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Carbon footprints of the horticultural products strawberries, asparagus, roses and orchids in Germany

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ABSTRACT

Global climate change problem can be linked to production efficiency and everyday consumption patterns by calculating the greenhouse gas emissions resulting from each product. This is usually referred to as product carbon footprint (PCF). Only limited information is available about the PCF of German horticultural products.

We measured the cradle-to-grave PCF of German strawberries, asparagus, roses and orchids in different production systems and compared it to the PCF of the same products grown in other countries. For the production and customer stage we collected primary data, for the comparison with products in other countries we used literature data.

The results showed that the average consumer stage constitutes 3–71% of the PCF, the best case consumer scenario 1–39% and the worst case 60–99%. The consumer shopping trip was a hotspot in all analysed systems where a private car was used. Electricity for production, fuel use for soil management, and cooking and washing dishes were also among the most often identified hotspots. German open field strawberries perform better, German open field roses and asparagus are on the similar level with the same products produced abroad. However, asparagus transported by plane, and strawberries and roses grown in greenhouses have several times higher PCF regardless of the producing country.

Consumers as well as producers are responsible for reducing the climate impact of horticultural products. Shopping trip on foot or by bike and using renewable energy can reduce the PCF significantly. We recommend extending the analysis to the life cycle assessment or product environmental footprint to consider more indicators to identify which products are less harmful to the environment.

1. Introduction

Climate change has become one of the most relevant global challenges. One way to combat climate change is to calculate and reduce the climate impacts of single products. An estimate of the total amount of greenhouse gases (GHG) emitted from a life cycle perspective of a good or service (later referred to as product) gives an overview of the contribution to climate change from this product (Galli et al., 2012; Jensen, 2012), usually referred to as product carbon footprint (PCF). A full life cycle PCF is necessary to identify emission hotspots in the product value chains and thereby address the climate change on the product level in the most efficient way. PCFs also make it possible to compare the climate impact of competing horticultural products, *e.g.* tomatoes coming from different countries but sold in the same store. However, only limited amount of PCF including the raw material acquisition, production, distribution and the consumer stage have been published about horticultural products (*e.g.* Schäfer and Blanke, 2012; PCF Pilot Project Germany, 2009b; Yoshikawa et al., 2008).

In terms of the production area, asparagus is the most produced vegetable in Germany with almost 20,000 ha (Statistisches Bundesamt, 2014b). On the second place are strawberries with 19,000 ha (Statistisches Bundesamt, 2014a). Roses are the most important cut flower and orchids the most important indoor plant in Germany encompassing 37% and 25% of total revenue from cut flowers and indoor plants respectively (Dirksmeyer, 2009).

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In Germany, strawberries are produced in the open field as well as in greenhouses. Asparagus is produced in open field and in the field with heated soil. Roses are cultivated in greenhouses and in the open field. Orchids are produced in greenhouses. Therefore all these products have potentially high PCFs as suggested by Stoessel et al. (2012). According to Cellura et al. (2012a,b) one of the main causes of environmental impact of horticultural products is cultivation in greenhouses.

Climatop (2009) and Blanke and Schaefer (2012) have researched the PCF of asparagus produced in Germany. In both cases, the asparagus is produced in open field with no additional heating. We found no studies on other asparagus production systems. Also no information is available on the strawberries, roses and orchid production in Germany. Without knowing the PCF of horticultural products from different production systems it is impossible to claim if German production methods are more or less climate harmful than that of the imported products.

PCF analysis normally includes processes from the raw material acquisition to the end of life (cradle-to-grave) or to the point, where the product is leaving the production facilities (cradle-to-gate). Cradle-to-grave system boundary includes also the consumer stage, *i.e.* all activities from the moment of purchase until the product is consumed or disposed. According to PAS 2050:2011 (BSI, 2011), the consumer stage must be included if the system boundary is from cradle-to-grave. During the time we carried out this study, there were no guidelines available for gathering data and designing the consumer stage.

Although some authors strongly advocate that the full life cycle, including the use phase, should be considered in the PCF (PCF Pilot Project Germany, 2009a), there are more PCF and climate impact LCA studies available which end at the producer's gate and do not include the customer stage (*e.g.* Torrellas et al., 2012a; Zafiriou et al., 2012; Gunady et al., 2012). For many products, the consumer stage contributes the biggest proportion of the PCF, *e.g.* a shampoo (PCF Pilot Project Germany, 2008) or a car (Carbon Trust, 2011). The consumer stage of horticultural products can contribute as little as 13% (*e.g.* Page et al., 2012) up to as much as 95% (*e.g.* Schäfer and Blanke, 2012) to the PCF. It shows that not only the producer but also the consumer has the potential to reduce the GHG resulting from the agricultural and horticultural sector. Data to calculate the consumer stage GHG emissions is not widely available. Acquiring such data requires questioning many people about their shopping trip and product use habits. It is also unclear what proportion of the total PCF is related to the consumer stage in the case of different production systems.

The PCF of the same agricultural product can be highly variable, depending on the production system, methodological choices in the PCF assessment (Röös, 2013), transport distance, means of transport, and consumer activities. Thus, also the processes which contribute the most to the PCF, the hotspots, are different. For example, in the case of olive oil the two processes contributing the most to the PCF are the use of fertilizer and the burning of prunings (Close the Loop, 2013), for pumpkin these are the consumer shopping trip and N_2O emissions (Schäfer and Blanke, 2012), for field tomatoes it is the transport to the market, and for greenhouse tomatoes the greenhouse heating (Page et al., 2012). To reduce the PCF of a specific product, identifying the hotspots can help to concentrate the climate performance initiative on the most relevant issues. This helps to find the best PCF reduction results in relation to the cost of making the change.

It is assumed that cultivation in greenhouses and transport by plane are the hotspots of horticultural products. The comparison of hotspots of the same horticultural products from different production systems combined with alternative transport types and distances, and consumer scenarios is missing. It is also unknown which different products or product groups have similar hotspots.

Therefore, the objective of the current research was to calculate and analyse the PCF of the horticultural products strawberries, asparagus, roses and orchids produced in Germany and to compare the PCF if the plants are grown alternatively in an open field and in a heated system. Additional aims were to compare these results with the PCF of the same products from other countries, to acquire customer stage information based on empirical data and research its impact on the PCF, and to determine the GHG emission hotspots.

2. Methods

2.1. Production systems

Four horticultural products were analysed in two different production systems (Table 1) in Germany. In addition, for all products three consumer stage scenarios (Table 2) and for asparagus and strawberries two distribution channels were considered. By combining different production systems with distribution channels and consumer stage in total 12 asparagus, 9 strawberries, 9 roses and 6 orchid value chains were analysed.

The distribution channels of asparagus and strawberries were through the local sales stalls, operated by the producer, and selling to a wholesale company, which organised marketing and distribution to the supermarkets. All flowers were sold directly to the marketer, therefore only one supply chain was included.

2.2. Functional unit

The functional units used in this study were 1 kg of asparagus in a plastic bag or plastic wrapping, 1 kg of strawberries in plastic punnets, 10 cut roses in a foil, and for orchids, a pot with 12 cm diameter and 2 orchid plants on a tray at the point of sale. Some transport processes required using weight for functional unit. In such cases we calculated the weight of 10 roses with a proportion of water in the transport bucket and the orchid pot with its plastic tray.

2.3. System boundaries

The system boundary of food PCF commonly ends at the farm, at the retail outlet or at the plate (Röös, 2013). The current study went beyond that and included all product related processes from the raw material acquisition to consumption or disposal at the end of life. Processes, which were included in the study, are listed in Table 3. Not all processes applied to all four products. Transport,

Table 1
Production systems included in the study. All variants were also combined with the best, the average and the worst case consumer scenario.

Production system	Open field, no heating		Open field, soil heating		Greenhouse, non-renewable heating (for orchids, conventional system)	Greenhouse, renewable heating (for orchids, sustainable system)
Product	Supply chain					
	Marketer	Sales stalls	Marketer	Sales stalls	Marketer	Marketer
Asparagus	x	x	x	x	–	–
Strawberries	x	x	–	–	–	x
Roses	x	–	–	–	x	–
Orchids	–	–	–	–	x	x