Carbon footprint of food – An approach from national level and from a food portion

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Abstract: *The evaluation of food chain environmental impacts was conducted using an environmental accounting model developed for the Finnish food sector, and a model of a Finnish standard lunch plate, which followed nutritional recommendations and represented division of a plate into three parts; half of the plate comprising vegetables, one quarter protein and one quarter carbohydrate.The impacts on climate change were analysed over the whole food chain. Different methods of food processing were assessed: preparation of a standard lunch plate at home, public food service preparation of lunch portions and industrial processing of ready-made food. The overall aim was to help consumers make environmentally responsible choices in consumption and identify the key areas requiring improvement in terms of climate change and the food supply chain.According to environmental accounting in the food sector, the food chain accounts for 7% of CO_2 emissions, 43% of CH_4 emissions, and 50% of N_2O emissions produced across the entire economy. Impact contribution of the Finnish food chain in climate change was calculated to be 14%. Food represented 15-20% of the climate change impact of daily consumption. The carbon footprint ranged from 570g to 3.5kg equivalent CO_2 for a single food portion. Impact profiles of portions varied depending on raw material composition and production procedure. Producers of animal products, food consumers making their food choices, and particularly decision makers in public catering are the critical stakeholders for minimizing climate change impacts of the food chain.*

Keywords: *LCA, input-output statistics, lunch plate, food, carbon footprint*

Introduction

The concept of a carbon footprint has been introduced in food production, but variation in published footprint values is substantial and arises from variation in system boundaries, allocation methods, farm management, and logistics during the various phases of food production (Edwards-Jones et al. 2009, Coley et al. 2009). A comprehensive 'big picture' of climate impacts of food has yet to be built and interpretation of the results and their implementation by farmers, food processors and consumers has to be better standardized and made more understandable and more easily implemented.

Considering the carbon footprint and other LCA-based impact assessments, two different approaches can be taken: 1) to learn from and optimize a production processes and management of production systems and 2) to steer consumers towards sustainable choices in their food purchasing.

For the first approach, we need integration of specific process-based and system-structure-based data. Requirements to be efficient in decreasing climate change impacts in ruminant-based processes (Edwards-Jones et al. 2009), and in production of two or several products from one production chain, are most challenging. A comprehensive, systematic and system-based picture is needed for overall performance of food sub-systems and to help develop the potential for carbon neutrality in food production through, for example, carbon sequestration. The essential background assessment over all national economic sectors, representing the baseline information, was provided by Seppälä et al. (2009). The food sector assessment, presented in this paper, was planned for benchmarking emerging trends in environmental performance in the national food sector.

For the second approach, to steer consumers, we would need representative data to allow the critical differences associated with consumption to be shown without adversely affecting the basic nutritional principles of consumption. The nutritional purpose of eating was therefore introduced as a constant starting point to facilitate an objective comparison between the lunch portions based on different raw material compositions or different production processes. Conventional home-made lunches are currently only a common feature of family weekends. Ready-to-eat meals represent a very strong trend in modern Finnish weekday food consumption, either for lunch or for dinner. It is interest to compare them with conventional home-made food portions. Public catering currently dominates weekday lunch consumption. Considering public catering, school lunches were considered to represent an excellent example for steering food consumption towards sustainable choices. Discussing the food composition of a lunch portion downstream of a production chain and upstream to ingredients represents a novel educational package and was therefore included in this study.

The aim is to provide consumers with relevant data on which to make choices in their consumption patterns, and to provide all stakeholders and society with a comprehensive picture of the environmental performance of the national food system.

LCA research approach in Finland

This research approach was based on 1) life-cycle assessment (LCA) models of various food products from work of the team (Usva et al. 2009), including their unpublished and public databases, 2) on an environmental assessment of the food system based on national input-output statistics, and 3) on a model of lunch portions standardized according to nutritional recommendations for young people by the National Nutrition Council (2005). ISO 14040 and 14044 standards represented the references for the general principles and the framework for LCA applications.

The IO approach was funded by the National Quality Strategy for the Food Sector, and the model of a standard lunch plate by Finland's Ministry of the Environment, which included it in the national programme to promote sustainable consumption and production. Support was also provided by five Finnish food enterprises. The Ministry of the Environment used the results for its strategic communication approach, the Ministry of Agriculture and Forestry in their programme for promotion of Finnish Food Culture and the Government of Finland in their National Food Strategy for 2020-2030.

The input-output (IO) approach

The evaluation of the food sector's environmental impacts was conducted using an environmental accounting model developed specifically for the Finnish food chain. The model is based on national statistics of production and environmental impact data from 2005. The model considers both Finnish production and Finnish imports in addition to their transport. Environmental impacts of the end-use phase, that is the activities of food consumers, were not assessed. The report was published for a national forum (Virtanen et al. 2009)

The model of the food chain is structurally similar to that of Life Cycle Analysis. The boundary condition of the model was determined solely by the end-use of the food chain products. The end-use consists of the standard end-consumption batch from the national accounts and also from industrial usage, which includes the consumption of the service sector and other sectors of the economy independent of the food chain. The processes of the model, which are termed 'production nodes', are industries and services, which by definition are in accordance with the national accounts - except for agriculture. In addition to impacts on climate change, the evaluation includes ozone creation impacts in the lower atmosphere, acidification impacts, and impacts of eutrophication of waterways. The results are presented according to life cycle stages of the whole food chain. Finnish production and imports, including transport, and the chain as a whole were reported separately.

The lunch plate approach

Thirty lunch portions of various compositions were investigated. The impacts of food portion components were assessed through the food chain and environmental impacts reported phase by phase as a source through the production chain (Table 1).

A nutritional serving for a standard lunch plate was regarded as a functional unit for calculating the environmental impacts. The lunch plate model incorporates the principle of dividing the plate into three parts; half of the plate comprises vegetables, one quarter the protein source and the remaining quarter comprises the carbohydrate source. The plate is completed with a portion of bread and milk. The composition of the dishes took into account the intake of energy (740 kcal), fat (25–35%), protein (10–20%) and carbohydrates (50–60%) in relation to the total energy intake represented by a portion. The serving sizes for the compositions of different food items were adjusted according to the Finnish nutrition recommendations for young people (740 kcal standard lunch plate).

The amount of the main course of the lunches ranged between 250g and 430g. The highest quantities of the main courses were in plant product based diets. The quantity of bread was quite high and varied among the plates (30–100g). The amount of vegetable spread (70% fat) on the bread was 10% of the quantity of bread. For some plates the spread was left out if the ready-made salad accompanying the ready meals contained a fatty dressing. Serving size of salads was 150g for each plate. There were two basic types of salad, one based on greenhouse vegetables and another based on outdoor vegetables and berries.

Table 1. Food portions that were assessed for environmental impacts.

Home-made servings	Ready-meal servings	School dining room servings
…………..**Macaroni casseroles**………		
➢ Minced meat-macaroni casserole ➢ Minced chicken meat-macaroni casserole	➢ Minced meat-macaroni casserole ➢ Chicken-pasta casserole	➢ Minced meat-macaroni casserole ➢ Vegetable-macaroni casserole
………**Potato based casseroles**………		
➢ Ham casserole, ➢ Chicken casserole, ➢ Rainbow trout casserole ➢ Vegetable casserole	➢ Ham casserole, ➢ Chicken casserole, ➢ Rainbow trout casserole ➢ Vegetable casserole	➢ Ham casserole, Rainbow trout casserole ➢ Vegetable casserole
…………**Chicken sauces**……………		
➢ Chicken sauce with wholemeal rice ➢ Chicken sauce with wholemeal pasta	➢ Chicken in cream sauce with rice	➢ Chicken sauce with wholemeal rice ➢ Chicken sauce with wholemeal pasta
……………**Sausage meals**…………….		
➢ Frankfurter and mashed potatoes		
…………...**Porridge meals**…………….		
➢ Barley porridge with berry fool	➢ Barley porridge with berry fool	➢ Barley porridge with berry fool
………..**Vegetable patty meals**……….		
➢ Beetroot patty with barley, ➢ Soy bean patty with mashed potatoes (vegetarian.), ➢ Soy bean patty with mashed potatoes (ovo-lacto-vegetarian) ➢ Broad bean patty with mashed potatoes		➢ Beetroot patty with mashed potatoes

The home-made servings and ready-meal servings were standardized for 740 kcal and followed the recommendations for young people published by the National Nutrition Council. The school dining room servings followed the previous recommendations, but the size was defined according to actual size of lunches eaten by the pilot school children,

Teaching experts were used to introduce pedagogic aspects into the lunch plate presentation. Thus the project focused on consumption throughout the school system, especially in connection with a ready-planned follow-up project that assesses the potential for procurement of public catering to enhance sustainability.

The main factors involved were raw materials for meals, and energy in preparation of the meals. Regarding raw materials, it is essential to consider material efficiency as well as food items from which the meals are prepared. Losses from pre-processing vegetables, for example, could be as high as 25-70%, depending on the season and raw material quality. Default numbers from the literature were used in assessing the material efficiency.

Comparing home-cooking with ready-to-eat products and the lunchroom kitchen represents a new approach in LCA. The energy use for school catering was assessed from investigating school catering practices and equipment; warming and lighting of the cafeteria building was added. The home catering was assessed based on a process using values from the literature. Catering of ready-made-food was assessed according to investigations of the processing facilities. All the energy impacts were assessed according to the average environmental profile for Finnish energy consumption.

Impacts of fuel used for transportation were assessed on the basis of different national data sources. Default values for different vehicles were used.

Water use was not so crucial because waste water from most of the component processes goes to operationally effective sewage plants. We did not measure virtual water in this project.

Results

According to the input-output analysis, the food chain accounts for 7% of the total domestic CO_2 emissions, 43% of the total domestic CH_4 emissions, and 50% of the total domestic N_2O emissions. The impact contribution of the Finnish food chain to climate change, including imports, was 14%.

According to the food plate approach, the impact contribution of the Finnish food chain was approximated to be 18%. The difference between this value and that from IO-analysis is because in IO-analysis the activities in private homes were not included, but were in the food plate approach.

The life cycle stages of agriculture dominate in the total environmental load of the Finnish food chain. The contribution of agriculture in terms of methane, nitrous oxide and ammonia emissions is over 90%. The contribution of agriculture regarding carbon dioxide is 32%. The dominant position of agriculture with regard to greenhouse gas emissions is reflected in the total climate change impact of the food chain. The share of agricultural processes is 69% for the total climate change impact. The share of the food processing industry is 5% of the chain's entire domestic climate change impact, and the share of other economic areas is about 26% in total. The share of imports in the climate change impact of the food chain is 39%. The contribution of transport to impacts of imported food products is small, only 0.2% of the total.

The largest share of the environmental impacts of the actual end-use of food chain products results from household consumption in Finland. This represents 61% of the entire food-chain climate change impact, 58% of the chain's domestic climate change impact, and 65% of the chain's climate change impact related to imports. The share of domestic food services is 13% of the whole chain's climate change impact, as well as of the domestic impact. Of the chain's climate change impact related to imports, the share of domestic food services is about 14%. The share of other domestic industries' foodstuff use is 6% of the whole food chain's climate change impact and of the impact related to imports, and about 5% of the chain's domestic climate change impact. 19% of the whole food chain's climate change impact, 22% of the domestic impact, and 15% of the impact related to imports is attributable to exports of foodstuffs.

Of the environmental impacts of actual end-use of food, the consumption of meat, dairy and grain products, and catering and bar services together are responsible for 72% of climate change impacts. The remaining 28% is attributable to other foodstuffs, including vegetables, fish, fruits and beverages. The total per capita food chain climate change impact per day is 7.7 kg CO_2 eq/person per day, of which domestic impact accounts for 4.7 CO_2 eq/person per day and imports for 3.0 CO_2 eq/person per day.

According to the lunch plate approach, an average food represents 15-20% of climate change impact for daily consumption of a Finnish consumer. This was assessed using the benchmark approach that describes the total climate change impact of an average Finnish consumer (Nissinen et al. 2006). An impact of a single lunch portion (among the case portions) ranges between 570g and 3.8kg of equivalent CO_2 (Fig.1). Impacts of vegetarian and animal based products differ most, but differences can be found between alternatives for carbohydrates and vegetable components on a lunch plate. The carbon footprint of the salad portion (150g) from greenhouse vegetables is over 600g CO_2 eqv, and that for the one from outdoor products varies between 130g and 370g CO_2 eqv. For an average lunch plate, including animal products, about 70% of the carbon footprint originates from raw material production processes in farming. In vegetarian diets the relative contribution of raw material production to total carbon footprint is smaller, from 30 to 50% (Fig. 1).

In the food plate approach, variations were noted in the contribution of various stages of the food chain to climate change. For home-made dishes, the contribution of agriculture varies from 31% to 84%, being lowest in vegetarian dishes and highest for animal based portions. With ready-to-eat dishes the variation is from 52% to 69% and in school catering from 39% to 67%.

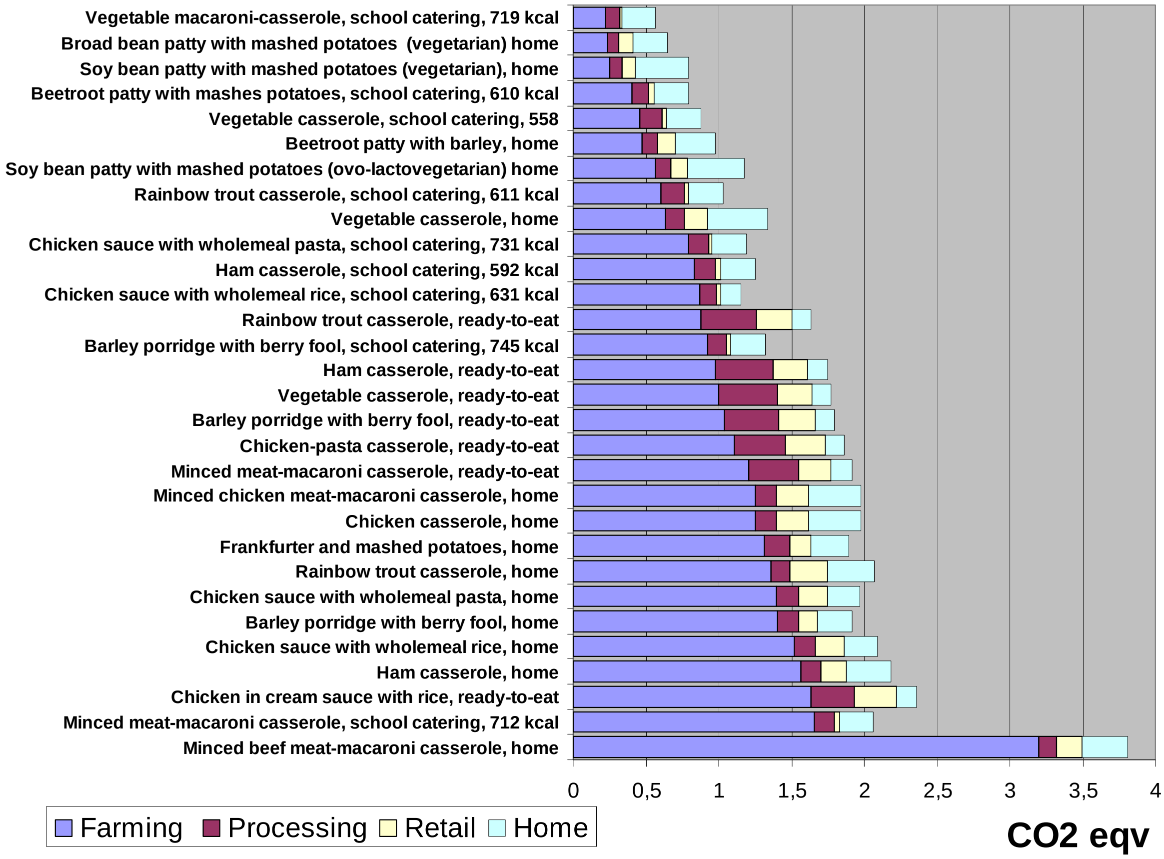

Figure 1. The carbon footprints for a set of food portions: standard plates of 740 kcal from home, equal standard portions made from ready-too-eat foods and a set of school lunch portions that did not strictly follow the lunch plate standard, but represented actual consumption of various school lunches served following the nutrition recommendations for school children. The energy consumption of the school lunches is indicated in the portion description.

Climate change impacts of processing are highest with ready-to-eat portions, and are half of those or less for school catering and home-made food. The impacts of the retail phase were minor for school catering, and highest for ready-to-eat portions. The values varied however in relation to the product base for food compositions of home-made portions. Impacts of home activities were lowest with ready-to-eat portions (these were designed to heat in a microwave oven) and highest for the vegetarian lunch portions made at home. Energy saving in public catering was reflected in lower impacts of school catering compared with home preparation of lunch portions.

Discussion

When evaluated in terms of production volumes, the Finnish food chain is of minor global significance. However, as global transition progresses its importance is set to grow in the European Union and beyond. Taking full advantage of the growth potential requires that the food chain is increasingly eco-efficient in both the home market and globally. The food chain is becoming more global and food will be transported over long distances for various purposes. The contribution of logistics to climate change impact in the Finnish food sector was very low. However, as a result of the rebound effect of the ever increasing role of logistic services in the food chain, the impact is set to grow. Also in the case of Finland, we have to follow the impacts of transportation critically, as was done in the UK a few ears ago by AEA Technology (2005).

The contribution of agriculture in terms of methane, nitrous oxide and ammonia emissions is highly significant. The substantial variation that exists among farming conditions and private farms in terms of the impact on climate change is critical for Finnish conditions, as was recently reported for Wales by Edwards-Jones et al. (2009). Direct and indirect emissions of N_2O from soil and CH_4 emission from manure management are also important. There is a challenge in Finland to improve ruminant production systems towards improved environmental performance. Furthermore, more generally, emphasis on overall food chain improvements should be directed at animal farming systems.

A very promising feature of the methodology used is that the results of the IO-based study confirm the preliminary conclusions of impact assessments concerning single food products (Usva et al. 2009).

An approximate interpretation of the food consumption results implies that by balancing our diet we could reach a situation that is good for human health and the environment. ‘Eco-food’ could include: more vegetarian dishes, outdoor-grown vegetables, fruits, and pulses. We should create a demand for meat with lower impact on the climate in order to induce a supply chain focusing on systematic development of the carbon balance in production systems, potentially by sequestration of carbon on-farm. The food portions making a low contribution to climate change comprised outdoor vegetables, which could be seasonally grown or easily preserved over winter. More of these could be included in the diet to emphasize seasonal features of food. Challenges linked to storage of waste and to inefficiency of short distance transportation have to considered, as highlighted by Coley et al. (2009).

The impact of a single consumer becomes apparent fairly slowly, but groups of consumers as clients of public food services have the potential to make a major change over the short term (Risku-Norja et al. 2010). Thus, emphasis should be put on public procurement and on integrating school food services with environmental education and education for food sustainability (Kurppa et al. 2009).

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