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# Environmental impact of four meals with different protein sources: Case studies in Spain and Sweden

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ABSTRACT

The production of food protein has a considerable impact on the environment. This paper investigates the potential environmental benefits of introducing more grain legumes in human nutrition. Four meals with different amounts of soybeans or peas (either used as feed for production of pork or directly consumed) were analysed using life cycle assessment methodology. The results of this analysis demonstrate that it is environmentally favourable to replace meat with peas. In particular, the addition of more legumes to human nutrition potentially aids in the reduction of global warming, eutrophication, acidification, and land use; however, in terms of energy use, a completely vegetarian pea burger meal requires the same amount of energy as other meat-containing meals. Feeding pigs with European-produced peas instead of imported soybeans, in addition to partial replacement (10%) of meat protein with pea protein, failed to reduce the environmental impact of the meal. In summary, peas can be considered 'green', but there remains a significant need for more energy-efficient processing of vegetarian products.



## 1. Introduction

Food is a major contributor to both local and global environmental impact and resource use. For example, Steinfeld et al. (2006) stated that 18% of global emissions of green house gasses is due to the animal husbandry sector alone, which means that the food sector as a whole contributes even more.

One of the most important components in our diet is protein, both nutritionally and from the point of view of the resources needed and the environmental impact caused when producing it. Proteins are often used as an indicator for food security, that is, if the protein supply is sufficient, then the food supply can be said to be sufficient, since the energy derived from food can be supplied by proteins and by the two other macro-components of food, fat and carbohydrates. Micronutrients (e.g., iron, magnesium, calcium, and zinc) are very important for a healthy and balanced diet. Since the meals investigated in our study were defined according to the dietary recommendations, we assume the micronutrients continued therein to be balanced.

In Europe, the primary dietary source of protein is meat. According to De Boer, Helms, and Aiking (2006), European diets include 40 kg of protein per year, of which 62% is of animal origin. Pork is the primary type of meat produced (Eurostat., 2008). Meat production in Europe highly depends on imported plant protein supplies as feed, which predominantly include soya that primarily originates from South America. Approximately 70–80% of all feed protein concentrates used in Europe are imported (Crépon, 2004). The production of soya in these South American countries causes severe environmental problems, including soil erosion and emissions from increased global transports. The increase in soya production in South America also increases pressure on the remaining rain forests in that region of the world (Fearnside, 2008).

One way of reducing the negative impact of European overseas soya dependence is to instead use grain legumes, e.g., field peas, faba beans, or lupins, grown within Europe. Growing more grain legumes has several agricultural and environmental benefits, as discussed by AEP (2006), Nemecek et al. (2008).

A relatively large number of studies have assessed the environmental impact of various food products using life cycle assessment (LCA), which is a methodology that covers the entire "cradle-to-grave" impacts of products (more on LCA in Section 3). LCA has primarily been applied to food produced in Europe, in particular western and northern Europe (e.g., Andersson, 1998; Berlin, 2002; Thomassen, van Calker, Smits, Iepema, & de Boer, 2008; Ziegler, Nilsson, Mattsson, & Walther, 2003), but the use of LCA for foods is rapidly expanding (e.g., Avraamides & Fatta, 2008; Dalgaard et al., 2007). The results from LCA studies generally indicate that vegetable products have lower impacts and resource use per kg compared to meat, with dairy products in between; however,

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differences in agricultural production, transport distances, and transport method can alter the general picture of environmental impact per kg of food for vegetable versus animal products. Moreover, a comparison between products must also encompass differences in nutritional value and preferably other functions of foods, like taste experience and possibly cultural identity.

One way of managing this complexity is to study diets or meals, thus including these factors on an aggregate level. An example of this was presented by Dutilh and Kramer (2000), who analysed the energy use in some aggregate food chains, and concluded that meat was the most energy-demanding type of food, but some vegetable products could be just as energy demanding. Kramer, Moll, Nonhebel, and Wilting (1999) analysed the emissions of global warming gases from the total food consumption in the Netherlands using a combination of LCA and environmental input–output analysis. Since the results were aggregated, no discussion or conclusions were possible on comparisons and improvements within product groups. Carlsson-Kanyama (1998) also focused on the global warming potential in her study. As opposed to Kramer et al. (1999), she analysed different meals with similar contents of protein and energy. A comparison between protein from pork and quorn was presented by Nonhebel and Raats (2007), wherein quorn was observed to be more efficient in the use of nitrogen and sugar, but required more energy inputs. No other impacts in this study were considered. Sonesson, Mattsson, Nybrant, and Ohlsson (2005a) used LCA to compare three ways of preparing a whole meatball meal, and Davis and Sonesson (2008b) quantified the environmental improvements for two different chicken meals. Baroni, Cenci, Tettamanti, and Berati (2006) compared conventional, vegetarian, and vegan diets, and concluded that decreased meat consumption was beneficial for most environmental impact categories, most prominently for land use. A second assessment of dietary environmental impact was presented by Wallèn, Brandt, and Wennersten (2004), wherein a 'sustainable diet' was compared to the average food consumption in Sweden. In contrast to Baroni et al. (2006), the result showed only minor improvements in the global warming potential by changing the average Swedish diet, a conclusion heavily affected by the exclusion of emissions of methane and nitrous oxide, which generally account for more than 50% of food-related greenhouse gas emissions. Carlsson-Kanyama, Pipping Ekström, and Shanahan (2003) presented a similar study, wherein energy usage from food production and the connections to consumption patterns were analysed. A framework on how to analyse different diets from health, economic, and environmental perspectives was presented by Duchin (2005), wherein a combination of LCA and input–output analyses of scenarios were key elements.

The aforementioned studies all address the question of how choices of meals or diets affect the environmental impact of food consumption; however, they do not address the question of what the impacts of different protein sources are, including different ways of producing and processing the same type of protein. In the present study, we examine, using LCA, four different ways of delivering proteins in a meal, covering both the aspect of raw material sources and processing alternatives. The alternatives studied include, replacing soya with grain legumes in animal feed, replacing part of the meat with pea protein in a processed meat product, and finally replacing meat with peas.

### 1.1. Aim and objectives

- *Aim*: To increase the understanding of the environmental implications of different meal compositions, with a focus on protein source.
- *Objective*: To compare the impacts on the environment from four meals with different protein sources in two countries.

## 2. Studied systems

Food has many functions for humans, supplying nutrients, such as energy, proteins, and vitamins, but also offering pleasure, culture, and social identity. We have chosen the function of food as a basic nutrient supply in this study; hence, the functional unit of the study is one meal served at the table in a household, in two different countries, Sweden and Spain. The reason for placing the case studies in two different countries was not to compare the countries, but to highlight how the results and improvement potentials depend on the surrounding systems, thus investigating both general and specific aspects.

The study includes four meals with different amounts of soybeans or peas (either as feed for pork production or directly consumed):

1. *SOY pork chop* Pork chop produced with conventional feed (SOY = pig feed based on soyabean meal imported to Europe and cereals), potatoes, raw tomatoes, wheat bread, and water.
2. *PEA pork chop* Pork chop produced with alternative feed (PEA = pig feed based on peas, rape seed, cereals mostly grown in Europe, and some imported soyabean meal), potatoes, raw tomatoes, wheat bread, and water.
3. *Sausage partial PEA* Meal with partial replacement of pig meat by peas; a sausage in which 10% of the animal protein is replaced by pea protein (the pork is produced with PEA feed), raw tomatoes, wheat bread, and water.
4. *PEA burger* Meal with full replacement of meat by a pea burger (the peas are grown in Europe), accompanied by raw tomatoes, wheat bread, and water.

The meals differ in the choice of protein source: Pig meat produced with contemporary protein feed largely based on soya bean meal, pig meat produced with peas grown in Europe, part of the meat replaced with peas, and finally a meal where all meat is replaced by peas. The composition of each meal has been put together so that each meal provides the same (or similar) amount of protein, energy, and fat, as well as with the intention that the overall size of the meal and the proportion between meal components are reasonable; see Fig. 1 and Table 1. Recommendations from the Swedish Food Administration on nutrient intake have been used to define the amount and proportions of the nutrients. The meals might not represent a typical meal that people normally eat, e.g., the amount of meat in the case study meals is probably less than what the average person normally eats in a meal, but this is because we seldom eat according to the health recommendations.

In the Spanish scenario, the peas, pork, wheat, and potatoes were produced in Spain, whereas in the Swedish scenario, the origin of these products were Germany, except for the potatoes, which were cultivated in Sweden. The tomatoes originated from Spain in both scenarios. The potatoes are either roasted in the oven (Spain) or boiled (Sweden). The pork chop, sausage, and pea burger are fried in a frying pan in both cases. In the Spanish case, 300 mL of mineral water is served with the meal, coming from a 1.5 L bottle.

In the Spanish scenario, the pigs were slaughtered at 105 kg, the feed conversion rate was 2.8 kg feed per kg weight gain, and there were 2.6 cycles per year. The pigs for the Swedish scenario had a slaughtering weight of 115 kg, the feed conversion rate was at 2.7 kg per kg weight gain, and there were 2.4 cycles per year. The production intensity in Spain is relatively low (Nemecek et al., 2008). The yield of peas was 1.2 t/ha with no use of mineral fertilisers. Wheat yield was 3.0 t/ha with fertiliser inputs of 80 kg $Nha^{-1}a^{-1}$, 72 kg $P_2O_5$ $ha^{-1}a^{-1}$, and 24 kg $K_2O$ $ha^{-1}a^{-1}$. Peas produced in Germany had a yield of 3.3 t/ha with 54 kg $P_2O_5$ $ha^{-1}a^{-1}$