The Food Short List

Recommendations for Swedish consumers to reduce the environmental impact of their food choices

Nadia Karami

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LUCSUS
Lund University Centre for
Sustainability Studies

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Submitted October 20, 2014

Supervisor: Kimberly Nicholas, LUCSUS, Lund University

Abstract

The issue of an increasing number of people globally that are adopting unsustainable lifestyles is important because we are destroying the earth's resources at an accelerating rate.
In particular, the pattern of major increasing environmental impact caused by modern food production has the potential to become an important sector for climate change mitigation, but despite the myriad of guides available for reaching a sustainable lifestyle, not enough emphasis is put on the importance of individual consumption choices and increasing consumer's awareness of the significance their dietary decisions have.

In this thesis, I studied Swedish dietary choices and the environmental impacts these incur in order to define a "short list" of dietary choices that Swedish consumers could make that would make the biggest contribution on reducing their environmental impact. I defined environmental impact in terms of three indicators: energy use, greenhouse gas (GHG) emissions and water footprints. I gathered data on environmental damage caused by the 15 most consumed foodstuffs in these three categories, using the data sources of the Swedish board of Agriculture and peer-reviewed literature. I then ranked these indicators to compare the impact between different food choices. The shortlist for beverages was beer for energy, orange juice, milk and beer for greenhouse gas emissions, and milk for water; and for food it was chocolate and processed meat for energy, exotic & citric fruit and pork for greenhouse gas emissions, and for water it was chocolate. This was important because it demonstrated the complexity and potential contribution dietary choices have to climate change mitigation.

As a result of this work, actors such as local authorities and the national food agency should be able to focus research and development of a guide concentrating on strengthening the awareness of the importance of individual consumption choices and clear information on how much environmental impact is affected by dietary changes.

Keywords: *food, consumption and production, energy, greenhouse gas emissions, water footprint, sustainability.*

Word count*: 12 642*

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1 Introduction

A great majority in many parts of the world have adopted lifestyles that are unsustainable. This has resulted in human activities that are degrading, depleting and wasting the earth's natural resources at an accelerating rate (Foley et al. 2011; Godfray et al. 2010). This pattern of unsustainable consumption has led to several global problems, such as poverty, famine, disease environmental damage, unequal consumption, scarcity of natural resources and climate change, which pose a threat to future survival of humanity (Munasinghe 2012). The fifth assessment report released 2013 from the International Panel on Climate Change reports that climate change is "extremely likely" to be caused by human activities resulting in increased greenhouse gas concentrations (Stocker et al., 2013). Furthermore a majority of the scientific community is in agreement that climate change is attributed to human caused increase of greenhouse gas emissions (Oreskes 2004).

The current global economy is dependent on overconsumption and today we use the equivalent of 1.5 planets to indefinitely sustain the resources humanity uses and absorb its waste (Global Footprint Network 2012). This means we are exceeding the earth's biological capacity to replenish resources and it takes Earth one year and six months to regenerate what humans have used and absorb waste and pollution produced in one year. Growing human pressure has raised concerns for exceeding thresholds in other sub-systems, i.e. planetary boundaries, which are vital for the Earth system to maintain its function as a whole (Rockström et al. 2009). As a result of human activities, such as consumption, three out of the nine boundaries have been overstepped (Rockström et al. 2009).

The raised issues caused by overconsumption is signaled in the progress of Millennium Development goals and the post 2015 Agenda, where the Sustainable Development Goals (SDGs) provides an opportunity for addressing the objective of achieving sustainable consumption and production through an international development framework (Horn-Phathanothai 2014). Particularly important point in the agenda is production and consumption of food as it will require a major integrated effort to address the considerable failings of the present food system (UNEP n.d.).

1.1 Problem area

Food plays an integral part of causing environmental and health problems. Under-consumption of food is responsible for that more than one in seven people suffer from chronic malnourishment (Godfray et al. 2010; Foley et al. 2011). Meanwhile overconsumption is on the rise in almost every country worldwide and thus obesity is described as a global pandemic and addressing this issue is proving difficult (Swinburn et al. 2011). Food's role in providing nutrition is a basic principle for all humans and as such is hugely important part of the food sustainability debate. However due to the complexity of balancing nutrition with environmental impacts for the development of dietary guideline (Thompson et al. 2013), the inclusion of nutrition was considered beyond the scope of this thesis and thus not covered. Increased food production for a growing population has resulted in global land-use changes, which has also impaired ecosystem functioning, diminishing the planet's capacity to sustain food production (Foley et al. 2005). Agricultural production is responsible for as much as 92% of the global average water footprint, where consumption of cereals make up 27% of the water used by the consumer, and meat and milk contributing with 29% Furthermore food production has resulted in globally widespread issues, such as deforestation, pollution, climate change and water degradation (Foley et al. 2011).

The food the average Swedish consumer buys contributes with 25% to the total greenhouse gas emissions. There are user-friendly initiatives implemented in Sweden that aim to help consumers make environmentally conscious decisions, such as Eco labelling and the Green guide (website and mobile phone app) from Swedish Society for Nature Conservation (Naturskyddsföreningen). Obviously individual consumption choices are important in order to mitigate climate change, but consumers are often not informed about this in awareness-raising efforts as those mentioned above. The approach of informing consumers of the potential effective actions that they can adopt to reduce resource consumption on a household level exists for energy and water (Gardner and Stern 2008; Inskeep and Attari 2014). The motivation of developing the original short list was that consumers were often mistaken in the beliefs of which actions were the most beneficial (Gardner and Stern 2008), and thus did not direct their conservation efforts effectively.

The environmental impact of food has received increasing attention in media and scientific literature in relation to Sweden's sustainable development. The debate has been growing during some time, and over the years several terms and concepts has evolved to a reoccurring theme. An investigation initiated by the government coined the phrase the three Bs – "Bilen, biffen och bostaden" – in English 'the Car, the beef and the home', to highlight the important areas for sustainable development (Edman 2005). The Federation of Swedish Farmers (LRF) used the term climate smart food while promoting the sustainability of Swedish food production compared to imports (The Swedish Federation of Farmers, n.d.).

Current academic and governmental analyses of the environmental impacts of food consumption frame impacts in terms of the concepts sustainability (Geeraert 2013; Kumm 2002), climate change impact (Eriksson 2008; Angervall et al. 2008), greenhouse gas emissions (Bryngelsson, Hedenus and Larsson 2013; Wallén, Brandt and Wennersten 2004; Röös 2012)and carbon footprint (Minx et al. 2008; Berners-Lee 2010). Meanwhile, in the literature discussing food consumption in Sweden and other European countries or Europe as a whole the predominant terms used were environmental impact (Tukker et al. 2011; Hertwich 2010), greenhouse gas emissions (Vieux et al. 2012; Kramer et al. 1999; Katajajuuri, Grönroos and Usva 2014; Girod, van Vuuren and Hertwich 2014; Lesschen et al. 2011)and sustainability (Thompson et al. 2013; Torres 2013; Doublet et al. 2013; Garnett 2014)

Surprisingly the concept of water use and water footprint from food consumption was only used in a few Swedish and European studies (Ercin, Aldaya and Hoekstra 2011; Vanham 2012; Mekonnen and Hoekstra 2010a, 2010b). However this concept was used by WWF, the Swedish Environmental Protection Agency, and the Swedish University of Agricultural Sciences (SLU) with the Swedish Board of Agriculture to stress that global water resources are dwindling as a consequence of the 'hidden' water footprint of food production (Falkenmark 2004; The Swedish Environmental Protection Agency 2010; Wåhlander n.d.;).

The work of previous food footprint studies showed strong agreement that food consumption patterns was strongly linked to agricultural production and environmental damage (Geeraert 2013; Landquist et al. 2013; Doublet et al. 2013; Vieux et al. 2012; Tukker et al. 2011; Wolf et al. 2011; Carlsson-Kanyama and González 2009; Davis et al. 2010; Pizzigallo, Granai and Borsa 2008; Wallén, Brandt and Wennersten 2004; Carlsson-Kanyama 1998). The result of the recent studies revealed that the potential for a substantial reduction of resources use was achievable by changing the consumers' dietary choices (Van Dooren and Bosschaert 2013; Wolf et al. 2011; González, Frostell and Carlsson-Kanyama 2011; Carlsson-Kanyama and González 2009).

Another important school of thought that is predominant when investigating the environmental impact of food consumption was the life cycle analysis. These assessments commonly examined the impacts along the chain of production 'from farm to fork' focusing on either a few metrics, such as energy, water and greenhouse gas emissions, or on a comprehensive inventory of resource use (Landquist et al. 2013; Doublet et al. 2013; Pizzigallo, Granai and Borsa 2008; Ntiamoah and Afrane 2009; Reckmann, Traulsen and Krieter 2013; Comandaru et al. 2012; Talve 2001; Ercin, Aldaya and Hoekstra 2011; Beccali et al. 2009; Pizzigallo, Granai and Borsa 2008; Berlin 2002; Beccali et al. 2010; Cederberg and Flysjö 2004; Ingwersen 2012; Carlsson-Kanyama, Ekström and Shanahan 2003)

2 Research Aim

It is complicated to calculate the environmental impact for single food items available to purchase, which makes it difficult to easily share information to consumers on environmental impact from food consumption. This complication is because food originates in many different countries, raw material for processed food products are imported from different countries and processing takes place somewhere different to country of purchase, and thus it is very time consuming to trace the entire chain of production, different stages takes place in different countries and not every production step is monitored. Different food alternatives will have varied impact within different environmental categories. There is an interest from consumers to take part of this information, and food retailers have an opportunity to influence the consumer's decisions. This thesis examines the food impact of the most commonly consumed foods and beverages in Sweden in terms of greenhouse gas (GHG), energy and water footprints. This composite index of food impact will help inform consumers and could guide food policies in the sustainable development agenda of local authorities. This analysis will go some way to show the magnitude of overconsumption, the associated trade-offs when replacing different food items and inform on how much environmental impacts are affected by changing dietary composition.

2.1 Main Research Question

People are living increasingly busy and demanding lives. Any effort to guide consumers in their food purchase decisions should focus on which item's replacement will result in the most decreased environmental damage. Alongside the information on which food items to replace there should also be the associated reduction in environmental impact, preferably in quantitative terms.

2.1.1 Research Question 1: What are the 15 most widely consumed foodstuffs by weight in the Swedish diet?

Available data of individual consumption for a whole year will be analyzed by volume ranking to identify the most consumed foodstuffs in Sweden. The data were distinguished into two groups: beverages (measured in liters) and solids (measured in kilograms).

2.1.2 Research Question 2: What is the environmental damage of the most widely consumed foodstuffs of the average Swedish person's diet measured in energy, GHG and water 'footprints'?

Identification of the main impacts that different dietary choices incur, measured in energy use, greenhouse gas emissions and water requirements. This made it easier to develop suggested actions for the average Swedish citizen who wants to limit their environmental impact, even if only a little change was made, and thus can allocate their time and money to the best option.

2.1.3 Research Question 3: What are the top priority food items consumers can replace to reduce environmental impact and why?

The foodstuffs that were the most detrimental to the environment were easily noted by putting impact in quantitative terms, and by comparing across the different forms of analysis it can easily be determined what the tradeoffs were between different impact categories.

To determine the trade-offs of replacing a high impact food item with a low impact item, I performed four different forms of comparison; overall comparison, separated categories, annual impact and impact per calorie. These were carried out to see possible detrimental effects of such replacement. In order to determine which items that was most suitable for replacement the results from all four comparisons were compiled to see which items consistently had high impact. Then this was then cross-checked with the low impact item to see if any apparent trade-offs could be observed in the different comparisons.

To determine why certain items were more damaging than others I carried out a literature review of life cycle analysis studies on the chosen food items. These results will increase the readers' understanding of the underlying processes driving food impact, and possibly give a sense of the environmental impact of other commonly consumed food items. This lead to developing a list for the use of individuals that wants to focus their efforts to reduce environmental impact by changing food choices. Furthermore calculations were carried out to show how much potential savings for each environmental impact category the possible actions produce.

The shortlist presented here highlights the choices with the top most damaging products and/or processes, and why these should be avoided. This provides easily accessible display of the best and worst choices and the associated reduction of environmental impact by substituting better products for more damaging choices.

Table 1. Research questions, data sources and methodology. This table explains the main research question, sub-questions and how these will be answered and the methods used.

Main Research Question: Which foodstuff is the best option for replacement, and its associated scale of savings, to attain the most decreased environmental damage?		
Question	***Source***	***Methods to collect & analyze data***
What are the 15 most consumed foodstuffs in the average Swedish diet?	Statistical database, category direct food consumption, from website of the Swedish Board of Agriculture – www.jordbruksverket.se (Retrieved 15/02/2013).*	Identify the top 15 food items most widely consumed by ranking the amount consumed in liters and kilograms.
What is the environmental damage of the average Swedish person's diet measured	Scientific peer-reviewed papers, for complete references please see Table 2, page 6.	Impacts put in quantitative measures, by collecting data of energy, GHG, and water footprints per kilogram of

in energy, GHG, and water 'footprints'?		foodstuff from relevant scientific literature.
What are the top priority food items consumers can replace to reduce environmental impact and why? And how much reduction can the dietary impact potentially incur?	Overall comparison between impact categories and items, divided into two groups – drinks and foods.	Table 2, page 6. Calorie content of the top 15 items collected from statistical database on the National Food Agency website (Retrieved 03/05/2013).**
	Rankings of items within each separate impact categories to prioritize the foodstuffs / beverages with the highest environmental impact.	
	Calculated annual impact per person.	
	Calculated impact per calorie and compared to impact per kilogram / liter.	

**http://statistik.sjv.se/PXWeb/Selection.aspx?px_tableid=JO1301K1.px&px_path=Jordbruksverkets%20statistikdatabas__Konsumtion%20av%20livsmedel&px_language=sv&px_db=Jordbruksverkets%20statistikdatabas&rxid=5adf4929-f548-4f27-9bc9-78e127837625*

*** http://www7.slv.se/Naringssok/SokLivsmedelsGrupper.aspx*

3 Research Design

This thesis uses a deductive approach, whereby I tested the hypothesis that consumption of food has the potential to make an important contribution to mitigation of environmental damage and climate change. This paper is an endeavor to contribute to the myriad of available guides to attaining a sustainable lifestyle, especially focusing on the importance of individual consumption choices. The research design is based on a quantitative investigation of the potential reduction of environmental damage on the individual level, based on analysis of the impact caused by the fifteen most widely consumed foodstuffs.

3.1 Methodology

In order to answer the main research question the unit of analysis will be the average Swedish person's diet, i.e. the 10 most commonly consumed foodstuffs; and their related environmental impact. The categories chosen for inclusion in environmental impact were encountered in concepts and terms used by the scientific literature as described in section 1.1. Terms and concepts such as food print, carbon footprint and water footprint were combined to create my own term Food impact. In this thesis, I define food impact as the combined impact across multiple metrics, specifically greenhouse gas emissions, energy and water footprint. These impacts were identified and quantified in peer-reviewed studies by researchers, e.g. energy from González, Frostell and Carlsson-Kanyama (2011), greenhouse gas emissions from Wallén, Brandt and Wennersten (2004) and water from Mekonnen and Hoekstra (2010a). The study area as such will be focused on environmental impact of food and the dietary choices that the average Swedish person can feasibly adopt in their home to reduce such impact. The field research with desktop data collection was carried out in May 2013.

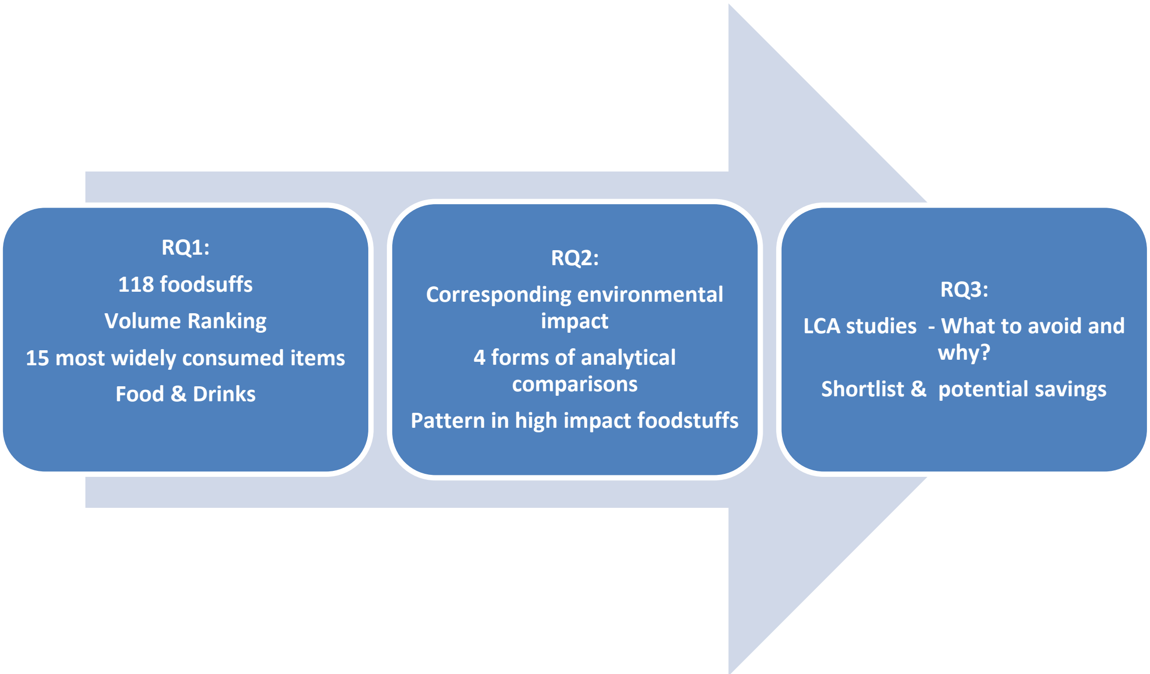


Figure 1. Description of the methodological process, corresponding to the three research questions outlined in Table 1.

3.1.1 Food consumption data

In order to build a comprehensive overview of what kind of food and drink people widely consume in Sweden, data on food consumption was taken from the statistical database produced by the Swedish board of Agriculture (Jordbruksverket). The data was gathered by SCB Statistics Sweden, and was made up of 118 food and drink items that are consumed during a year. This included data of agricultural produce, processed products such as canned products and frozen cooked food. I chose to use the data for 2007, as this was the most recent year with available data to download in an Excel spreadsheet format. The data used in the present study was for direct consumption of foodstuffs, which includes all food that was used by individual households, on-farm consumption and catering for institutional households, such as schools, day-care centres and hospitals (Jordbruksverket 2012). The data for direct consumption was gathered by the Swedish board of Agriculture from food producers such as slaughter houses and mills. This is complimented by further data gathered from the industrially produced food for import and export by SCB. To identify the most commonly consumed food and drink items, the data was ranked based on consumption in kilograms or litres. This narrowed it down to 20 items, which were re-organized to 15 items, and selected for further analysis. After identifying the most widely consumed food items by ranking, further analysis was carried out on drink and food items separately.

3.1.2 Environmental Impact Data

Data on environmental impact of the selected food and drink items was collected from the scientific studies that had established the energy consumption, greenhouse gas emissions equivalent and water footprint of primarily Swedish food, and if not available then European food.

Table 2. Data sources for environmental impact of each food item most widely consumed in Sweden 2007.

Food product	Energy use	Greenhouse gas emissions	Green, Blue & Grey Water Footprint
Milk	Carlsson-Kanyama and González (2009)	Carlsson-Kanyama and González (2009)	Mekonnen & Hoekstra 2010b
Soft drinks	Carlsson-Kanyama, Ekström and Shanahan (2003)	Berners-Lee (2010)	Ercin, Aldaya and Hoekstra (2011)
Beer	Carlsson-Kanyama, Ekström and Shanahan (2003)	Wallén, Brandt and Wennersten (2004)	Mekonnen & Hoekstra (2010a)
Orange juice	Carlsson-Kanyama, Ekström and Shanahan (2003)	Berners-Lee (2010)	Mekonnen & Hoekstra 2010a
Wine	Carlsson-Kanyama, Ekström and Shanahan (2003)	Berners-Lee (2010)	Mekonnen & Hoekstra (2010a)
Bread	Carlsson-Kanyama, Ekström and Shanahan (2003)	Berners-Lee (2010)	Mekonnen & Hoekstra 2010a
Potatoes	Carlsson-Kanyama and González (2009)	Carlsson-Kanyama and González (2009)	Mekonnen & Hoekstra (2010a)
Exotic fruit	Carlsson-Kanyama, Ekström and Shanahan (2003)	Berners-Lee (2010)	Mekonnen & Hoekstra (2010a)
Citric fruits	Carlsson-Kanyama, Ekström and Shanahan (2003)	Berners-Lee (2010)	Mekonnen & Hoekstra (2010a)
Processed meat	Carlsson-Kanyama, Ekström and Shanahan (2003)	Wallén, Brandt and Wennersten (2004)	Mekonnen & Hoekstra (2010b)
Frozen	Wallén, Brandt and	Wallén, Brandt and	Mekonnen & Hoekstra

processed meat	Wennersten (2004)	Wennersten (2004)	(2010b)
Apples & pears	Carlsson-Kanyama and González (2009)	Carlsson-Kanyama and González (2009)	Mekonnen & Hoekstra (2010a)
Chocolate	Carlsson-Kanyama, Ekström and Shanahan (2003)	Wallén, Brandt and Wennersten (2004)	Mekonnen & Hoekstra (2010a)
Pork	Carlsson-Kanyama and González (2009)	Carlsson-Kanyama and González (2009)	Mekonnen & Hoekstra (2010b)
Poultry	Carlsson-Kanyama and González (2009)	Carlsson-Kanyama and González (2009)	Mekonnen & Hoekstra (2010b)

3.1.1.1 Quantitative Analysis

A total of 5 environmental impact categories were identified for 15 food and drink items, as the water footprint is made up of 3 categories, i.e. green, blue and grey water. For the purpose of easier comparison between each environmental impact category, the categories were normalized by the maximum value, i.e. the most damaging value; except for water, where green, blue and grey make up the total water footprint. Thus the highest energy value for beer and wine was 12 MJ per liter, which all the other drink items were calculated as a percentage of the two highest items (equal to 100%), then repeated for each environmental category, to be able to compare across all items and categories. As the data on environmental impact used for this study, was obtained as environmental impact per kilogram or liter consumed, the total annual amount of damage for the 5 impact categories was calculated. In order to investigate the possible trade-offs the impact per calorie for each food and drink item was calculated.

3.2 Assumptions and Boundaries

I have chosen to focus the environmental damaged caused by the top fifteen most widely consumed items in Sweden by weight. The assumption is then that overconsumption can be reduced without regard to nutritional and health aspects. This does not take into consideration how well the nutritional requirements are satisfied with the diet composition in relation to reducing the environmental impact. As mentioned before the nutritional aspect of food is important, but previous food footprint studies support the difficulty of balancing nutrition with environmental impact (Carlsson-Kanyama and González 2009; Van Dooren and Bosschaert 2013). Depending on how nutrition of food was defined and measured (calories vs. protein content), the results showed a significant difference in the scale of potential reduction of environmental damage as a result of changing food consumption patterns (Wallén, Brandt and Wennersten 2004; González, Frostell and Carlsson-Kanyama 2011; Vieux et al. 2012). Furthermore it does not take into consideration all the aspects of how a lower impact foodstuff is actually suitable for replacing a higher impact foodstuff. For example this may pose a problem in the case of health concerns with sugar-containing drinks substituting milk.

The sources for the environmental damage for the chosen items presented here have been chosen with regard to the most likely food options that are available. Thus this means that for those products that can be and commonly was produced domestically, the life cycle analysis data for Swedish produce has been used when available. For products such as bread, milk, meat, potatos, apples and pears Sweden is fairly self-sufficient, meanwhile products such as exotic and citric fruit, wine, beer, orange juice and cocoa is mostly imported (Carlsson-Kanyama, Ekström and Shanahan 2003; González, Frostell and Carlsson-Kanyama 2011).

The life cycle analysis used for explaining the possible underlying causes for why certain food items were worse than others was for food consumption in Sweden as much as possible. If not available then life cycle analysis from food consumption in a neighboring country with similar production processes was used.

4 Results

4.1 Consumption

Re-organizing the food consumption data resulted in 118 food items, which reached the total weight of 876.3 kg per person. The weight proportions of all the food products that were consumed in Sweden during 2007 are shown in Figure 1. Interestingly the top 15 food products chosen for my analysis added up to 58.5%, in comparison to the remaining 103 food items that make up the other 41% of the total consumption that year.

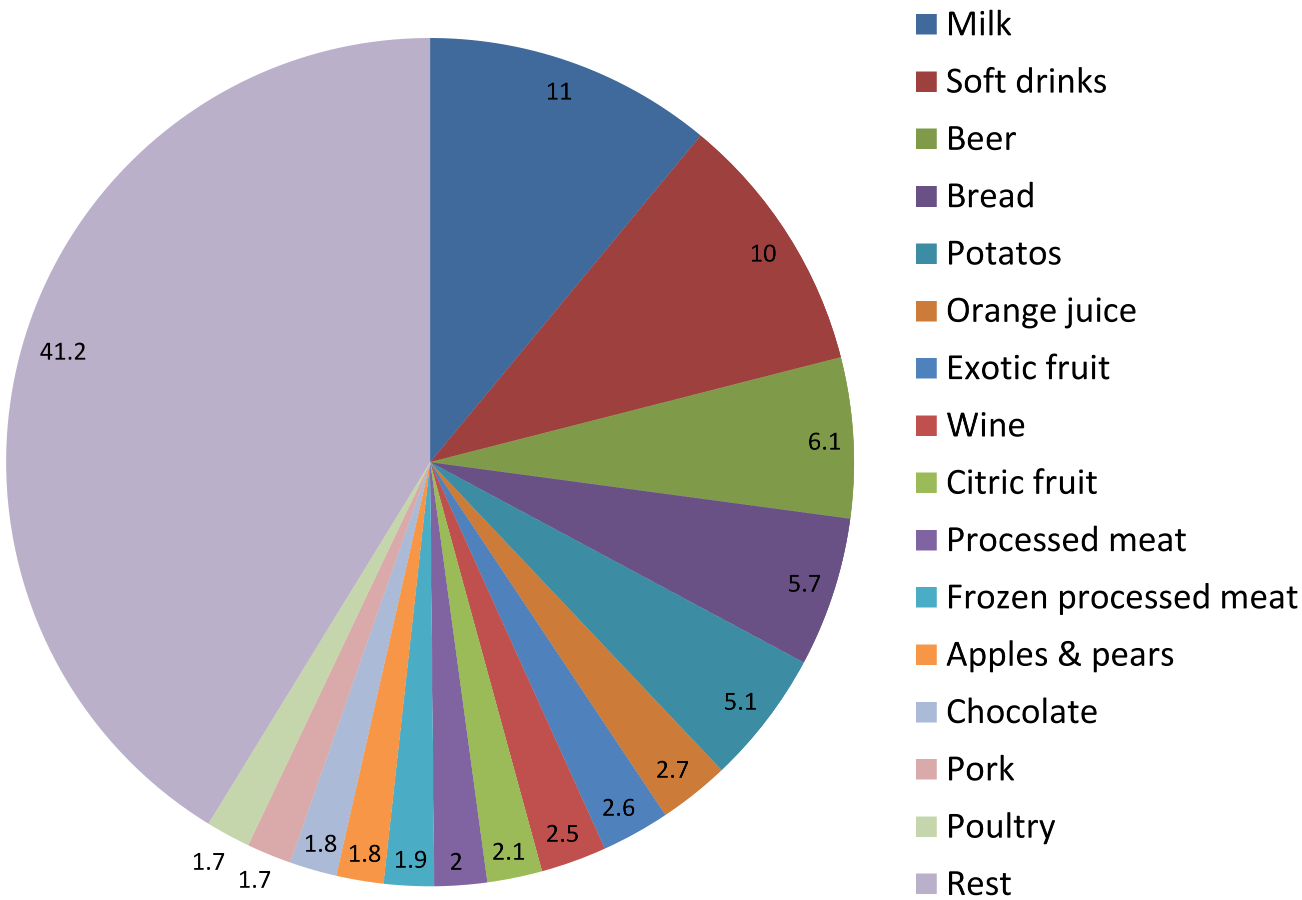


Figure 2. Total food supply in Sweden 2007. The 15 most consumed foodstuffs by weight in the Swedish diet, versus the rest 41% made up of 103 food products, expressed in kilograms or liters respectively. Percentage weight of consumed foodstuffs in Sweden expressed in liters/person/year.

The most consumed beverage of a Swedish person is milk, with a yearly consumption of nearly 97 liters. Soft drinks and bottled water is commonly consumed in Sweden, with a yearly consumption of nearly 88 liters per person. Annual consumption of beer is not as high as milk and soft drinks, at 54 liters, but considerably higher than consumption of fruit juice and wine (Fig. 2).

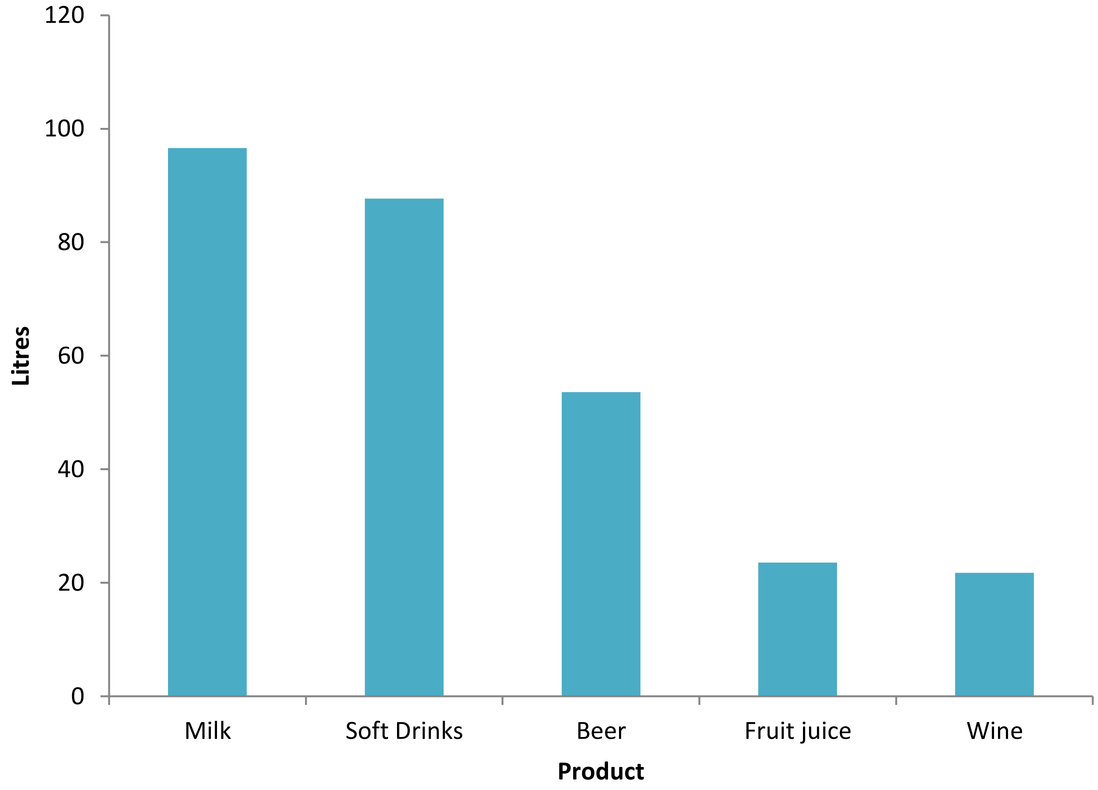


Figure 3. The amount of the top five most widely consumed drinks by volume in Sweden, 2007 displayed in liters/person/year.

In terms of weight, bread is the most commonly consumed food item, with an annual consumption of just over 50 kilograms per person. Ranking the food items by most consumed product, the order is then potatoes, exotic and citric fruit, processed meat products, apples and pears, followed by chocolate, pork and poultry meat (Figure 4).

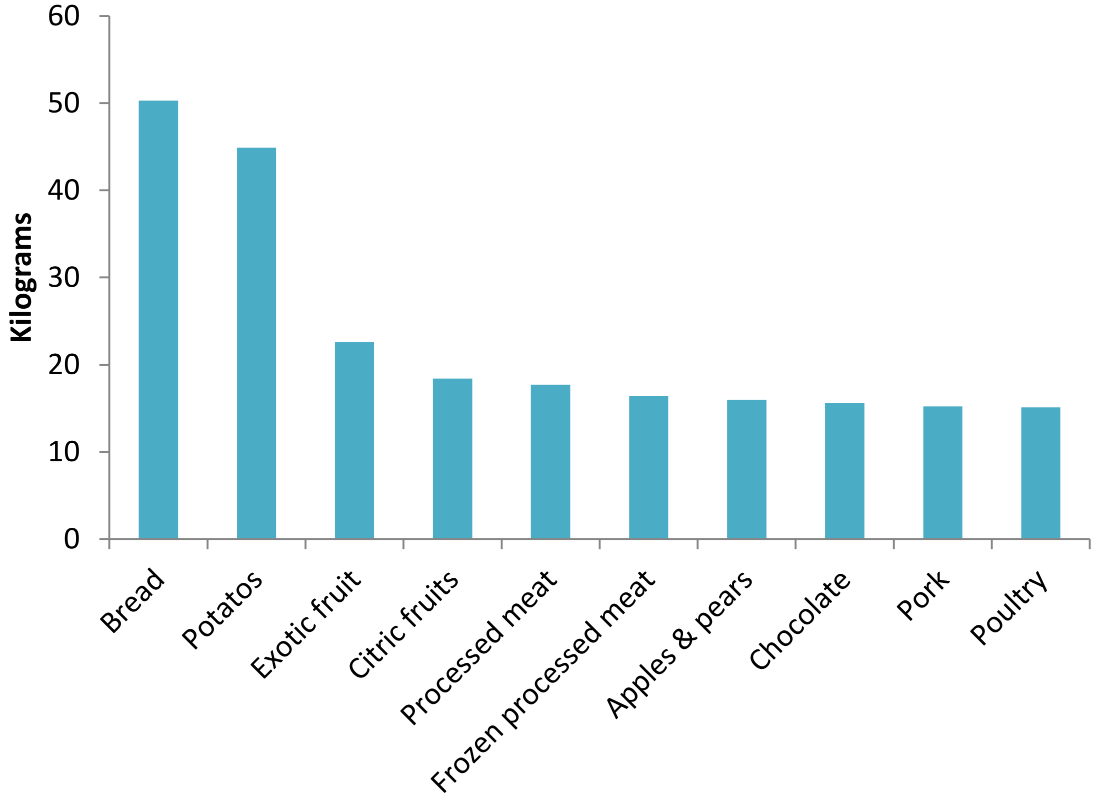


Figure 4. The amount of the ten most widely consumed foods by volume in Sweden 2007 displayed in kg/person/year.

4.2. Overall comparison

Comparing the environmental impact for the most commonly consumed beverages in the Swedish diet, it appears that milk is the drink that has comparatively low impact, except for green water footprint (figure 5). The green water footprint is fairly consistently high across all the most commonly consumed drinks (figure 5). Soft drink could also be considered a like-worthy drink option to milk, when considering all the environmental impacts, as the energy used for production, green and blue water footprint is greater than milk (figure 5). However the greenhouse gas emissions equivalent and grey water is lower for soft drinks compared to milk (figure 5). The main environmental impact that differs between milk and soft drinks is energy used for production, which is nearly twice as high as that of milk (figure 5). Overall the environmental impacts such as energy produced, greenhouse gas emission equivalent and green water footprint for beer, fruit juice and wine are greater, whereas fruit juice has greatest greenhouse gas emissions (Figure 5).

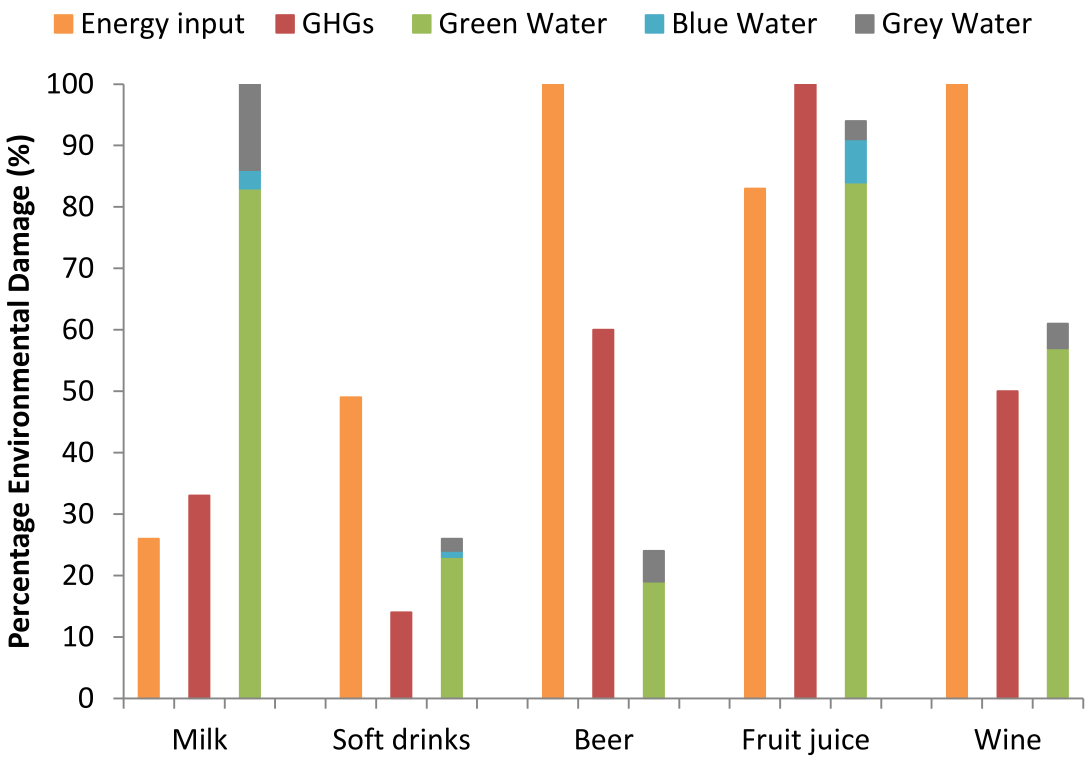


Figure 5. Overall comparison of weighted environmental impact for the 5 most commonly consumed beverages in the Swedish diet 2007, measured as impact per liter. Each environmental category was normalized by the highest value, which for energy = 12 MJ/liter, GHGs = 3 kg CO2 eq./liter, and green, blue and grey water = 17196 liters.

Overall the environmental impacts are consistently low for bread, potatoes, apples and pears compared to the other commonly consumed food items (figure 6). The citric and exotic fruits are very high in greenhouse gas emission equivalents, but fairly low in energy used and water footprints compared to the other food items. Processed meat products, both fresh and frozen have a comparatively fairly high environmental impact in energy used for production, green and grey water footprints. The environmental impact of chocolate is also comparatively greater than the other food items, such as potatoes and apples. Again greenhouse gas emissions are comparatively high for pork, whereas energy used and water footprints are lower than processed meat and chocolate. Of the meat food items poultry has comparatively lower environmental impact compared the other meat products and chocolate (Figure 6).

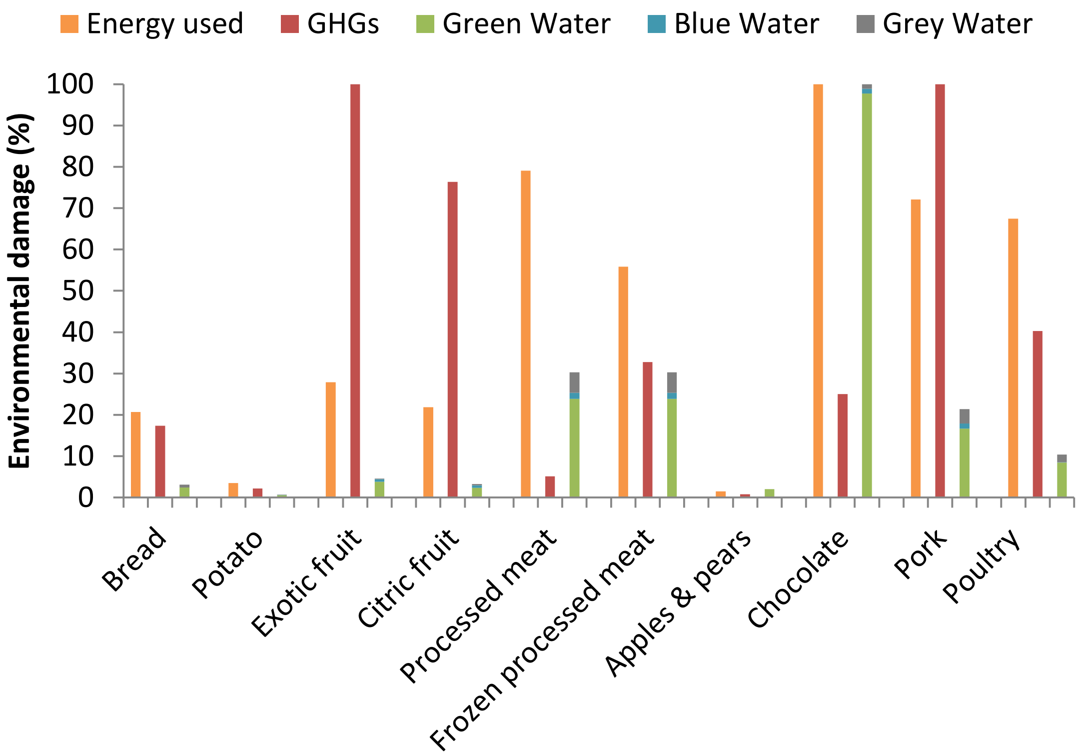
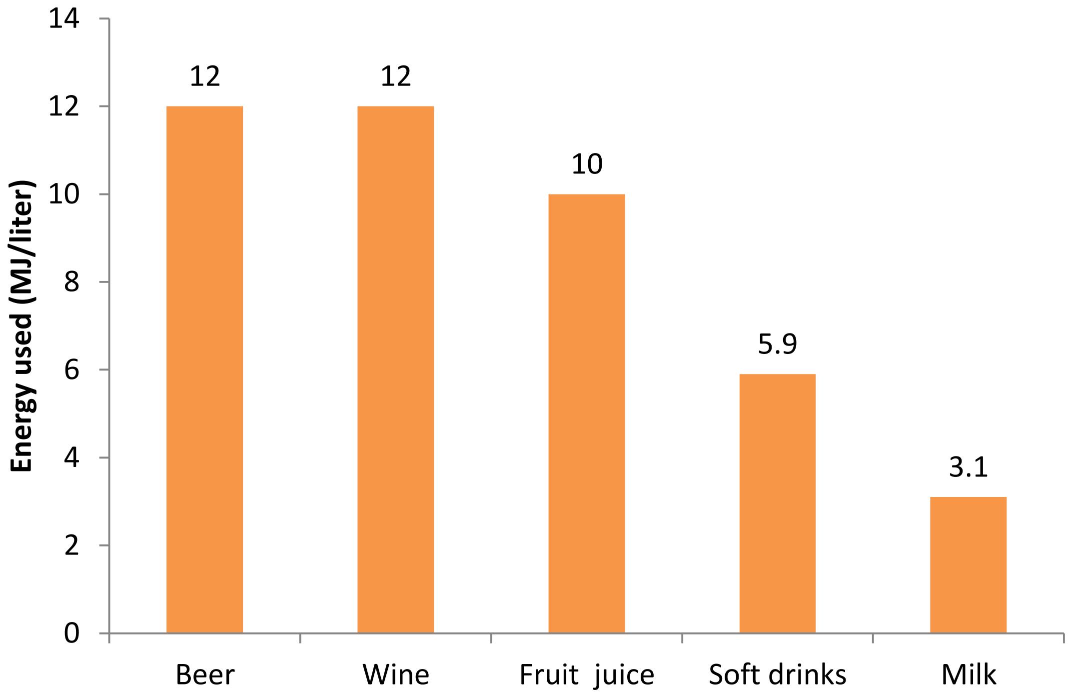


Figure 6. Overall comparison of weighted environmental impact for the 10 most consumed foodstuffs by weight in kilograms in the Swedish diet 2007, measured as impact per kilogram. Each environmental category was normalized by the highest value, which for energy = 43 MJ; GHG emission = 7.2 kg CO2; water footprint = green + blue + grey water = 17196 liters.

4.3 Separated Categories

Depending on the different category type of environmental impact it is apparent that different drink items are a cause of concern. Considering only energy used then the impact of beer, wine and fruit juice is of most concern, but milk and soft drinks are comparatively less of a concern (Figure 7a). However if considering only greenhouse gas emissions the impact of fruit juice is of most concern, wine and beer is of intermediate concern, whereas soft drinks has comparatively the lowest impact (Figure 7b)



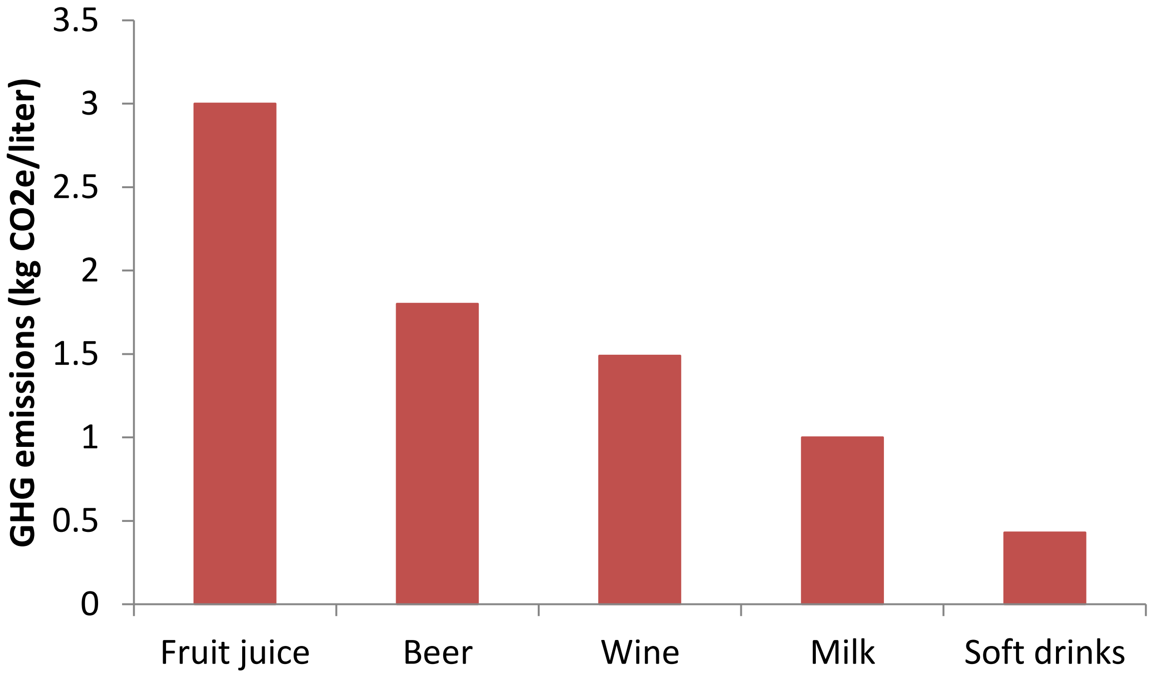


Figure 7a – b. Comparison between a) energy used (MJ/liter) marked in yellow, and b) greenhouse gas emission (CO_2 equivalent) marked in red, for the most consumed drink items, by volume, in Sweden 2007.

Total water footprint for most commonly consumed drink items was the greatest for milk in the Swedish diet 2007 at 593 liters of water per liter of milk, closely followed by fruit juice at 558 liters of water per liter of juice (Figure 8). Wine has a smaller water footprint at 361 liters water per liter of wine, whereas soft drinks and beer had comparatively smaller water footprints at 152 and 139 liters of water per liter of drink respectively (Figure 8).

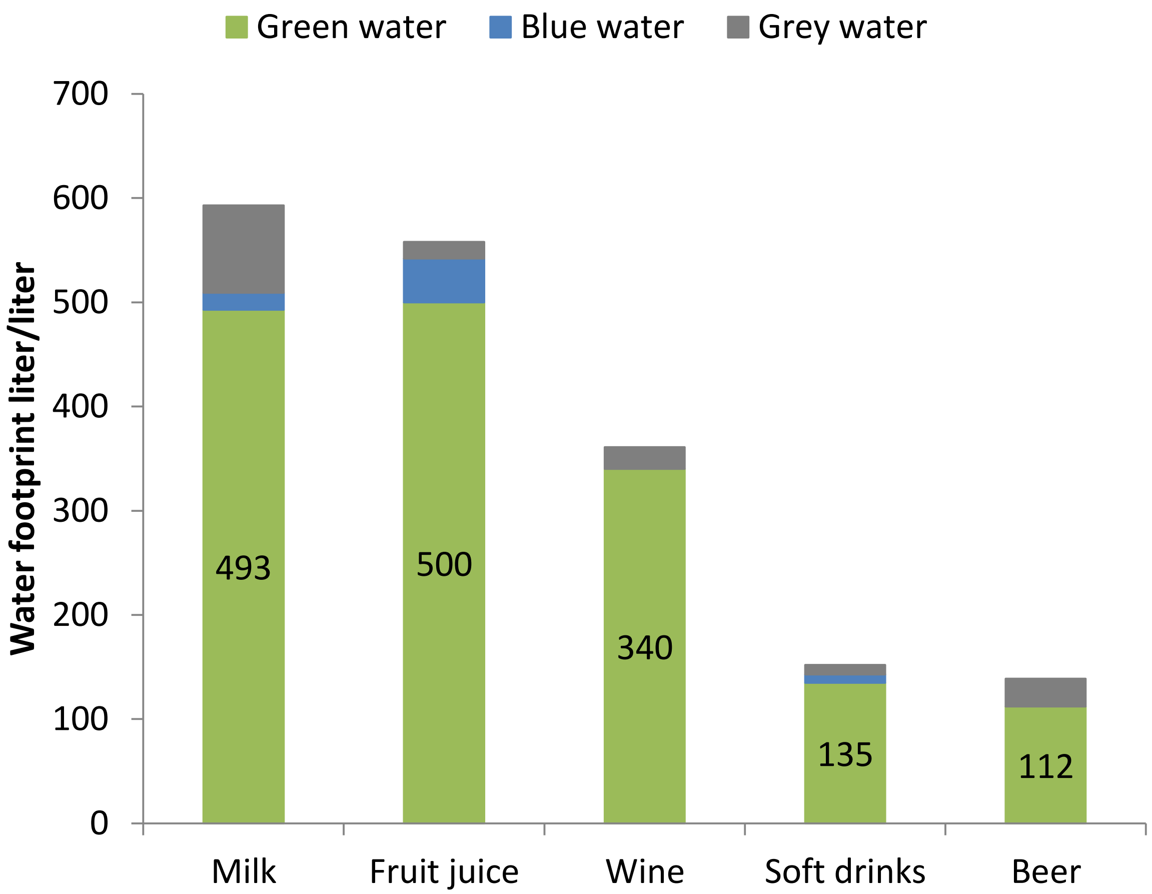
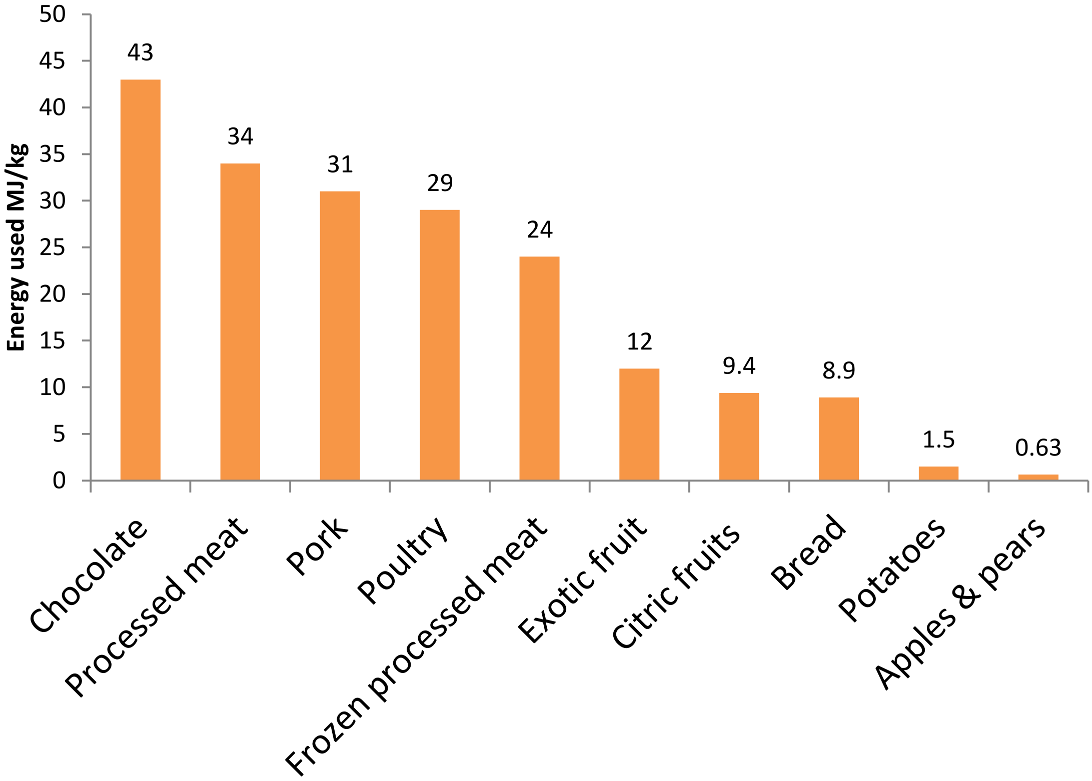


Figure 8. Total water footprint of most consumed drink items, by weight in liters, in Swedish diet 2007, shown in stacked bars, made up of green, blue and grey water as modelled by Mekonnen & Hoekstra, 2010.

Again the pattern differs in comparison of environmental impact categories of energy used and greenhouse gas emissions for most commonly consumed food items in the Swedish diet 2007 (Figure 9a-9b). Considering only energy used it is noted that chocolate is of the most concern, and then followed fresh processed meat products, pork, poultry and then frozen processed meat products. The bread, potatoes and fruits are comparatively lower in energy used. However the trend is quite different when considering greenhouse gas emissions only it is evident that chocolate is comparatively lower.



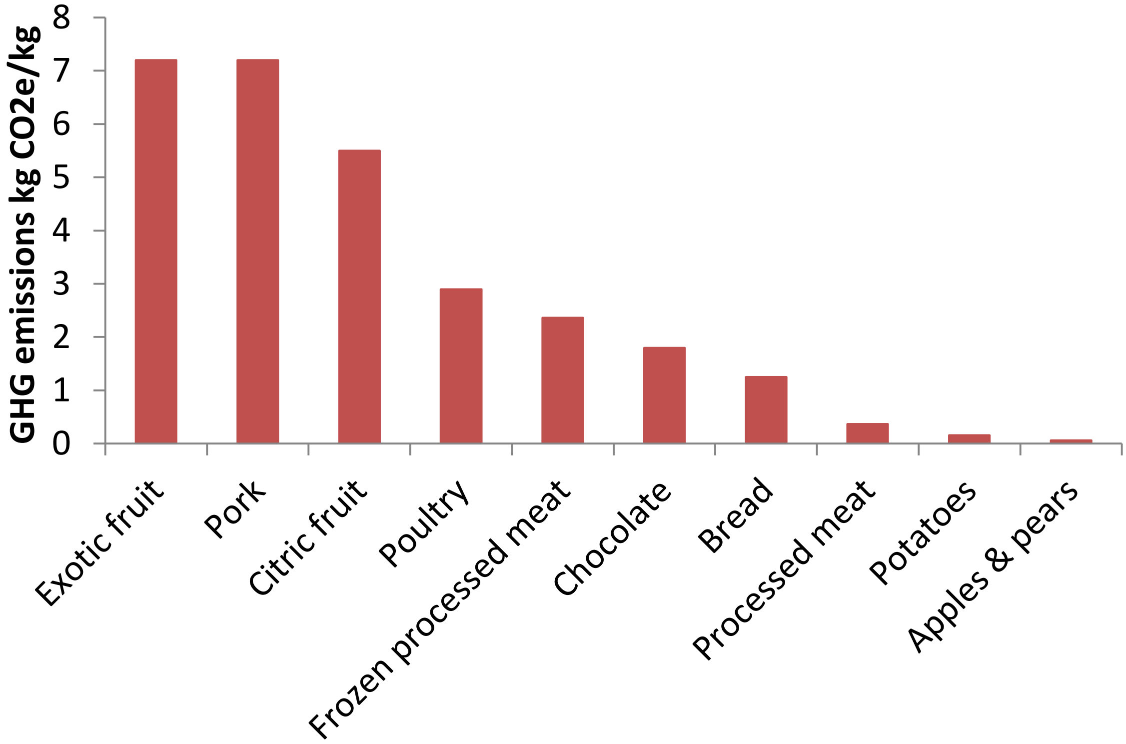


Figure 9a – b. Comparison between a) energy used (MJ/kg) marked in orange, and b) greenhouse gas emission (CO2 equivalent) marked in red, for the most consumed food items, by weight, in Sweden 2007.

Interestingly for the comparison of the impact of total water footprint for the most consumed food items, chocolate has the greatest impact at 17 196 liters of water per kilogram chocolate, followed by processed meat at 5 206 liters per kilogram, pork at 3 672 liters per kilogram, and poultry at 1790 liters per kilogram (Figure 10). However the water footprints for bread, potatoes and fruits ranging between 125 - 790 liters of water per kilogram food item, are comparatively lower than chocolate and meat produce (Figure 10).

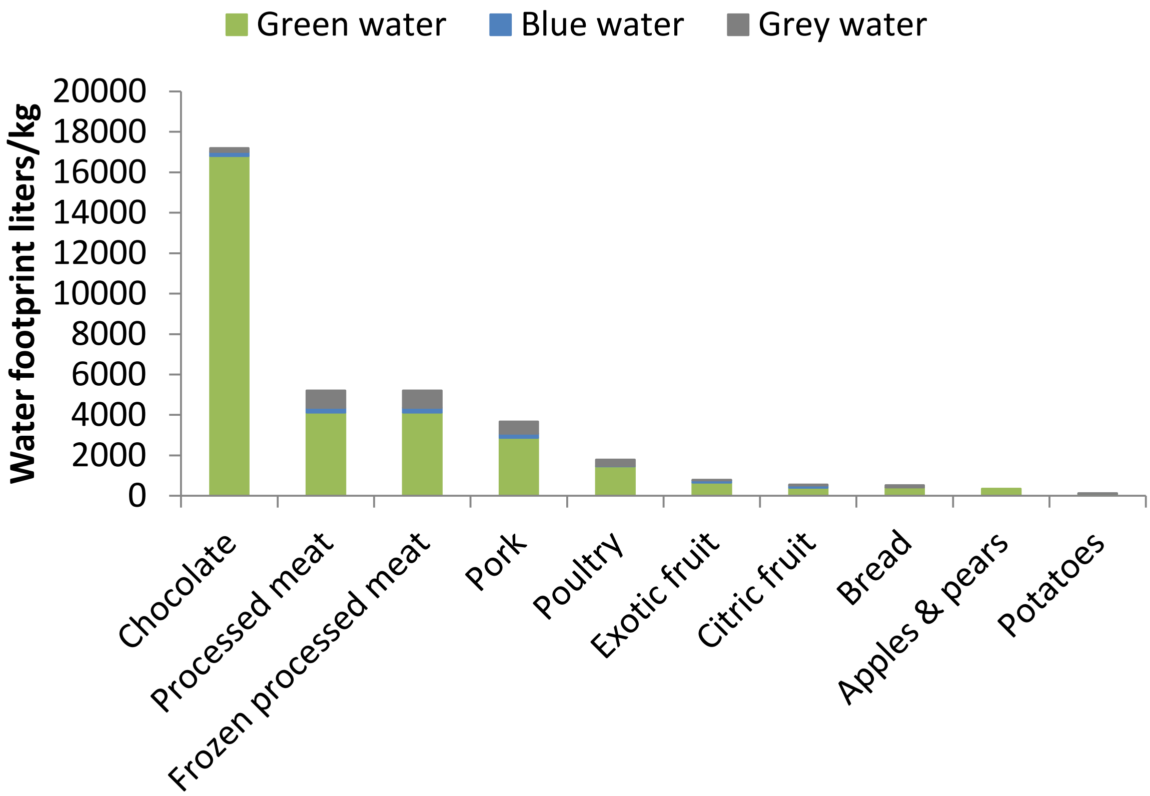
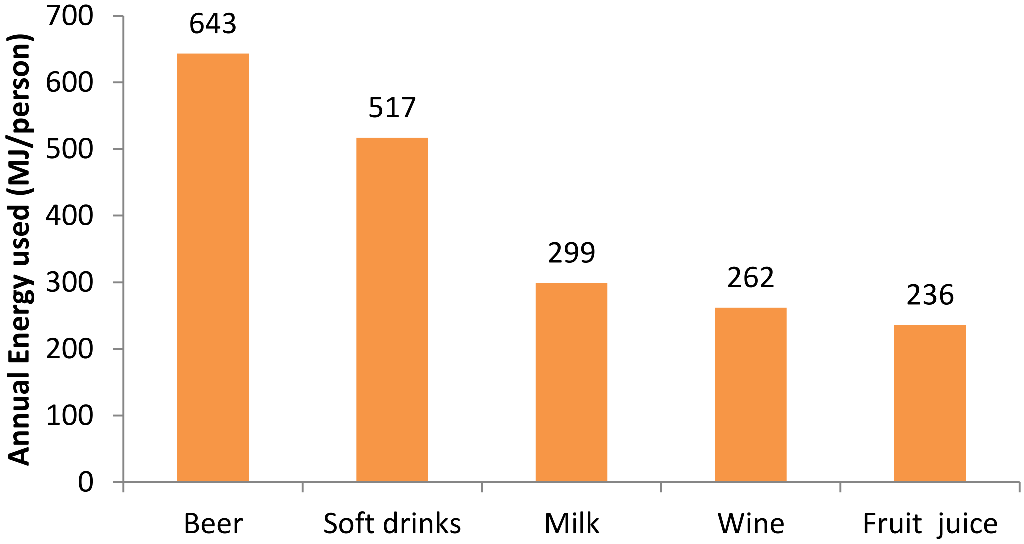
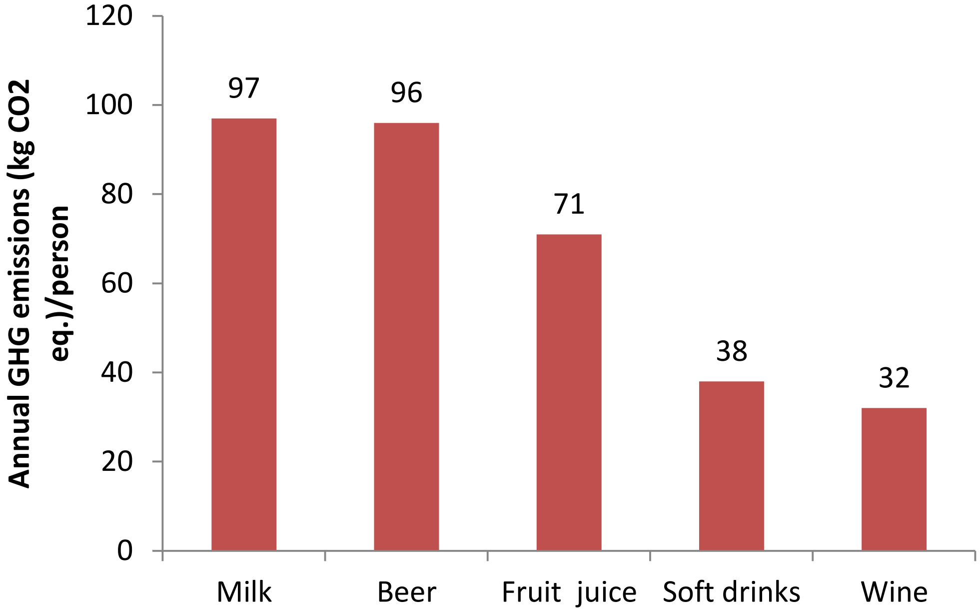


Figure 10. Water footprint per kilogram of the 10 most consumed foodstuffs by weight, in Swedish diet 2007, shown in stacked bars, made up of green, blue and grey water as modelled by Mekonnen & Hoekstra, 2010.

4.4 Annual Impact

Previously displayed data above showed the environmental footprints in energy, GHG emissions and water per kilograms or liters of foodstuff consumed in Sweden 2007. This means that if the consumption of beer for the whole year was 54 liters, then the total energy used for the yearly consumption in 2007 was 643 MJ per person. Thus if the energy used is of highest environmental priority, then beer has the largest footprint, closely followed by soft drinks at 517 MJ per person.


Annual Energy used (MJ/person)
0
100
200
300
400
500
600
700
643
517
299
262
236
Beer
Soft drinks
Milk
Wine
Fruit juice


Annual GHG emissions (kg CO2 eq.)/person
0
20
40
60
80
100
120
97
96
71
38
32
Milk
Beer
Fruit juice
Soft drinks
Wine

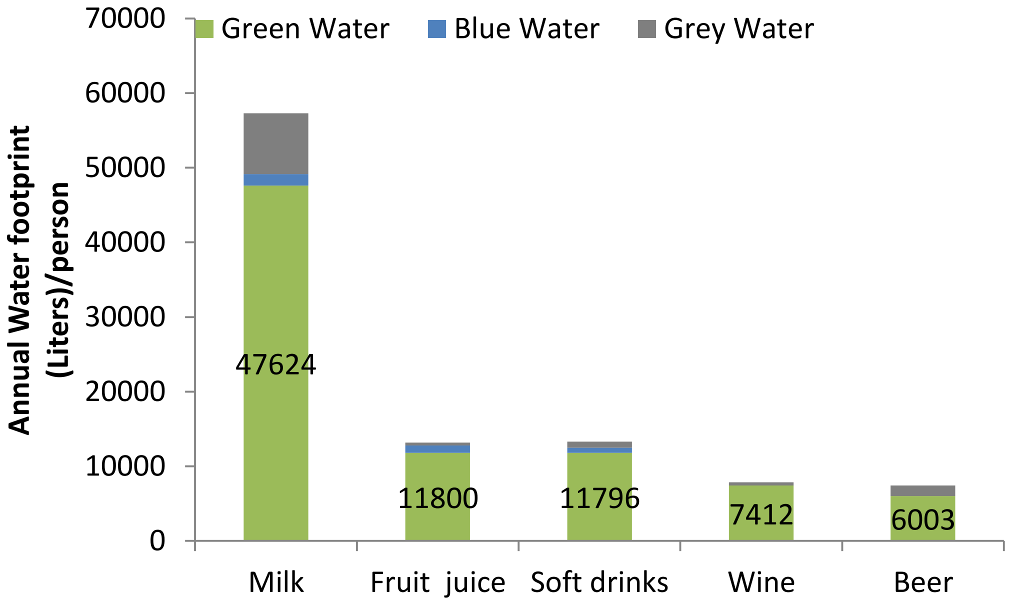
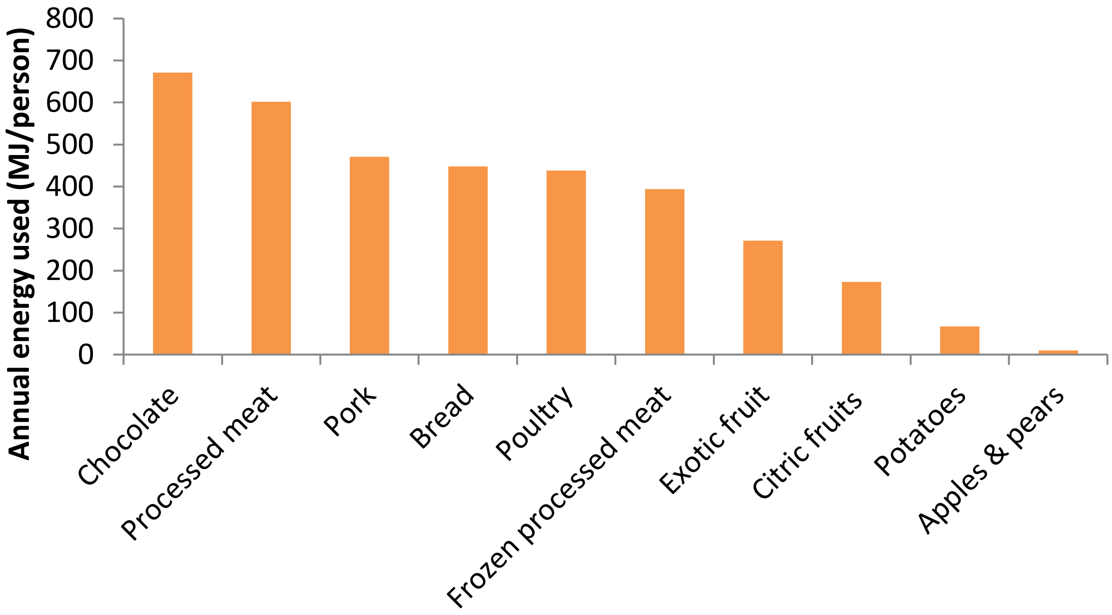


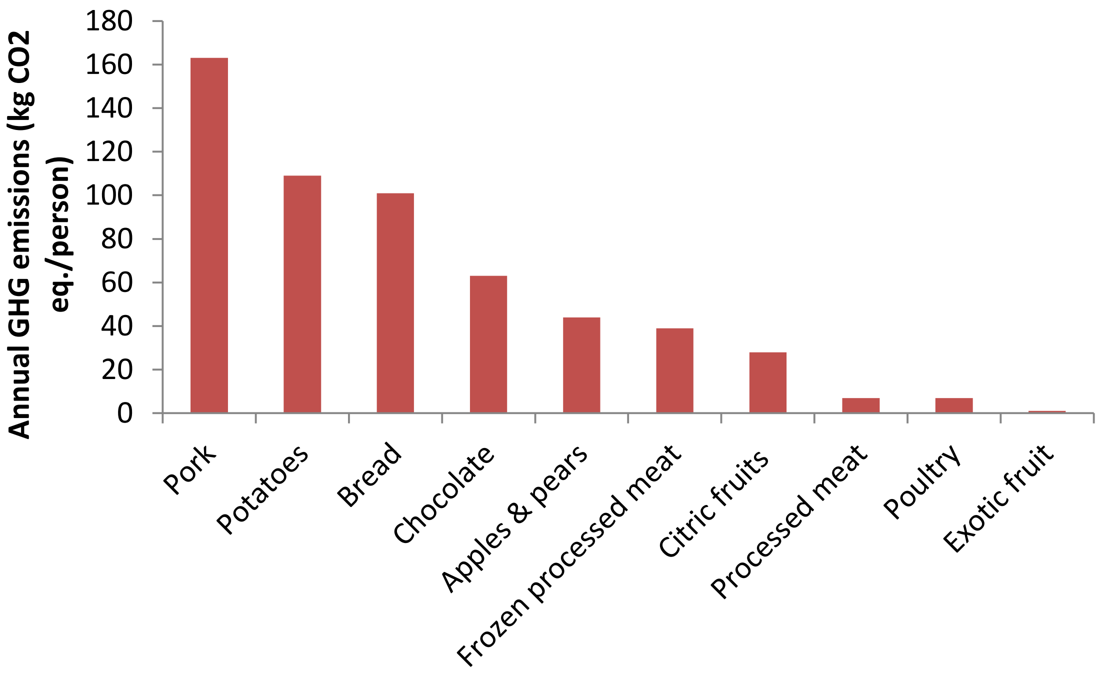
Figure 11a-c. Total annual environmental impact of the 5 most consumed beverages, by weight in liters, for one Swedish person in 2007.

The annual energy footprint of milk at 299 MJ/person is less than half of beer's footprint. Both wine and fruit juice have smaller energy footprints than milk, with 262 MJ and 236 MJ/person (Figure 11a).

Comparing the annual GHG emissions footprints of beverages milk and beer were the worst polluters at 97 and 96 kg CO2 equivalent. Fruit juice had an annual GHG footprint that was about 25% less than beer and milk, whereas the GHG footprints of soft drinks and wine are less than half of milk and beer (Figure 11b).

The water footprint for milk was clearly much larger than the water footprint of the other beverages at nearly 60 000 liters/person (Figure 11c). This was due to the green water footprint that was more than 4 times greater than fruit juice, soft drinks, wine and beer. The annual green water footprint of fruit juice and soft drinks is less than 14 000 liter, whereas the green water footprint for wine and beer was less than 10 000 liters/person (Figure 11c). Milk and beer had the largest annual footprint in two environmental categories out of three analysed here.


Annual energy used (MJ/person)
800
700
600
500
400
300
200
100
0
Chocolate
Processed meat
Pork
Bread
Poultry
Frozen processed meat
Exotic fruit
Citric fruits
Potatoes
Apples & pears


Annual GHG emissions (kg CO2 eq./person)
180
160
140
120
100
80
60
40
20
0
Pork
Potatoes
Bread
Chocolate
Apples & pears
Frozen processed meat
Citric fruits
Processed meat
Poultry
Exotic fruit

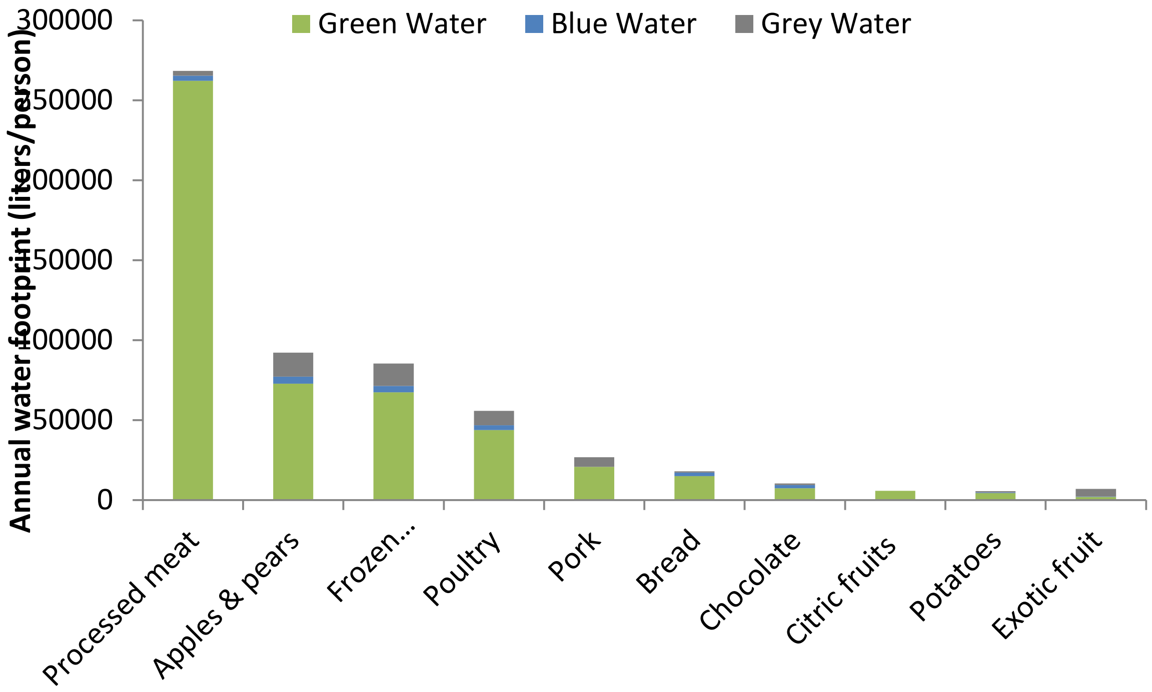


Figure 12a-c. Ranked total annual environmental impact of the 10 most consumed foodstuffs, by weight, for one Swedish person in 2007.

The annual consumption of chocolate had the largest energy footprint, followed by processed meat, both over 500 MJ per person. The other 8 foodstuffs are less than 500 MJ per person. However the annual consumption of pork has the largest GHG emission footprint at 160 kilograms of CO2e, which is more than the GHG emission footprint of travelling 1300 kilometers by train (calculate using data from Berners-Lee 2010). Potatoes and bread had a GHG emission footprint closer to 100 kg of CO2e (Figure 12a), which is approximately the same GHG footprint of using a mobile phone for 2 minutes per day for two years (Berners-Lee 2010). On the other end of the scale, annual consumption of processed meat, poultry and exotic fruit all had GHG footprint smaller than 20 kg CO2e (Figure 12b). The trend differs again for the water footprint of the annual consumption of foodstuffs, where processed meat evidently had the largest water footprint (Figure 12c). There was a 2.5-fold difference between the water footprints of annual consumption of processed meat, and apples and pears (Figure 12c). The really low impact foodstuffs with comparatively small water footprints, less than 6 000 liters, were exotic fruits, citric fruits and potatoes (Figure 12c).

4.5 Impact per Calorie

The nutritional content in calories for the analyzed food, as well as amount of foodstuffs consumed and the nutritional proportion supplied by the top 15 foodstuffs are shown in table 2.

Table 3. The calorific values of the 15 most commonly consumed foodstuffs in Sweden 2007, A) amount foodstuffs consumed (kg); B) calories per kg/liter; C) calories consumed per day A x B; D) how much is C of the daily recommended intake.

Product	Calories per 100g foodstuff	A) Calories per kg foodstuff	B) Amount foodstuffs consumed 2007 (kgs/person /year)	Calories consumed/Year (AxB)	Calories consumed/ day/person	Percentage of Recommended Daily Intake (RDI) Men	Percentage of Recommended Daily Intake (RDI) Women
Bread	247,5	2475	15,6	38610	106	4	5
Potatoes	83	830	15,2	12616	35	1	2
Exotic fruit	52	520	17,7	9204	25	1	1
Citric fruits	49	490	50,3	24647	68	3	3
Processed meat	252,5	2525	16,4	41410	113	5	6
Frozen processed meat	215	2150	15,1	32465	89	4	4
Apples & pears	55	550	23,6	12980	36	1	2
Chocolate	547	5470	44,9	245603	673	27	34
Pork	394	3940	21,8	85892	235	9	12
Poultry	115	1150	16	18400	50	2	3
Milk	49	490	22,6	11074	30	1	2
Soft drinks	21	210	18,4	3864	11	0	1
Beer	39	390	96,6	37674	103	4	5
Fruit juice	106,5	1065	53,6	57084	156	6	8
Wine	70	700	87,7	61390	168	7	8

The top 15 most consumed foodstuffs by weight in kilograms or liters added up to supply 78% of the recommended daily intake of calories based on an average of 2000 kcal. The highest supply was provided by bread and chocolate in Sweden 2007, at 17% and 12% (Table 2). Considering that there are another 103 foodstuffs that also were consumed during 2007, many with much higher calorie content, it seemed possible that the calorie intake exceeded the RDI in Sweden. According to FAO food balance statistics the calorific intake for 2007 was 3096 kcal per day per capita (FAO, 2014).

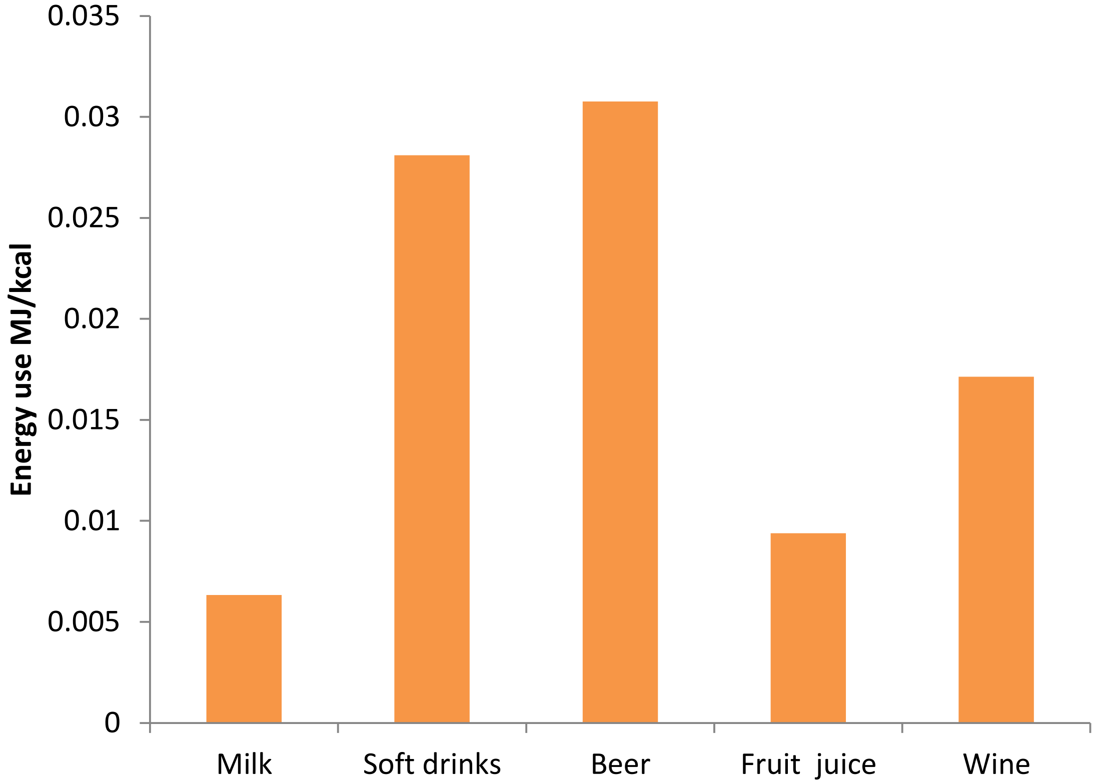


Figure 13. Energy used for production (kJ) per calorie of the 5 most consumed beverages by weight in liters consumed in Sweden 2007.

In terms of the energy efficiency for beverages per calories, energy inputs ranged from 6 to 31 kJ per calorie, where beer had the highest energy use and milk had the lowest energy use per calorie (Figure 13). Considering that one bottle or can of beer may contain 0.5kg of liquid, it is easily recognized that drinks can significantly contribute to the total energy footprints of a diet. The energy footprint per calorie of beer, soft drinks and wine can be large, at 31, 28 and 17 kJ per calorie. The amount of beer consumed in Sweden is just slightly higher than the consumption of bread (Table 2) at 50 kg. The high consumption of beer, soft drinks and wine is therefore not only an environmental concern, but also contributes to damaging the health. Interestingly in comparison to energy footprint per liter, beer has the largest energy footprint both per liter and per calorie. Furthermore a similar pattern was distinguishable for wine and milk for the comparison of energy footprint per liter and per calorie (Figure 7a and Figure 13). However the pattern differed markedly for the energy footprint per kg and per kcal of fruit juice and soft drinks, especially considering that energy footprint per kg was expressed in MJ, while energy footprint per calorie was expressed in kJ (Figure 7a and Figure 13).

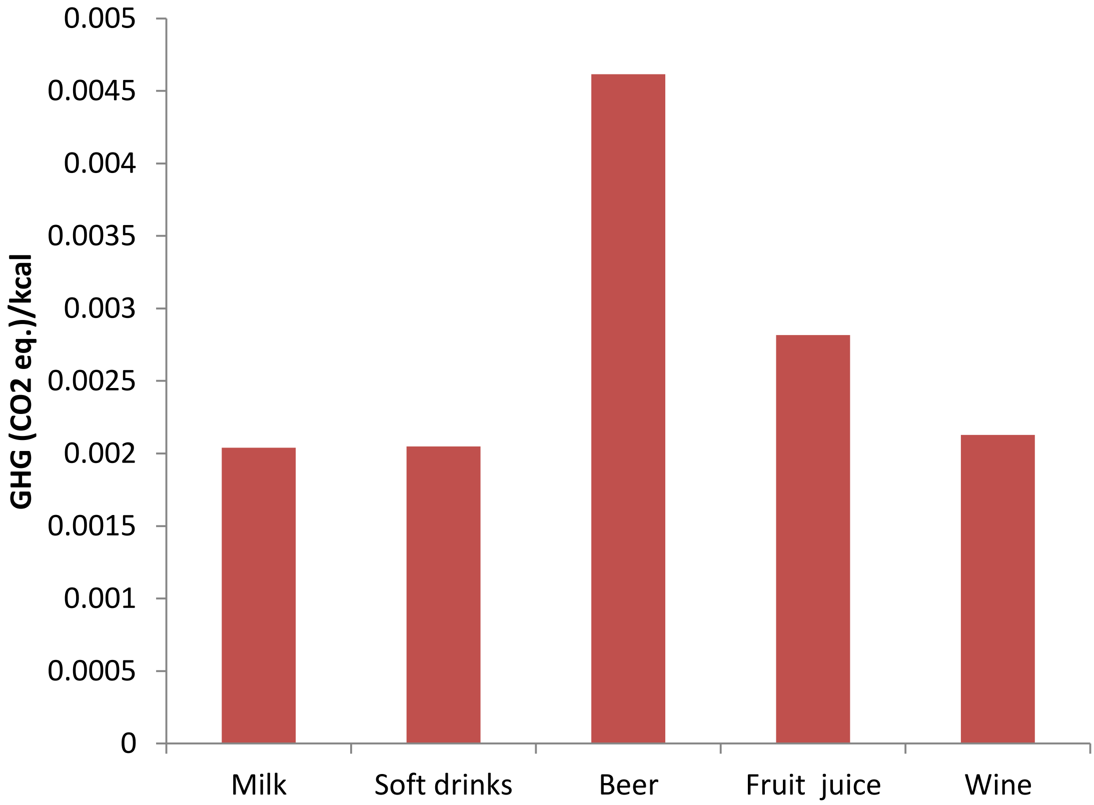


Figure 14. Greenhouse gas emissions (kilogram CO2 equivalent) per calorie of the 5 most consumed beverages by weight in liters, in Sweden 2007.

The GHG emissions footprint per calorie for beverages consumed in Sweden 2007 ranged from 4.6 to 2 g CO2e. Beer has the largest GHG footprint per calorie, whereas milk, soft drinks and wine was about the same and fruit juice slightly higher, but overall showed similar pattern (Figure 14). Yet again beer was of both environmental and health concern. However a comparison between GHG footprint per kg and per calorie revealed different trends when ranking beverages based on largest GHG footprint (Figure 7b and Figure 14).

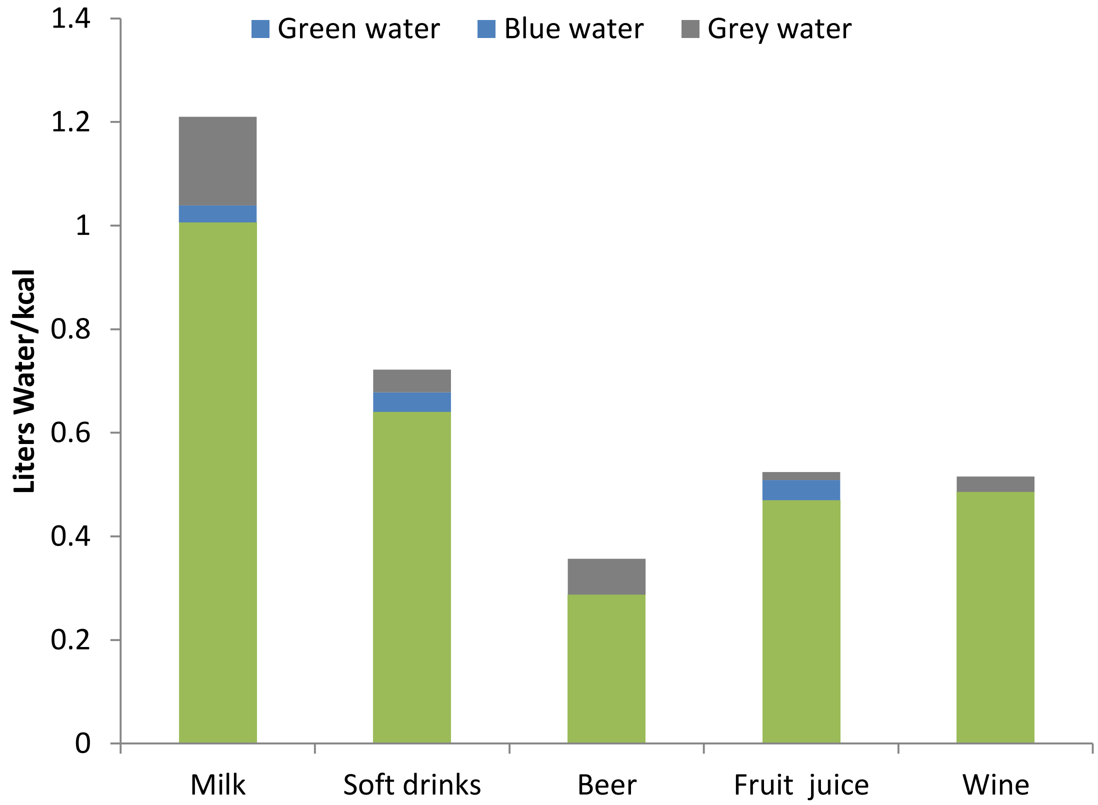


Figure 15. Water footprint per calories of the 5 most widely consumed beverages in Sweden 2007, shown in stacked bars made up of green, blue and grey water as modeled by Mekonnen and Heokstra, 2010.

The total water footprint of beverages ranged from 1.2 to 0.356 liters per calorie, where milk had the largest footprint and beer the smallest footprint (Figure 15). The comparison between trend patterns of water footprint per kg or per calorie differs markedly, with little overlaps (Figure 8 and Figure 15). Beer had the smallest footprint per calorie, but one of the largest water footprints per liter. Furthermore milk displayed the largest water footprint per calorie, but had the smallest water footprint per liter (Figure 8 and Figure 15).

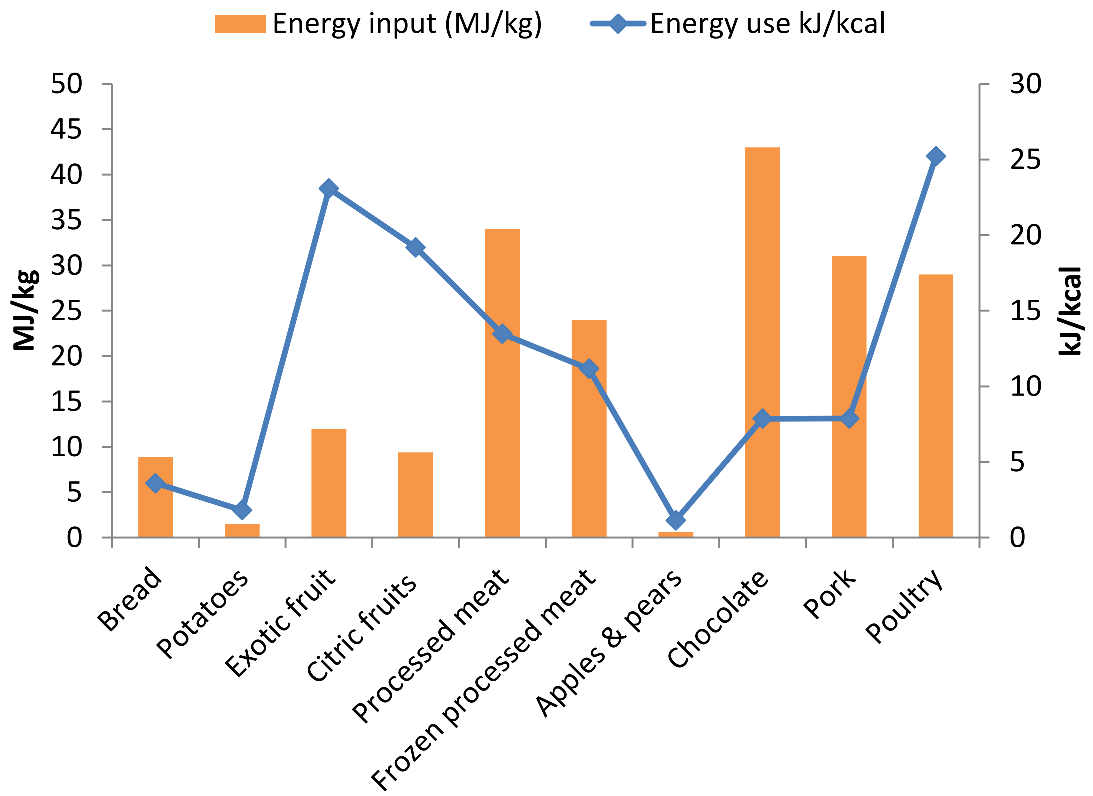


Figure 16. Energy input for production per calories of the 10 most consumed foodstuffs by weight in Sweden 2007 (MJ/kcal).

The energy input footprint in relation to nutritional value ranged from 1 to 15 kJ per calorie (Figure 16). Within the category of food products there were substantial differences between products, where poultry had the largest energy footprint, closely followed by exotic fruits. At the other end of the scale potatoes, apples and pears had the smallest energy footprint per calorie. There were important comparative differences between energy footprint per kg and per calorie. These differences were particularly evident for the exotic and citric fruits, chocolate and pork (Figure 16). While the energy footprint per calorie was comparatively larger for exotic and citric fruit, the energy footprint per kg was comparatively smaller for the same food products (Figure 16). This can be contrasted with the energy footprint per calorie for chocolate and pork that were comparatively smaller, meanwhile for the same food products the energy footprints per kg were comparatively larger (Figure 16).

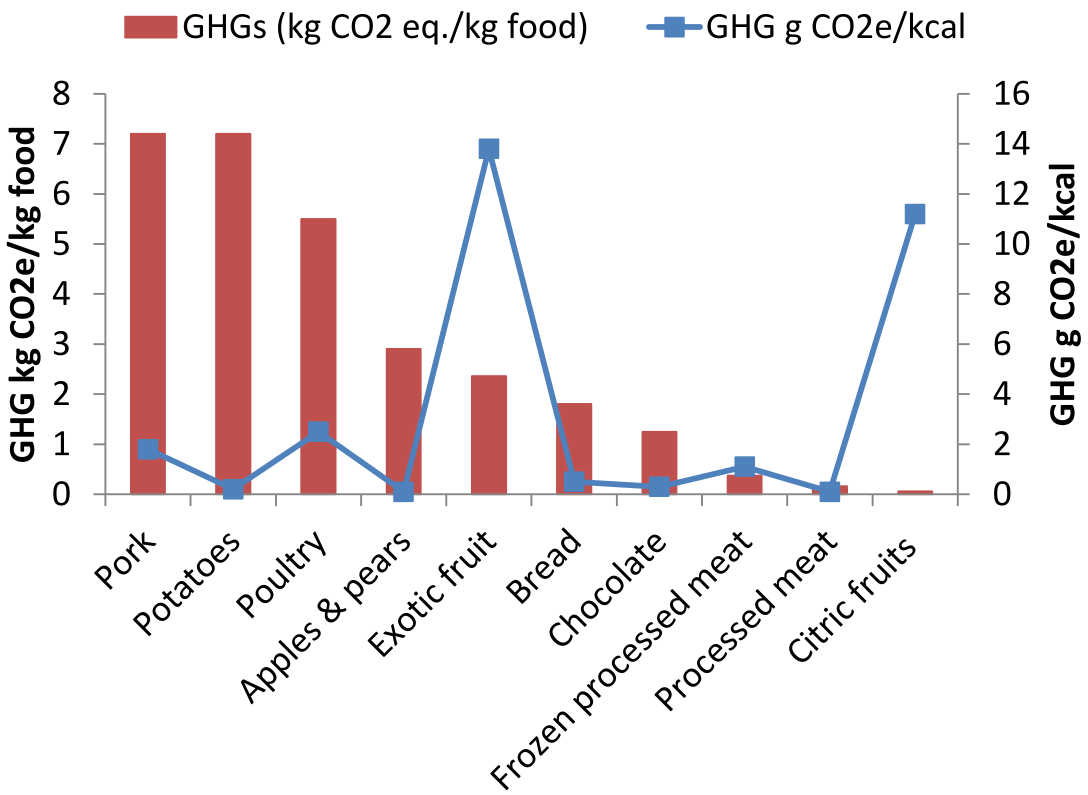


Figure 17. Greenhouse gas emissions per calories of the 10 most consumed foodstuffs by weight in Sweden 2007, displayed in kilograms CO2 equivalent per kcal.

In general, most of the food products had energy footprints between 0 to 2.5 g CO2e per calorie, except for citric and exotic fruits 11.2 and 13.8 g CO_2e per calorie respectively (Figure 17). A somewhat different pattern than described previously (Figure 9b) appeared when comparing energy footprint per calorie instead of the energy footprint per kg. Pork, potatoes and poultry emerged as more energy efficient choices with energy footprints ranging between 0.2 to 2.5 g CO_2e per calorie, compared to 5.5 to 7.2 kg CO2e per kg. In contrast citric and exotic fruits appeared as the least energy efficient alternatives when compared to the other food products energy footprint per calorie, while pork and potatos presented as the least energy efficient when compared to the other food products footprint per kg (Figure 17).

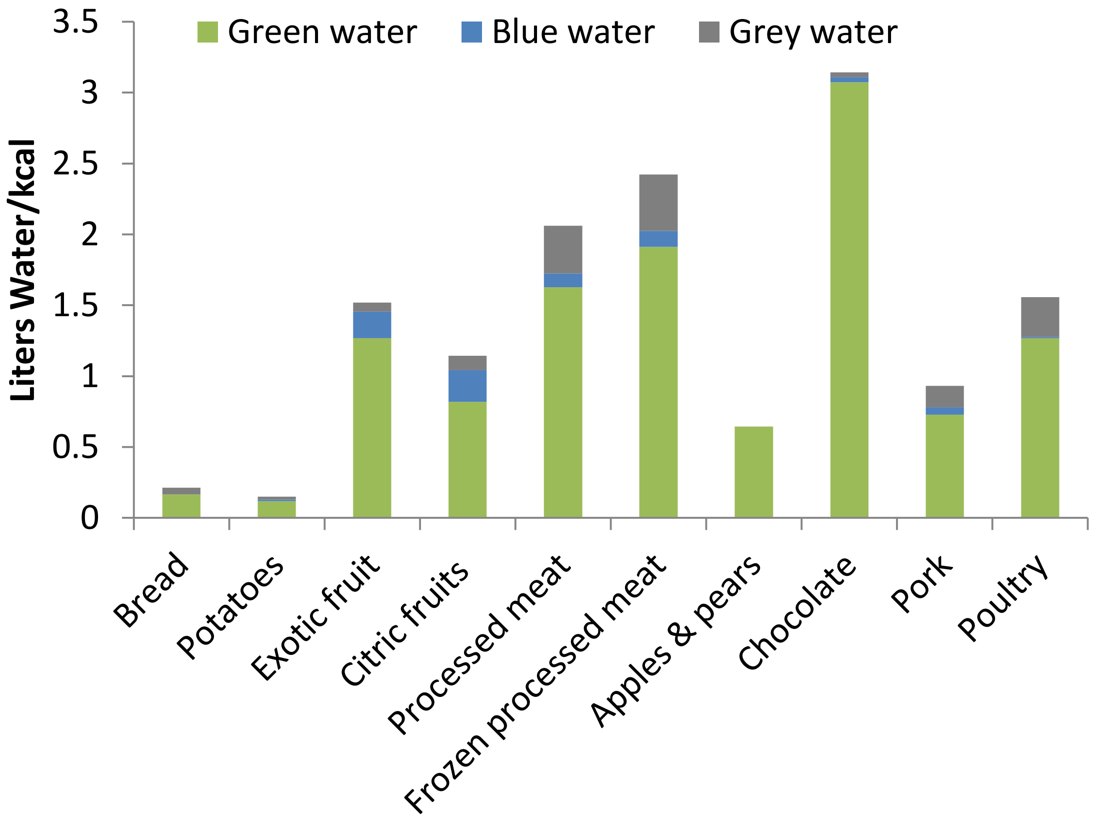


Figure 18. Water footprint per calories of the 10 most consumed foodstuffs by weight in kg, in Sweden 2007. Data shown in stacked bars made up of green, blue and grey water as modeled by Mekonnen and Hoekstra, 2010.

The total water footprint ranged from 0.15 to 3.14 liter per calorie, while potatos had the smallest water footprint and chocolate had the largest water footprint (Figure 18). In general all the food products had a much smaller water footprint per calorie compared to the water footprint per kg, with a 1000-fold difference (Figure 10 and Figure 18). Furthermore the all the food products had a high green water footprint ratio, and chocolate had the highest ratio. Different patterns were distinguishable when comparing the water impact per kg with impact per calorie. Thus chocolate emerged as the worst choice as water footprint per calorie, but was one of the best alternatives when analyzed as water footprint per kg (Figure 10 and Figure 18). However, a fair similarity of the patterns of frozen processed food was noticeable both when analyzed as water footprint per kg and per calorie.

5 Discussion

The comparison of the different analyses here showed that different foodstuffs had varying severity in the different environmental categories. In the overall comparison the drink items that had the highest impact was fruit juice, wine and beer, and for food it was chocolate and pork, and to a lesser extent even citric & exotic fruit, processed meat and poultry. For the other three forms of analysis: separated categories, annual impact and impact per calorie, there were drink and food items that consistently had the highest impact. These were beer, orange juice and milk among the drinks, and for food it was chocolate, processed meat, pork, poultry and exotic fruit.

The environmental impact of these foodstuffs are highly dependent on were in the world they have been produced and processed, and thus the damage may not occur in the same country as they were consumed. Certain food and drink items are mostly produced and processed in Sweden, such as, bread, beer, meat, milk, in-season fruit and vegetables, e.g. apples, pears and potatos. Meanwhile other food and drink items cannot be produced in Sweden, such as chocolate, exotic and citric fruit. There is a great variety of foodstuffs that are globally sourced, meaning that it is possible for consumers to purchase food and drink from all corners of the world despite that the same products are produced in Sweden. This means that a lot of the environmental impacts occur in other countries outside of Sweden as a result of food consumption in Sweden. This environmental impact is sometimes much more detrimental in other countries as the effects of climate change, water scarcity, pollution and resource shortages are more acutely felt. Thus the water footprint of foodstuffs analyzed here may not seem to be a problem for Swedish consumers as Sweden is not a country that suffers from water scarcity. However globally environmental impact of food production and consumption poses serious problems.

5.1 Underlying reasons for food items with high environmental impact

In the global economy, goods such as food produce are increasingly produced and traded worldwide, and many foodstuffs have a long production chain, that may be take place in different locations worldwide and is transported between the many steps. This is one of the reasons behind the variability in environmental impact trends of comparing the different environmental categories caused by the same foodstuffs. Foodstuffs consumed in Sweden have different countries of origin, which may have undergone production practices unlike those for domestically produced goods according to national and European policies.

5.1.1 Drinks high in greenhouse gas emissions

Going into the detail of the production of the foodstuffs that stand out as having a significant environmental impact here, allows for a better understanding of how different dietary alternatives can contribute to climate change mitigation.

5.1.1.1 Beer

The production of beer is made up of many steps, where greenhouse gases emitted at every step (Garnett 2007). The main important ingredients that are needed to make beer are barley, hops and yeast. A life cycle analysis of beer reveals that greenhouse gases mainly are emitted at the agricultural stage, primarily for fossil fuels use and fertilizer applications (Garnett 2007). The authors calculated that as much as 39% of total greenhouse gas emissions were caused in the agricultural crop production stage (Talve 2001). If the barley is grown in Sweden it can be assumed that the transport to malting is negligible, however on a global scale transport at the malting stage has a significant contribution to greenhouse gas emissions (Berners-Lee 2010). The greenhouse gas emissions at brewing stage makes up 24% of the total greenhouse gas footprint (Talve 2001). Production of beer cans make up 13% of the total GHG footprint, and as much as 15% of GHG emissions results from bottle production (Garnett 2007).

5.1.1.2 Wine

Very little wine is produced in Sweden, and mostly imported from countries in Europe, Africa, North and South America, New Zealand and Australia. Thus there is a great variability in production practices and associated impacts. Agricultural production of grapes result in a fairly low greenhouse gas impact, the fertilizer rates are comparatively lower than traditional food crops (Garnett 2007). However, due to wine production taking place in Europe, Africa, America and the New World the differences between climate, soil types and viticultural practices varies widely, and is reflected in the variability of greenhouse gas impacts (Garnett 2007). Environmental impacts also vary depending on the quality of the wine. Emissions are fairly evenly distributed over the growth process and production phase of wine, but it also has to be taken into consideration the impact of production and transport of bottles. According to a study in the UK the GHG footprint is divided up by the different production steps as follows: growing 14%, wine making 13%, bottle production 26%, packaging 2% and transport 45% (Garnett 2007). The transport stage has a large contribution to the total GHG footprint as I chose to use the case of wine imported for longer distances. However the GHG impact will decrease if the wine is imported from a European country, with as much as 39% (Aranda, Zabalza and Scarpellini 2005). Overall it can be estimated that the bottle has the same greenhouse gas footprint as the impact of the wine content inside. To reduce this it could be suggested that buying wine boxes or cartons is a simple way of reducing the energy and GHG footprint of transporting heavy and bulky bottles worldwide. It would also reduce the impact if wine was bought un-bottled and then packaged in the same country where it is sold. Overall it does not differ much in environmental impact based on which continent the wine originates from, so switching from Australian wines to French wines will not reduce impact caused by transport. However the mileage transportation by road has a significant impact both in the country of origin and in the country of consumption. Thus if possible environmental impact can be reduced by 25% by only consuming locally produced wine, or low road transport wine. For Swedish consumers this will be difficult as not much wine is made domestically due to climate, however there vineyards that produces wine in Southern Sweden that could be an alternative to reduce environmental impact. Thus it would be necessary to take into consideration road transportation, country of origin and packaging, which is rarely included in the labelling. Wine has a smaller greenhouse gas footprint compared to beer only because it is less dilute (Berners-Lee 2010).

5.1.1.3 Orange Juice

Fruit juice, such as orange juice is a popular drink with meals in Sweden, whereas consumption of vegetable juice is not as high. Thus for the purposes in this thesis I will focus on fruit juice, such as orange juice, as consumption in the Swedish diet was high and commonly life cycle analysis are carried out for orange juice. Orange juice is markedly inefficient in its production as it takes approximately 6 times the amount of fruit to make 1 liter of juice. The rest of the fruit peel and pulp is not used for juice production, and in worst case completely discarded as waste. There are greenhouse gas emissions along the whole production chain of orange juice, such as irrigation and fossil fuel use during cultivation; processing, including pasteurization and possibly turning into concentrate; transport from farm to processing plants to packaging factories to distributors tend to be significant and in different countries worldwide. Fresh orange juice requires refrigeration. The most critical stages that have serious environmental impact for orange juice production is during cultivation and the packaging process, which can explain its greenhouse gas impact. A life cycle impact assessment of orange juice production in Spain revealed that 50% of the total GHG footprint is due to the electricity used for irrigation, which is from combustion of coal and natural gas (Beccali et al. 2010). A further 25% of the GHG footprint is due to production of fertilizer, from the production of nitric acid used to make fertilizer (Beccali et al. 2010). An additional 10% of the GHG footprint is due to energy use and chemical production for pesticides, and another 10% is due to diesel use including machineries during orange juice production (Beccali et al. 2010). However this study does not include the impact of the transport for distribution to the country of consumption. Depending on the type of orange juice, packaging and country of origin, the impact may worsen. According to Landquist et al. (2013) orange juice made from frozen concentrate imported from Brazil has a much greater environmental impact than that of pasteurized orange concentrate imported from Spain. Furthermore environmental impact varies with different types of packaging, e.g. PET- bottles requires a lot of fossil fuel to produce, whereas the greenhouse gas footprint are lower for cartons and even less for Tetrapak. In Sweden the fruit juice distributors, e.g. such as Arla dairy, producers of popular brand Bravo, will pasteurize and package orange juice made from concentrate using on-site Tetrapak packaging technology, at the distribution site.

5.1.2 Drinks high in energy use

5.1.2.1 Beer

Energy is needed during all the stages of beer production, and as energy and GHG emissions are often closely linked in that if a production step requires a lot of energy then there will usually also be a lot of greenhouse gas emissions as a result. This is mainly due to fossil fuel use for energy production and operating machinery. Subsequently the energy requirements for beer production is the highest for the agricultural stage that requires pesticides and herbicides, followed by the brewing step where intensive processes, such as mashing, boiling, fermentation and filtration requires high energy use (Garnett 2007). Added to this is then the packaging process, which includes the energy and greenhouse gas emissions from producing the raw material, for aluminum cans and glass bottles (Talve 2001).

5.1.2.2 Wine

Similarly to greenhouse gas emission for wine production the energy use during cultivation of grapes is comparatively low as the fertilization application is lower than what other crops require (Garnett, 2007). Energy use varies substantially depending on the country of production as different energy-mixes provide the energy supply (Garnett 2007). The energy use follows the same pattern as the greenhouse gas emission along the chain of production of wine. Thus the energy use for transport is the highest, if the wine is imported for long distance, e.g. Australia (Garnett 2007). If the transport distance is shorter, as from a European country, then the bottle production stage is the most energy use intensive step in the chain of production (Garnett 2007). This can then be reduced by buying wine packaged in cartons.

5.1.3 Drinks high in water use

5.1.3.1 Milk

Milk was the beverage with the largest total water footprint per liter in Sweden, and the green water footprint was the main contributor. There are several factors that explain this, but it has to be noted that these vary greatly depending on the country of origin and its agricultural system (Mekonnen and Hoekstra 2010b). As much as 98% of the water footprint of milk is due to the water use to produce fodder for dairy cows (Mekonnen and Hoekstra 2010b). Depending on the type of fodder the cows consume and the type of production system the size of the water footprint varies. in Sweden the dairy production system is mainly divided into conventional farms (high and low yielding) and organic farms, the fodder is grown on the farms as much as possible and complemented with purchased fodder, and the resource allocation is 90% to milk and 10% to meat (Swedish dairy cattle is commonly slaughtered for human consumption at the end of their milk-producing lifetime (Cederberg and Flysjö 2004; Cederberg, Flysjö and Ericson 2007).

5.1.3.2 Orange juice

Orange juice was the beverage with the second largest water footprint, and the largest share of this was made up of green water, which was the global trend for crop production (Mekonnen and Hoekstra 2011). According to a lifecycle analysis of citrus-based products produced in Italy, such as natural juice and concentrated juice, 99.5% of the water footprint was for irrigation during the cultivation stage of the crops. Very small share of the water footprint was made up of water used during selection of fruits and washing (0.23%); concentration and cooling (0.17%); thus the smallest share of water used was for pasteurization and cooling (0.05%) (Beccali et al. 2010). Wine had the third largest water footprint, and similarly to citrus fruit juice production the green water use was the main contributor to this. In a lifecycle analysis of wine in Romania the authors found that 99.7% of the water consumption was used during the growth stage of the grapes (Comandaru et al. 2012). The remaining 0.03% of water consumption took place during the vinification process (Comandaru et al. 2012). It should be noted that the authors included reporting the water used for the initial 3 year period it took to establish the vineyard, when no wine can be produced. For the purpose of this investigation I did not include this into the calculations, but if I had considered this the establishing phase would have contributed with the largest share of the water footprint and probably significantly increased compared to the other beverages.

5.1.4 Foods high in greenhouse gas emissions

5.1.4.1. Chocolate

Chocolate was the food product that stood out with the highest energy impact per kilogram of chocolate at 43 MJ. According to a life cycle assessment of cocoa production and processing in Ghana this was due to energy input during the processing stage for running boilers and roasters on diesel, which accounted for more than 80% of energy input over the whole production cycle (Ntiamoah and Afrane 2008). The cultivation stage was responsible for 16% of the energy use, and transport for a further 2%, which is mainly due to usage of fossil fuel run machinery (Ntiamoah and Afrane 2008). However, the analysis assessed cocoa production in Ghana and therefore only included transport within this country, i.e. approximately 250 kilometers. Most chocolate is processed in Europe and this involves much greater distances of transportation of cocoa, and hence it can be assumed the energy and greenhouse gas emissions footprint was much larger for transportation stage than reported by Ntiamoah and Afrane (2008).

The life cycle assessment in Ghana only focus on environmental impact of cocoa production, and as a general rule chocolate is made up 30-50% cocoa, approximately 50% sugar and 20-25% milk. Therefore it was necessary to take into account the environmental damage caused by sugar and milk. The life cycle analysis of milk focusing on water footprint was investigated in the previous section, but it has to be noted that milk production also has an energy and greenhouse gas emission footprint due to fodder production and livestock rearing. Hence milk contributed substantially to the environmental impact of chocolate according to study done on Swiss chocolate (Steiger, 2010). As a general estimation of the environmental impact of crop production it was reported that about 80% of the energy, greenhouse gas emissions and water footprint is due to primary production in agriculture (Angervall et al. 2008). The environmental impact during primary production of crops is due to resources use in the production and use of fertilizers and pesticides, fuel requirements for machinery, water input and water emissions (Angervall et al. 2008).

5.1.4.2 Animal-based food products

The energy consumption for the other food products show a clear pattern where animal-based products showed much higher energy footprint compared to plant-based products (Figure 7a). This pattern is mainly due to energy input required during primary production of crops for animal fodder, where the environmental load can be as much as 90-95% as a result of fodder production (Angervall et al. 2008). Furthermore the high energy footprint of livestock has most likely to do with the structure of meat production, more specifically feed conversion (Carlsson-Kanyama and González 2009). Livestock has a lower efficiency to convert feed energy into edible energy, such as protein and fat, when compared to plant-based energy content (Angervall et al. 2008). Similarly life cycle analysis studies carried out on pork production in Europe indicated that energy input was the highest (Ranging from 85-92%) during fodder production, than housing and slaughtering (Nguyen, Hermansen and Mogensen 2012; Reckmann, Traulsen and Krieter 2013). For poultry the energy input for feed production was not as high as for pork, but showed the same pattern with 25% of energy input was due to fodder production, 20% for refrigeration and 16% for housing (Katajajuuri, Grönroos and Usva 2014).

5.1.5 Foods high in energy use

5.1.5.1 Pork and Poultry

Interestingly figure 7b showed that pork, exotic fruit and citric fruit had the highest greenhouse gas emission footprint of the food products. In the literature the consensus was that animal-based products had a higher greenhouse gas emissions footprint compared to plant-based products (Angervall et al. 2008)., 2014; González, Frostell and Carlsson-Kanyama 2011). Life cycle analysis of the greenhouse gas emissions from meat production in Sweden revealed that most emissions was due to fodder production for pork at 50%, followed by manure management at 32% and manure application at 8% (Cederberg et al. 2009). Similarly, a life cycle assessment for broiler chicken in Finland revealed that the fodder production was responsible for 36% of the total greenhouse gas emissions and broiler housing for 29% (Katajajuuri, Grönroos and Usva 2014).

5.1.5.2 Exotic and citric fruit

Perhaps surprisingly was the large greenhouse gas emissions footprint for exotic fruit and citric fruit, which had impact in the range of meat production in Sweden. Basically the life cycle analysis of exotic fruit, such as pineapples, bananas, mangos and avocados, produced in Costa Rica in South America, revealed similar environmental load during the production stage as other crops (Ingwersen 2012). More than half of the greenhouse gas emissions footprint (60%) is due to the cultivation stage at the farm, where N2O emissions from application of nitrogen fertilizers were responsible for more than 40% of total emissions at the farm (Ingwersen 2012). Approximately 41% of the farm stage emissions were due to production of fertilizers, pesticides and fuels requirements for farm machinery. A further 18% was due to the actual fuel used on the farm for machinery (Ingwersen 2012). Packaging of pineapples was responsible for 24% of the total greenhouse gas emission footprint, 15% was due to distribution and a further 5% was due to refrigeration storage (Ingwersen 2012). However it has to be noted that distribution in this case study was from Costa Rica to the US the greenhouse gas emissions footprint would be substantially larger for transport to Europe. Commonly fruit from South America is shipped to Europe; however some supermarkets will use air-freight to get fruits in the shops quickly at the start of the season, which will dramatically increase the greenhouse gas emissions footprint of exotic fruits (Carlsson-Kanyama, Ekström and Shanahan 2003). Similar transportation modes may occur for citric fruits exported from e.g. Brazil, who export large quantities of oranges to Europe (Beccali et al. 2009).

5.1.6 Foods high in water use

5.1.6.1 Chocolate

The water footprint of chocolate was substantially larger than the other food products investigated here showed in figure 8. The cause for this was not obviously clear from the literature, however the indication was that there could be a few reasons for this pattern. The general water footprint pattern for crops was reported by Mekonnen and Hoekstra (2011), and thus crops with low yield or small fraction crop biomass harvested tend to have larger water footprints. Furthermore the authors reported this to be known for commodity crops such as coffee, tea, cocoa, spices etc. (Mekonnen and Hoekstra 2011). In the report the total water footprint for cocoa beans was very large at 19 928 m3/ton, where the share of green water footprint of this was 99% (Mekonnen and Hoekstra 2011).

5.1.6.2 Meat products

Similarly to the water footprint of milk, the meat-based products in Figure 8 all showed that the share of green water was the most significant contribution of 98% to the total water footprint, which is caused by the fodder they were fed on (Mekonnen and Hoekstra 2010b). The differences seen between the different meat-products depend on the animals different feed conversion efficiencies and feed composition (Mekonnen and Hoekstra 2010b). Animals that required more feed per kilogram of meat and consumed a higher proportion of concentrate feed had a larger water footprint (Mekonnen and Hoekstra 2010b).

5.2. Implications for consumers of switching to lower impact foodstuff alternatives in relation to impact per calorie

5.2.1 Drinks

As shown, the drinks that were most consumed differed widely in their environmental impact per kilogram. In order to lessen the impact consumers can opt to switch their high impact food products for alternatives with lower impact, while satisfying their daily recommended calorie intake. Comparing the environmental impact per kilogram with impact per calorie for the top most consumed drinks showed a fairly similar trend (Figures 5a-b, 11 and 12). The product that stands out as a bad environmental choice was beer for both energy and greenhouse gas emissions per kilogram and calorie, making it easier to identifying the product most suitable for switching. However it may be more difficult identifying the most suitable drink with lower environmental impact per kilogram and calorie as the pattern is a little divergent. Clearly milk is a good low impact alternative to switch to in both energy and greenhouse gas emissions per kilogram and calorie, but not for water (Figures 6 and 13). It may seem that soft drinks provides consumers with a suitable lower impact drink alternative, but as it is high in calories and has a high energy impact per calorie, this alternative can have implications for the consumer when considering sugar content and environmental impact per calorie for energy and water use. Although not included in the present analysis above, a previous food and life cycle analysis in Sweden showed that tap water was most likely the best low impact drink that consumers can switch to (Carlsson-Kanyama, Ekström and Shanahan 2003).

5.2.2 Food

The consumption of chocolate, pork and processed meat has the severest annual environmental impact across the impact categories analyzed (Figure 10a-c). Putting aside the consumption of chocolate, as this is not considered a staple food product important for satisfying the daily recommended calorie intake. Then this left consumption of pork and processed meat as the highest environmental impact across the categories. For ease of continuing the discussion from now on the term meat in this thesis will include all meat products with pork and poultry, such as fresh and frozen, processed, deli and ready meals.

5.2.2.1 Alternatives to certain meats

One option for consumers to reduce environmental impact is to switch from more to less damaging forms of meat. In total the meat consumption added up to 54.4 kg in 2007, and pork consistently had a more severe impact across all environmental categories than poultry (Figures 10a-c). Of this total meat consumption, poultry added up to 15.1 kg, which left 49.3 kg for pork and processed meat. For example in a bid to reduce the environmental impact of meat consumption in Sweden consumers could replace pork and processed meat products with poultry. Considering a comparison of environmental impact of 54.4 kg mixed meat and 54.4 kg poultry meat only was calculated and results are shown in the table below. The impact in energy and greenhouse gas emissions did not differ substantially by replacing 49.3 kg of meat with poultry. However the difference in water footprint is dramatically reduced by eating 54.4 kg of poultry only compared to eating mixed types of meat. The total annual footprint is more than 8 times greater when consuming pork, processed meat and poultry compared to eating poultry only.

Furthermore the environmental impact per calorie for poultry was the highest of all the meat-based food items (Figure 14) at 25 kJ/calorie, compared to pork at 8, processed meat at 13 and frozen processed meat at 11 kJ/calorie. This pattern was also true for greenhouse gas emissions and water footprint (Figures 15 and 16). Therefore from the aspect of impact per calorie, replacing pork and processed meat with poultry can prove to be more detrimental to the environment.

5.2.2.2 Reduce meat consumption

To provide consumers with a viable dietary choice that takes into consideration both environment and health the latest dietary recommendations in Sweden had to be recognized. The latest report from the National Food Agency recommends a maximum of 500 g of meat/week/person, which includes all types of meat such as beef, pork, lamb, poultry and processed meat products, fresh or frozen (Darnerud 2014). In total this would up to a total meat consumption of 26 kg/person/year, but the latest statistical data from the Agricultural department in Sweden recorded an annual consumption of 80.5 kg in 2012, nearly four times higher than the recommended level. This revealed that Swedish consumers can from a health and environmental aspect afford to significantly reduce their meat consumption.

5.2.2.3 Replacement of meat with other foodstuffs

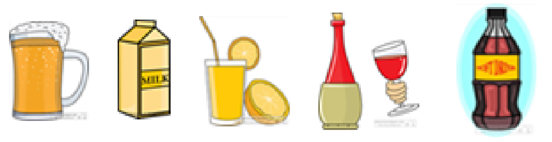
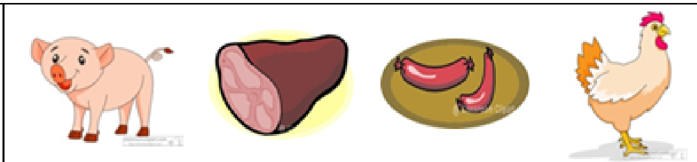
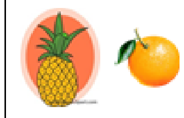
The National Food Agency recommend to consumers to eat fish 2-3 a week, eat more beans, pulses, vegetables and roots instead of meat. Although the environmental impact for these food items were not analyzed and is beyond the scope of the present study to discuss in detail, it is important to recognize the potential for consumers to satisfy their energy requirements and lower the environmental impact of their food consumption. Previous studies in Sweden have shown that the energy and greenhouse gas emissions impact can be substantially lowered by replacing meat with fish, beans, vegetables and/or pulses (Carlsson-Kanyama 1998; Carlsson-Kanyama, Ekström and Shanahan 2003; Carlsson-Kanyama and González 2009). However it was important to note that different types of food items within same categories can vary dramatically in their environmental impact. Comparing the life cycle impact of fishing for different types of domestic fish caught and consumed in Sweden, the greenhouse gas emissions footprint was more than 5 times larger for cod than herring (Carlsson-Kanyama and González 2009). Furthermore it is important to consider the state of the fishing stocks and the environmental impact of different fishing practices.

Similarly this difference in environmental impact between types of food items was observed in the present study in the case of fruit. This was particularly evident when examining environmental impact per calorie, where exotic fruit was as detrimental to the environment as certain meats, and sometimes even more damaging than meat (Figures 14 and 15). Exotic and citric fruit had a dramatically larger environmental impact, than domestically produced apples and pears, due to being air-freighted rather than shipped (Carlsson-Kanyama and González 2009). Hence it is important that consumers can easily access information on the differences in environmental impact of food items that have been proposed to replace meat-based items.

5.3 Shortlist and Recommendations

Table 4 is a guide to prioritizing potential actions for consumers to reduce the environmental impact of their food choices. Although the savings are only approximate calculations, these can help individual consumers differentiate between higher and lower mitigation potentials. Readers can deduce the action with the top priority and decide which is possible and suitable for them to take. The reasoning behind the short list was that consumers that are motivated to reduce their food impact can easily find which action is the most beneficial. The main objective with the list is that consumers with busy and demanding lives, open to making more sustainable choices, but finding the myriad of eco-labels and environmental advice on food confusing, are encouraged to at least adopt a one action and can chose the most effective.

Table 4. The Short List: Percentage of energy use, greenhouse gas emissions and water footprint that can potentially be saved, indicated by individual actions adopted to change food consumption pattern. The food products are sorted from left to right in descending order of the environmental priority.

Food items							
Action		Replace half of yearly consumption of beer, milk, orange juice and wine with soft drinks	Replace 50-100% of all drinks with tap water	Replace the 49.3 kg consumption of pork, fresh and frozen processed meat with poultry	Reduce meat consumption to 26 kg per year (6.5 kg of each - pork processed and poultry)	Reduce chocolate consumption from 15.6 kg with 50% to 7.8 kg per year= 150 g per week	Replace with domestically produced apples and pears
Savings	**Energy**	15%	49.97-99.94%	17%	69%	50%	92%
	GHG	63%	49.995-99.99%	27%	58%	50%	98.7%
	Water	Green water 55% Blue water 30% Grey water 77%	47.5-98.95%	Green water 80% Blue water 94% Grey water 96%	Green water 60% Blue water 61% Grey water 60%	50%	Green water 9% Blue water 100% Grey water 100%

However it should be emphasized that the savings potential may be greater or less than indicated, due to not taking into consideration different diet compositions. For example some consumers eat more or less meat than the average Swedish individual, and thus potential savings increase or decrease accordingly. The maximum total sum of potential savings estimates for the actions above – 3265 MJ, 450 kg CO_{2e} and 255 242 liters of water – is an overestimation due to several reasons. Mainly as it will not apply to all individual consumers, and for different reasons the consumers will not be able to adopt all actions simultaneously. Thus this opens the scope for developing this shortlist further into a more interactive guide that could allow individuals to tailor the actions to their diet composition.

An important restriction of the recommendations in the short list that is important to highlight for consumers, namely it only takes into account the environmental impacts. Thus before consumers actually adopt the recommendations it is vital that they also considers nutrition. As a consequence it would not be advisable from a health perspective to replace milk with soda, as the sugar-content is significantly higher and poses a serious health threat when consumed in large quantities.

Using the life cycle analyses to examine which foodstuffs were detrimental to the environment and why highlighted some issues. All the LCA analyses discussed in this thesis had different system boundaries, where some studies did not include transport, or only parts of the transport along the production chain, or did not include the establishment phase of crops or storage at the retailers. Thus it produced skewed results, as products that were shown to have high environmental impact in one study, was shown to have low impact in conflicting results in another study. These limitations are very difficult for consumers to be aware of when making food purchases as it is not possible to see the details of the entire value chain of a certain product in store. However the LCA studies did reveal that the majority of the environmental damage occurred during the production phase. Although consumers may benefit from this knowledge through their purchasing power, it is difficult for them to directly influence impact during production. This indicates that while the focus on consumers individual actions are important in order to achieve sustainable food consumption, it is not sufficient on its own. Thus to become more environmentally sustainable, it indicates a need for broader changes to production and food distribution systems. However I believe that consumers that consciously change their food choices to reduce environmental impact can make a real start to steer food consumption towards sustainable development.

The use of the term food impact by combining environmental parameters, energy, GHG and water footprint has made me realize that more parameters included in the analysis, the more apparent the complexity of food consumption was. The approach in this thesis is, as far as possibly discernable, novel from other previous approaches. The results presented here support the work of Carlsson-

Kanyama, but further highlights the intricacy of analyzing environmental impact of food consumption. The main difference between the work in this thesis and previous studies was the emphasis of the complexity of global food production and consumption, and how the environmental impact of food choices in Sweden also affects people in other countries.

Adoption of the short list among consumers has real potential to substantially reduce the environmental impact from food consumption by Swedish consumers both domestically and globally, considering that 25% of the total greenhouse gas emissions for individuals were caused by their food consumption. Furthermore a total of 20% of all energy supply in Sweden was used for food production (Wåhlander n.d.), which further supports the need for conserving resources by changing consumers' dietary patterns. Hence individual action by consumers could be an important contribution to the driving force of sustainability. The work in this thesis is supported by the work by Waggoner and Ausubel (2002), which claims that if we accept current trends in population and affluence, then changes in consumption and technology provides "sustainability levers" in their framework for sustainability science, i.e. these are the two major paths to actually achieving more sustainability. The latest Greendex study by National Geographic showed in their global survey that a majority of consumers believed they lacked sufficient information and influence to actually become more sustainable consumers (Wåhlander n.d.). As such the work presented in this thesis is very much still relevant and aims at contributing to the problem-solving, rather than critical research aspect of sustainability science.

5.4 Limitations and Further Research

I took this approach in this study mainly for the reason of providing a sense of the scale of environmental damage from the consumption of food to consumers that are interested in changing their consumption pattern. The results are aimed at giving the average busy consumer a perspective on how to best reduce their environmental damage from food consumption; within the boundaries presented here. The purpose of the shortlist is to point consumers in the right direction to where get the best return for their effort.

Upon reflection I realize the limitations are numerous. Obviously the actions suggested in the shortlist are not suitable for everyone, due to other barriers. But the desire was to contribute to the bigger picture of environmental guidance for consumers. Hence the results shown above may be considered as a first attempt to ascertain how important the contributions of environmental guidance for sustainable dietary options can be.

Due to the necessity of food for our survival, recommendations for dietary changes have to aim at being both healthy and environmentally sustainable. This is in line with the recent work of food footprint studies in Sweden and the Netherlands indicated that shifting the diet from a mainly animal-based diet to plant-based diet would be beneficial from health and environmentally sustainable perspective (González, Frostell and Carlsson-Kanyama 2011; Van Dooren and Bosschaert 2013). The implications of including the health perspective in this thesis may have further accentuated the complexity of food consumption in relation to sustainability. As it is complicated and time-consuming to collect the data for each environmental parameter, thus adding health as a parameter would probably make a more significant contribution to research, but would presumably involve substantially more work before the results could be considered ready for consumer use.

Consumption and environmental impact data needs to be improved and expanded. The environmental damage data was gathered from numerous life cycle assessments carried out in various countries based on different boundaries and assumptions, and consequently have limitations. Due to these limitations the uncertainties are probably fairly large in the study presented here. The sensitivity of the current results needs to be explored further. Clearly the findings presented here indicate the need for inclusion in a larger scale investigation taking into consideration further impacts from food consumption, e.g. biodiversity, land/use change, eutrophication, acidification etc. However despite the limitations, this study is important as some of the result allows the reader to consider the environmental impact of dietary choices in 'good enough' terms, and to highlight the potential magnitude of reduced environmental damage from changing consumption patterns in Sweden. Thus the results are important for the debates regarding the potential to mitigate the environmental impact related to individual food choices.

5.5 Conclusion

I estimated the environmental damage caused by the 15 most widely consumed foodstuffs in Sweden 2007. After analyzing the data in four forms of comparisons there were 7 items that consistently showed high environmental impact. The main contributor to environmental damage was beer and meat, slightly less so chocolate, milk and exotic fruit, followed by orange juice, wine and citric fruit.

The life cycle analysis revealed that environmental impact of foodstuffs consumed in Sweden occurred at all the steps of the production chain, but primarily during the agricultural production and to a lesser during extent industrial processing. In agricultural production there were energy inputs, greenhouse gas emission and water footprints to run machinery, labor and electricity, use of fertilizers and pesticides; emissions from livestock; transport, feed cultivation, water use and pollution.

The shortlist suggested that individuals have the potential to make substantial reduction in environmental damage by changing their dietary choices. Considering that food consumption is responsible for 25% of the total greenhouse gas emissions from individuals their potential changes made to their diet is important. This opens up the scope for expanding the results presented here further through research mainly in academia. Consequently shifting the diet towards more environmentally sustainable consumption patterns in developed countries will contribute to reducing humanity's footprint, i.e. the pressure on the planets capacity to sustain us. It will be an especially important part of sustainable development as the planet's population grows and increased food supply is vital.

This work is in the problem solving aspect of sustainability science and can contribute to further research in academia by providing a starting point. By developing this study further it could facilitate the process for different actors, such as local authorities and the national food agency, to be able to focus research and development of a guide concentrating on strengthening the awareness of the importance of the individual consumption choices and clear information on how much the environmental impact is affected by changing the diet composition.

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