 2, which is followed by three respective potential reduction measures. Apart from beef and pork dominating on total GHGE per portion, cooking energy has a significant effect on total emissions per portion. Here, cooking energy is the sum of all preparation processes in the canteen kitchen including chilling and regeneration techniques, which are used in our project partner's food service and catering company. The implementation of organic meat was found to have a GWP reduction potential of more than 20 % (0.353 kg CO_2eq) including slightly lower cooking losses of the organic meat. The results show, that potatoes contribute 1-2 % of the total GHGE in the meat variant, which indicates negligible opportunities for reduction. The implementation of green electricity for the cook&chill and re-heating techniques has a potential reduction of 7 % related to the baseline, however in combination with organic meat and potatoes the reduction is about 40 % compared to the baseline. A total switch in the regenerative energy source in the canteen combined with organically produced ingredients reduces total GHGE by slightly more than 1.0 kg CO_2eq which is still higher than the vegetarian baseline.

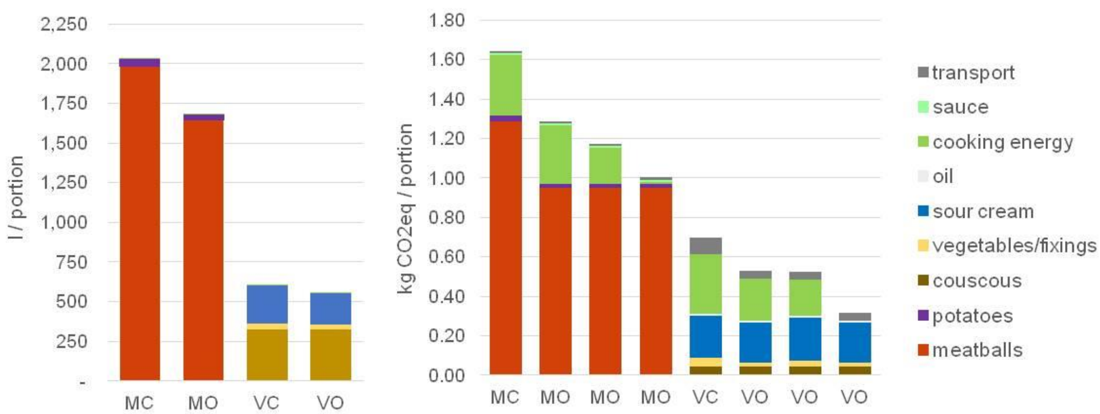

Figure 2. Virtual water demand (left part of the figure) and Global Warming Potential of vegetarian and non-vegetarian meals per portion after cooking, chilling and re-heating. Columns represent different plate variants and show incremental reduction measures. Conventional and organic ingredients were compared. MC: meat meal conventional; MO: meat meal organic; VC: vegetarian meal conventional; VO: vegetarian meal organic.

In the vegetarian meal variant, sour cream is of animal origin and contributes 0.3 kg CO_2eq to the total GWP. It can be seen from Figure 2, that a switch to sour cream from organic milk has a negligible reduction potential overall. The analysis shows that transport makes a higher contribution to the total GHGE per portion in vegetarian conventional and organic plates than in the non-vegetarian plates. Nevertheless, emission reductions due to the regional production of ingredients (presented in the first column) are negligible in comparison to the baseline and can easily be outweighed by calculation and data uncertainties. Although frozen vegetables from organic production show higher GHGE compared to the fresh organic variant, GHGE are found to be lower than a fresh conventional vegetables mix imported from Spain (regarding GHGE from agriculture and related upstream processes). However, in the case of a typical vegetarian meal with couscous and sour cream, no GWP reduction effect of using either fresh or frozen vegetables could be shown in our analysis. A considerable reduction potential is employing renewable energy to prepare vegetarian foodstuffs in the canteen kitchen. A switch from the average German power mix to green electricity for cooking, chilling and re-heating techniques in vegetarian plates could reduce the GWP of the vegetarian plate by 60 %.

4. Discussion and conclusion

Our current food systems are complex and ecologically, economically and socially unsustainable. Today, there are more people suffering from overnutrition and obesity than from undernutrition and related diseases (Searchinger et al. 2013). Due to the rising trend in out-of-home eating, food service companies are important stakeholders promoting sustainably produced and healthy foods.

Our results show that in addition to general suggestions of environmentally friendly measures, specifications on the energy mix used in the canteen kitchen should be considered. Substantial reductions of the climate effect, at least 22 %, can be achieved by switching from non-vegetarian to vegetarian plates (e.g. Stehfest et al. 2009, Carlsson-Kanyama and González 2009). Virtual water demands can be reduced by 17 % by shifting meat-eating habits from quantity to quality, specifically high quality organic meat., Beyond the impact of meal ingredients (directly related to consumer preferences), reduction potential also exists in the preparation of dishes and the selection of raw materials (an executive chief's decision). In German kitchens green electricity can reduce GWP considerably, because energy consumption from food preparation is a major contributor to total GWP, with a maximum of 65 % in vegetarian dishes and up to 30 % for non-vegetarian dishes. The virtual water demand is the lowest for the organic vegetarian dish with net gains of 1.126 – 1.431 l water per portion compared to the non-vegetarian variant. Plastically speaking, these amounts of water could be used to fill at least six bath tubes. The results show, that the virtual water demand of meat and vegetal ingredients is dominated by the amount of the grey water, which is calculated as the theoretical assimilation of nutrients in water bodies. Represented by grey water demand, the assimilation of nitrate and other harmful substances (such as pesticides) is 52 % and 33 % for conventional and organic meat ingredients respectively. For conventionally grown cereals and vegetables the share of grey water is 63 % and 41 % for organic products. It is evident that there is a close relation between our virtual water demand methods and the eutrophication potential commonly calculated in life cycle assessments (e.g. Saarinen et al. 2012).

One methodological limitation of our approach is that we assessed the environmental performance and reduction measures of lunch plates based on an isocaloric comparison instead of using a unit based on the nutritional quality of vegetarian and non-vegetarian plates. A detailed analysis of the environmental impacts based on the nutrient content of foods is desirable for further research. Nevertheless, carbon footprint and virtual water demands show similar performances regarding the incremental reduction plan based on the caloric value of meal portions. A relevant difference is that in order to reduce the virtual water demand per meal plate one would not consider the implementation of green. In a sensitivity analysis we considered the use of water power solely for the cooking, chilling and regeneration processes based on Mekonnen and Hoekstra (2012). The results showed that there is no meaningful impact on the total water demand for the non-vegetarian or vegetarian meal due to the use of hydropower.

One of the research questions addressed the differences between fresh and frozen vegetables, as this measure is easily implemented and reasonable in terms of cost from a food service company's perspective. We further wanted to evaluate the potential of frozen organic vegetables for consumption of organic vegetables produced regional but consumed outside the growing season. Here, we relied mainly on primary data and uncertainties were considered high. Although we found that frozen organic vegetables had a lower climate impact than conventional fresh vegetables and a slightly higher GWP than organic fresh vegetables, we did not consider the implementation of frozen vegetables as a major measure to reduce greenhouse gas emissions of food services companies based on a comparison of plate portions. We did not consider a detailed assessment of refrigerants that are related to a high amount of GHGE and which might lead to even higher GHGE from frozen products. The results show that the import of fresh organic non-seasonal vegetables including long distance transport would only have a small reduction potential compared to imported conventional vegetables. The latter would be overshadowed by uncertainties in the preparation process and waste along the supply chain and the use of animal-based side dishes such as sour cream.

This transdisciplinary approach enabled us to (re)act closely to the food service demands related to sustainability indicators. According to the manager of the food service company, data on the environmental impact is needed to directly inform the consumers in the canteen or to integrate labeling schemes directly in the menu. According to experiences of the food service company, consumers felt good about the fact that vegetables in the non-vegetarian meal are from organic production. An additional use of organic meat would require a much higher price per lunch portion and so far only few costumers are willing to pay more in our example. However, our results show that for the carbon footprint and virtual water demands, implementing organic potatoes has no potential reduction effect. Consumers tend to underestimate and misinterpret the complex interactions between raw material production, imported and regionally produced vegetables, and food processing. Integration of consumers in a transdisciplinary working group could help overcome this difficulty and could help researchers to better understand the preconditions under which consumers are willing to pay a higher price for sustainably produced food in canteens.

We conclude that taking environmentally responsible choices and measure for a reduction of the carbon footprint and virtual water demands in food service companies rely strongly on regional infrastructural constraints and company's internal preferences and strategies. The outcomes of our calculations and the valuable discussions with the partners provided the basis for the establishment of a 5-minute-check online tool where small and medium sized food service companies are able to evaluate the performance of their supply chains in terms of GWP (http://klimae3.fiblprojekt.de/).

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