

Exploring Greenhouse Gas Emission Factors for UBC Produce

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EXPLORING GREENHOUSE GAS EMISSION FACTORS FOR UBC PRODUCE

LAND AND FOOD SYSTEMS 450: Land, Food, and Community III

Team 5: Scenario II Greenhouse Gas Emissions



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1. Abstract

As part of Land and Food Systems (LFS) 450 community based food system project, we carried out research to estimate the amount of GHG emissions associated with produce purchased by UBC Food Services. Through consultations with the LFS 450 teaching team, Victoria Wakefield from UBC Food Services and Lillian Zaremba from the Sustainability office, we chose potatoes, tomatoes and apples as a focus for our project. We decided to investigate the emissions produced from production, processing, packaging and transportation. We reviewed literature from interdisciplinary studies in order to obtain emission factors. We also used to these articles to calculate the estimated GHG emissions from each product. The summary velocity report provided by the teaching team was useful for indicating the amounts of potato, tomato and apple products purchased by UBC Food Services. From our literature review, we determined there are many gaps in information with reference to GHG emissions caused by growing produce in Canada. Therefore, we used emission factors from different parts of the world to establish CO₂ emissions. Emissions factors for unprocessed tomatoes, potatoes, and apples are 0.771 kgCO₂/kg, 0.044 kgCO₂/kg, and 0.080 kgCO₂/kg respectively. Fries, a processed potato product, consumed at UBC in 2011 contributed a total of 297.7 kg of CO₂ whereas the whole potatoes purchased by UBC Food Services were associated with 0.121 kg of CO₂ emission. Carbon emissions for processed tomato products purchased by UBC Food Services during 2011 are 2264 kg CO₂ emitted for tomato juice, 8346.0 kg CO₂ emitted for diced tomatoes, 7955 kg CO₂ emitted for tomato paste, and 1933 kg CO₂ emitted for ketchup. The overall aim of collecting this data is to create recommendations for the stakeholders to lower the GHG emission caused by these produce items. We also recommend that the teaching team designs projects that will focus on identifying the most sustainable sources of popular produce items using other indicators in addition to distance from UBC.

2. Introduction

Our project aims to critically analyze the sustainability of the UBC campus food system centralized on Greenhouse gas (GHG) emission factors of food produce items. GHG emissions associated with UBC produce are contribute to UBC's food sustainability. This project is aligned with UBC's Climate Action Plan and encourages campus-wide awareness of GHG emissions associated with UBC produce. The UBC Climate Action Plan is based on intensive efforts to determine ways to reduce GHG emissions, develop measurable targets and practical goals in order to reduce overall carbon emissions in terms of the UBC food system (UBC Climate Action, 2011). This can be generalized to a national or global scale in order to establish assessment tools for emission factors.

Particular focus was placed on produce items including tomatoes, potatoes and apples for this project because they are produced, transported and consumed in large quantities on the UBC campus. In addition, there is currently a lack of knowledge, research and data available on the GHG emission factors for these produce items. Determining the GHG emission factors of these key produce items will provide us with necessary information and possible recommendations for UBC. These recommendations can be used by stakeholders to help create a more sustainable food system.

Our group collectively agreed and elaborated upon on the vision statement compiled by various community partners. We thoroughly discussed the compilation of UBC produce data based on the summary velocity sheet provided by our community partner, Victoria Wakefield. We created several guiding principles. The first guiding principle is to conduct a food system sustainability assessment for the three produce items we researched. Another guiding principle included communication with stakeholders and the teaching team. It also included identifying barriers to the transitions towards food system sustainability, and developing opportunities and recommendations for improvement within this system for our project partners. Our main focus

was the sustainability of the UBC food system. An additional principle included providing students with opportunities to apply knowledge gained from their program's specialization and the Land, Food and Community (LFC) series in a multi-disciplinary community based project. This involved providing recommendations to future LFS students.

Our vision for this project is to establish recommendations to reduce the emission factors caused by produce items in the context of sustainability of the UBC food system. Produce items from local farm production are generally considered nutritious and contribute to the health of its consumers. Therefore, ensuring that the production of produce items has low GHG emissions is important for ensuring the health of an ecosystem. Creating awareness among consumers and stakeholders about cultivation, processing, ingredients and nutrition of food products in the food system will enable them to make informed and educated decisions based on environmentally conscious produce items. Produce should be farmed using sustainable practices. Produce should also be distributed in a manner that supports local communities.

Produce items will contribute to the overall emissions of the UBC food system. This is a value assumption understood by the project team. The contribution may be minute in terms of CO₂ equivalents and may only affect the sustainability of the UBC food system slightly, but it is worth pursuing the contributions of emission factors associated with different processing methods.

Our group approached this project from the standpoint of bettering the UBC food system and promoting UBC food sustainability. We collectively agreed on the guiding principles of the project and elaborated on the objectives based on the information found to make recommendations for stakeholders.

3. Investigation Methodology

A literature review was conducted to i) review methodologies used in the calculation of GHG emissions from agriculture and food processing systems and ii) develop a database of emission factors related to the creation of tomato, potato, and apple products. Studies were sourced from the University of British Columbia's online search tool "Summon" or from Google Scholar and Google Web searches. Several key words were used in searching, including: GHG Emissions, Emissions, Carbon Dioxide, Produce, Agriculture, Tomato, Potato, Apple, Production, Packaging, Processing, Transport, Climate Change, and Emission Factor.

UBCFSP reports from previous years were retrieved from the UBC SEEDS (Social Ecological Economic Developmental Studies) Program website. Reports related to GHG emissions and LCA (Life Cycle Analysis) were reviewed to better understand GHG emission calculation methodology and to check for relevant recommendations. Meetings were conducted with UBCFSP stakeholders Lilian Zaremba and Victoria Wakefield. Victoria is the Purchasing Manager at UBC Food Services. In our meeting with her we reviewed the "Food Services Velocity Sheet". This sheet featured inventory data on the quantity of certain food items purchased by UBC Food Services during the year of 2011. During this meeting we also established our research objective: Identify the carbon emissions associated with potatoes, tomatoes and apples and use these figures to express the amount emitted carbon related to items purchased by UBC food services that are based on one of the studied produce items.

Lilian Zaremba is the Climate and Energy Engineer in charge of UBC's Climate Action Plan which reports UBC's GHG emissions. While our meeting with Victoria focused on identifying produce products to focus on in our research, our meeting with Lilian involved identifying our methods. During this meeting we were introduced to the use of emissions factors. Emission factors are figures used in GHG emission reporting that equate a given unit with the respective

mass of emissions related to it. For example: The consumption of 1 Megajoule (MJ) of energy represents 20 grams of Carbon Dioxide (CO₂) emissions (Lai). This quantifies the global warming potential of a given unit. There are many different greenhouse gases (CO₂, Methane, Nitrous Oxide, CFC-12) and each gas has a certain global warming potential. The potential to contribute to global warming depends on two factors: 1. The chemical efficiency of that molecule ability to trap thermal energy in the atmosphere and 2. How long that molecule remains in the atmosphere before it degrades. To express the global warming potential associated with produce and its production we decided to use “equivalent CO₂ emissions” as the standard for our emissions reporting. This means that while a certain process or product involved in our GHG emission calculation may produce multiple forms of greenhouse gases, these various gases total effect on global warming have been reduced to a single figure that relates how much emitted CO₂ has that same global warming potential.

With Lilian we developed our approach to finding final CO₂ emission figures related to produce. This involves examining the creation of a produce product in terms of production, processing, packing, and transportation. Emissions factors from research were chosen on the basis of applicability to production transport and processing of foods that are consumed on the UBC campus. More specifically the produce items listed in the UBC Food Services velocity sheet. To organize data and develop the emissions calculator, these factors were arranged by "tier". Tier 1 Emission Factors represented CO₂ emissions from basic inputs or processes. These include: agricultural inputs; chemical fertilizers, compost, herbicides, insecticides. Agricultural processes; tilling. Tier 2 factors represent the carbon cost associated with intermediate process and products. These include: unprocessed apples, potatoes, and tomatoes. transport factors: air, land, and sea. energy factors; mega joules (MJ), British Thermal Unit (BTU), gasoline. processing activities; refrigeration, mechanical chopping, freezing, packaging/canning, cooking. processing inputs; packaging, cans. Finally Tier 3 factors represent the total carbon costs of final processed

products: frozen french fries, ketchup, tomato paste, tomato juice, diced canned tomatoes.

While tier 1 emission factors for agricultural inputs and operations were readily available they were not used in the calculation of tier 2 and 3 emission factors for whole produce and processed products. The reason for this is twofold: 1) Many tier 2 and 3 emissions factors were available in the literature. These figures often represent a synthesis of information on agricultural production emissions from numerous areas and provide sound estimates of average emissions from production. 2) The use of tier 1 emission factors to develop more complexly based tier 2 and 3 factors was complicated by the variability in quantities of agricultural inputs used for production. Amounts of inputs, such as fertilizers and pesticides, vary not only across regions and production scheme but by production site and time. Due to a lack of data on inputs from different production schemes and regions, tier 2 and tier 3 emission factors used in this investigation come directly from literature sources as opposed to through the summation of tier 1 inputs. In summary, emission factors were organized into a hierarchy. Factors higher on the hierarchy were used whenever possible, to substitute use of more fundamental factors which were often overly site specific.

4. Results and Discussion

4.1 Potatoes

Introduction

Potatoes are a commonly consumed root vegetable popular in today's society both for its nutritional value and great flavour. It provides consumers with various nutrients, especially complex carbohydrates and fiber. Data has shown that roughly 159.89 million tons of potatoes have been produced annually in developing countries (FAO, 2008). In these developing countries

many of these potatoes are not sold in their fresh form, but rather are processed into a variety of different products. Some of the processed forms of potatoes include: fries, hash browns, chips or potato pom poms. The popularity of both fresh and processed potatoes in today’s society makes it a contributor to GHG emission. Potatoes are especially a main focus because of the large quantities that are transported and consumed on the UBC campus. The GHG emission related to potatoes is dependent upon production method, transportation and processing.

Production

The production method used for potato production plays an important role in determining the amount of GHG emission produced. Chemical factors such as fertilizers (nitrogen, phosphate and potash), herbicides and insecticides all play a major role in contributing to the GHG of potatoes. It’s important that farmers use these chemicals because they are all essential for achieving a successful, high yielding potato crop. Specific attention has been paid to the usage of nitrogen as well as carbon dioxide in the production of GHG emissions because they are one of the major emission factors. Research done in Seattle, Washington has shown that conventional potato production produces 0.01kg of carbon dioxide for the cultivation of 0.227kg of potatoes (Morgan et al, 2010). This comes to 0.044kg of CO2 emitted/ kg potatoes. To tie this data back to the UBC campus a calculation of fresh potatoes received at UBC in 2011 was completed through the addition of the data available in the velocity chart. The chart below shows the total carbon-dioxide emission created by the production of all the fresh potatoes UBC received in 2011.

Table 1: Amount of potatoes purchased and estimated emissions

Produce item	Amount received by UBC	Carbon-dioxide emission
Whole	2.77 kg	0.121 kg

Potatoes		
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An analysis of the other various chemical inputs used to produce potatoes is lacking due to the unavailability of data on emission factors for these chemicals.

Processing

As previously mentioned most of the processed potatoes received at the UBC campus come from McCain. Most of the emission factors from this processing plant comes from: machinery for cutting, freezing, frying and packaging of the products. A study completed in the UK showed that McCains processed potatoes uses 2.7MJ of energy/kilo of potato, which can be compared to the 1.3MJ of energy/kilo of potato used for fresh potatoes (Foster et al, 2006). To maintain standardization and uniformity of the calculation the 1MJ is equal to 0.025 carbon dioxide equivalent. Therefore, processing of 2.7MJ of energy/kilo of potato creates 0.054kg of carbon dioxide equivalence whereas conventional potatoes causes 0.026kg. The production of different products such as fries and baked potatoes all have a different GHG emission factor due to the unique way they are processed. The length and type of cooking has an important impact on post-farmgate emission. For example, a baked potato has a much higher GHG impact than french fries because the fries are cooked in about five minutes while a baked potato takes about an hour to be cooked. Given the amount of energy that goes into baking vs. deep-frying, french fried potatoes are still the more efficient way to eat potato (Foster et al, 2006).

McCains has been trying to increase their use of biofuels at their facilities and to improve their energy efficiency (McCains Food, 2011). They have reduced their GHG emissions from 244 grams per kilogram of french fries to 233 grams per kilogram (McCains Food, 2011). According

to the velocity chart UBC received a total of 1283.2kg of fries from McCains in 2011. Given that the processing of one kilogram of fries results in the emission of 0.233 kilograms of carbon dioxide, a total of 297.7 kilograms of carbon dioxide were emitted from the purchase of UBC's 2011 purchase of McCain fries.

Table 2: Amount of potatoes purchased and estimated emissions

Produce item	Amount received by UBC	Carbon-dioxide emission
Processed Potatoes (Fries)	1283.2 kg	297.7kg

Transportation

To maintain uniformity in our GHG emission analysis of potato production we are assuming that UBC receives potatoes from Seattle, Washington transported in trucks. Previous research shows that 0.000068kgCO₂/kg/km is produced from a truck (Morgan et al, 2010). According to Google maps the distance between Seattle and Vancouver is 227km. Therefore, through calculations it can be concluded that transporting one kilogram of fresh potatoes from Seattle to Vancouver produces 0.0155kg of carbon-dioxide emissions.

UBC particularly receives many processed potato products such as fries, hash browns or chips. Their main provider for these processed products is McCain. For the purpose of this project it is assumed that UBC receives their products from the McCains factory located in Manitoba because this processing plant is the closest to Vancouver. Therefore, when considering the carbon-dioxide

emission for processed potatoes we must account for the transportation of Seattle to Manitoba and then to Vancouver.

To maintain uniformity we assume that these potatoes only get transported in trucks. The distance from Seattle to Manitoba is 2507km and the distance from Manitoba to Vancouver is 1784km. Therefore, for the transportation of processed potatoes a total of 4291km leading to a higher carbon dioxide emission factor.

Discussion

Comparatively from the data presented above it can be concluded that fresh potatoes have a lower GHG emission factor compared to processed potatoes. Multiple factors such as the processing and extra transportation distance are an explanation for this. In Tables 1 and 2 we have provided examples of whole potatoes versus processed fries, the disparity in the values is accounted by the amounts purchased by UBC Food services and the entries in the summary velocity sheet. To maintain uniformity within our analysis we assume that all the potatoes received by UBC are transported in a truck. This assumption may have caused a variance of GHG emissions due to the lack of information available for other modes of transportations.

Tomatoes

A total of 126 million tonnes of tomatoes are grown around the world per year with about 30 million tonnes being processed into various products (Karakaya & Ozilgen, 2011). Worldwide, tomato consumption has increased over the past few years with the growing popularity of foods such as pizza and pasta sauces (Carlsson-Kanyama, 1998). Tomatoes are growing in popularity which is making them a significant contributor to GHG emissions associated with the production

of vegetables. Tomatoes are classified as a 'GHG intensive crop' because a large percentage of the world's annual output is grown out of season in greenhouses (Garnet, 2006). The different ways GHG are generated for tomatoes are briefly described below.

Sources of GHG emissions for Processed and Fresh Tomatoes

Production

There are several sources of GHG emissions during the production process and these vary depending on the production method. GHGs are emitted whenever energy is used to power primary farm processes and activities such as field preparation and irrigation (Garnet, 2006; Karakaya & Ozilgen, 2011). In addition, energy is used during the production of young plant tomatoes under controlled conditions of temperature and light (AAFC, 2006). The manufacturing of Nitrogen, Phosphorous and Potassium based fertilizers also contributes to CO₂ emissions associated with tomato production as do the making and application of herbicides and pesticides (Carlsson-Kanyama, 1998; Karakaya & Ozilgen, 2011).

Transportation

Transportation are a significant contributor to the total GHG emissions associated with tomato production. Young plant tomatoes are usually transported to farms for transplanting. The finished product is also transported from the farm to the retailer and finally to the consumer within individual countries and across international borders. Various modes of transport have different emission factors and contribute different amounts of GHG emissions depending on distance traveled and type of fuel used.

Refrigeration

Tomatoes are highly perishable therefore they require proper storage after harvesting in order to

maintain their freshness. Tomatoes are transported in refrigerated containers and emissions are mostly due to leakage of coolants into the atmosphere and the burning of fossil fuels to produce energy to power the refrigerators. There are also emissions from storage after the product reaches the retailer and the consumers (Garnet, 2006; Carlsson-Kanyama, 1998).

Processing and packaging

Tomatoes undergo various energy intensive steps to produce different products. Usually, the more processing steps required to produce a certain product, the higher the amount of emissions released (Karakaya & Ozilgen, 2011). Packaging also contributes to the total emissions through manufacturing of different packaging materials such as cardboard, plastic and tin cans. All these material have different emission factors associated with them (Karakaya & Ozilgen, 2011).

Waste management

5% of the total yield of tomatoes goes to waste at the farm stage in many production systems (Karakaya & Ozilgen, 2011). There is also wastage that is associated with the storage, transportation, processing, and retail stages. The source of emissions for this has been linked with the amount of fuel spent on managing waste e.g. conversion of waste tomato to organic fertilizer (Karakaya & Ozilgen, 2011). Another source waste related emissions is the decomposition of the tomatoes taken to landfills.

Assumptions and system boundaries

There were no fresh tomatoes summary velocity sheet therefore the GHG emission estimation was only done for processed tomato products. Over the last decade the vegetable processing industry in Canada has shrunk making the country a net importer of processed vegetables with the United States being the largest supplier of processed tomato products followed by Mexico (Agriculture and Agri-Food Canada, 2010). However for this project we assumed most of the

processed products come from south-western Ontario which is home to Canada's tomato processing industry (World Tomato Processing Council, 2006). The distance between the two locations was estimated at 3549km and the emission factor that was used for transportation was 62gCO₂/tonne/km (European Chemical Industry Council, 2011). We also assumed most of the tomatoes were produced in conventional heated greenhouses and transported using heavy duty commercial vehicles. Organic production was not considered because it only makes about 3% contribution to the entire processing industry (AAFC, 2010; Hartz et al., 2008). The different emission factors used throughout the calculation were obtained from various studies done around Europe because we could not get figures specific to North America.

For this study it was challenging to obtain packaging and processing information specific to North America. Therefore, data about canned processed tomatoes were obtained from a study carried out in Turkey on the tomato processing (dicing, Juicing and making paste) industry (Karakaya & Ozilgen, 2011). The authors used emission factors calculated from different production systems across Europe and Asia.

System Boundaries

- GHG emissions associated with the manufacturing and application of pesticides and herbicides, irrigation and waste management were not included in the calculations for this study because we were unable to obtain accurate and up to date information.
- The contribution for refrigeration during transportation was not taken into account as Carlsson-Kanyama (1998) found that the amounts of GHGs released were negligible when compared to those released by burning fossil fuels for the duration of the journey.

- The GHG analysis for the UBC food system was limited to tomato juice, tomato paste/puree, diced tomatoes and ketchup. Tomato based soups were excluded and there was also no exact amounts of fresh tomatoes used.
- The functional unit is defined as production or processing of 1kg of fresh tomatoes (Karakaya and Ozilgen, 2011).
- Calculations were only done for carbon dioxide as it accounts for a large percentage to emissions related to tomato production (Forster et al., 2006; Roy et al., 2008)

Tomato Findings

Processed tomatoes

Amount ordered by UBC Food services according to the Summary velocity sheet for 2011 are provided below. The table does not show such as soup products and fresh tomatoes although they were part of the total tomato consumption.

Table 3: Amounts of processed tomato products purchased in 2011.

Processed Product	Amount used in kg
Juice	1687
Diced	7679
Paste/Puree	7360
Ketchup	1252
Sundried	596
Total	17321

Estimated GHG Emissions

Based on studies carried out on European production and processing systems, the following are the estimated amounts of CO₂ emitted per kg of product.

Table 4: Estimated carbon dioxide emissions per kg

Tomato Product	CO₂/kg of product
Fresh	771g
Juice	1122.1g
Diced	866.9g
Paste/Puree	860.9g
Ketchup	1324g

The graph below shows the total GHG emission estimates associated with the amount that was consumed. The total emissions from tomato products in 2011 were estimated to be 20,500kg of carbon dioxide.

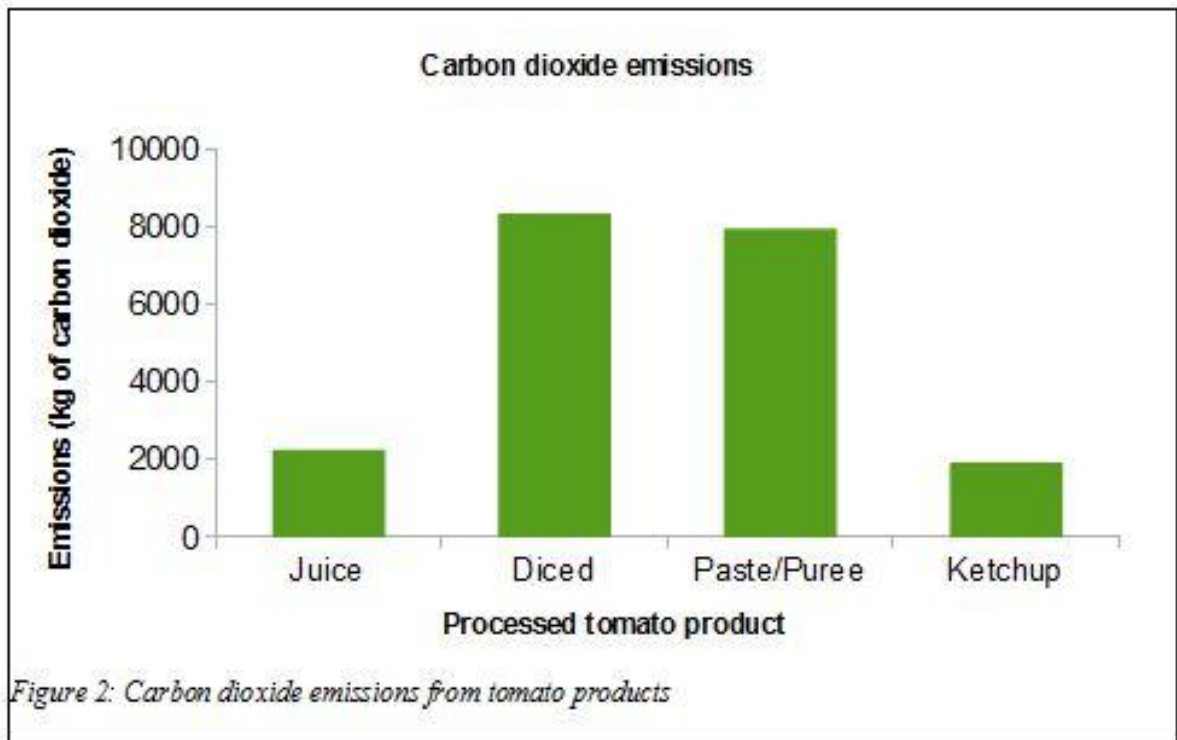


Figure 2: Estimated carbon dioxide emissions from tomato products used in 2011

Tomato discussion

GHG emission varied between different products. According to Table 3, Ketchup had the highest emissions per kg but did not contribute the most to the overall total because of the lower amount that was purchased. Diced tomatoes and tomato paste/puree were the two highest contributors of GHG emissions because more of those products were consumed. Processing and packaging can significantly increase the emissions for processed products and the more processing a product undergoes, the higher its environmental impact is likely to be (Andersson et al, 1998; Foster et al., 2006)

When compared to open-field production and unheated protected cropping, heated greenhouse tomatoes produce more GHG emissions overall because of high energy consumption from heating (Foster et al., 2006). For example, open-field and protected unheated systems usually

consume 5MJ/kg of energy whereas heated greenhouse systems use up to 137MJ/kg (Foster et al., 2006). Studies to estimate GHG emissions from organic production systems have not been comprehensively done. However, researchers in Europe have found that for an equal yield, organic farmers use up almost twice as much land as conventional farmers and this increases the GHG emissions related to energy use (Foster et al., 2006).

Local sources of crops may not always be the most efficient in terms of GHG emission reductions. A study that was done to compare fossil fuel carbon dioxide emissions from vegetables produced in Canada with emissions from those imported from southern USA found that crops produced in Canada emitted twice as much carbon dioxide (Dyer et al., 2011). This suggests that if CO₂ emissions are being used as an indicator for the environmental sustainability of consuming a certain food product, importing that crop may be the better option in some cases. This has serious implications for consumer because ‘local’ is not always better than ‘global’ (Foster et al., 2006).

APPLES

Production

Apples are not especially cost intensive to grow once an orchard framework is in place. Orchards however, can take years to grow to a maturity which will allow them to produce apples. Before this point the farmer who is growing the trees will not have any return on his investment. Once the apple trees begin production of apples the farmer has to ensure that they stay healthy and disease free. At this point the trees require generous amounts of irrigation (Kim, 2011). When

trying to imagine the scale of an orchard we can look at the rudimentary specifications for a dwarf tree orchard. "Dwarf trees are planted at a density of 300 to 400 trees per acre" (University of Minnesota). They can often range from approximately 300 bushels per acre to around 500 or more (University of Minnesota). The average bushel weighs about 40 pounds (University of Minnesota). Cultivation of apples can be intensive in terms of GHG emission and can produce 0.056 KgCO₂/Kg of apples cultivated (Foster, 2006). Thus an acre of trees planted at the previously stated density, in what is often described as an arid region in the Okanagan. Here the water needs to be pumped, sometimes for kilometers, in order to hydrate the gross amount of densely planted trees. Though water usage is not directly a GHG emission, it does affect the 0.056 KgCO₂/Kg of apples cultivated and the overall sustainability of the UBC food system (Foster, 2006). There are often a large variety of pests that can adversely affect the trees and the apple produce itself and as such pesticides are used to control these and are a factor in the final figure for production emissions. It is supplemental factors such as this that UBC must be ever vigilant to keep records about in order to maintain its status as a sustainable campus.

Processing

The processing of apples has the smallest input overall for apple purchasing. Fresh apples are not packaged or processed in the conventional sense. Some apples are given a sticker proclaiming the origin of the apple, but aside from that, when purchased in wholesale like UBC does the apples are stored in large bins and are then distributed throughout the campus (Fritz, 2012). Often these bins are reused for future purchases. The largest input with relation to apples does not come from their processing, but rather from the final stage before distribution and consumption which is the transportation of the product.

Packaging

Packaging for apples are minimal in wholesale. They are often stored in large crates which are kept in enormous coolers. These coolers help to decrease decomposition until transportation of the product can occur, they can however, have an impact on emission factors. Storage of the fruit for example can produce 0.0162 KgCO₂/Kg of apples stored (Foster, 2006). Because of the sheer size of many of the coolers used for preservation, traditional ice or fan powered coolers will not work. Here there are a few GHG emissions produced in the forms of a Tetrafluoroethane mixture which is pumped through pipes to keep temperatures at a regulated cool level (Fritz, 2012). If they escape, these gases can have adverse affects to the atmosphere and increase the carbon footprint for UBC indirectly. There are sometimes additional costs to packaging and storing of apples. If the coolers are held at an offsite facility there are additional transportation costs for bring the apples to the storage and packaging facilities. The packaging and storage of apples can produce 0.0032 KgCO₂/Kg (Foster, 2006). Fortunately the apples that are purchased are often sold as fresh as possible to increase return on interest for the farmers involved in production (Kim, 2011). One additional cost to packaging is usually associated with conventionally farmed apples, but can be found with organically grown ones as well. That is the use of a light coat of wax in order to keep pests from contaminating the product (Fritz, 2012). Fortunately GHG emission factors for the production of wax is minimal and has almost no effect on the carbon footprint for UBC, but it should be included for overall sustainability purchasing of the product. Packaging and storage, especially for fresh produce is important to consider for the final emission factors at UBC.

Transportation

Transportation and distance are important factors to consider when purchasing apples. Fossil

fuels are a direct contributor to global warming and have adverse affects on the atmosphere. Apples should be purchased from as locally possible when trying to minimize the ecological and economic costs of transportation. Transportation locally in Germany produces 0.0066 KgCO₂/Kg of apples (Foster, 2006). In comparison transporting apples from New Zealand to Germany had an energy cost of 0.056 KgCO₂/Kg of apples, which is comparable to the productions costs (Foster, 2006). Though the distance travelled by an average sized family vehicle can produce 340 pounds of carbon emission for a one way trip and according to Transportation Canada, commercial vehicles transporting apples for cargo can produce upwards of five times this amount (Transport Canada). Still, purchasing from the Okanagan is a lot more cost effective and sustainable than purchasing from the states or other distant orchards.

Total Emissions

When added together emission factors for production, processing, packaging, and transport to get the MJ used in the creation of one kilogram of apples. This figure was multiplied by the emission factor for mega joules we found that apples have a total emission factor of 0.08 KgCO₂/Kg.

Discussion

While looking at the production of apples the amount of organic and conventional apples purchased by UBC was undetermined. Our community partner stated that UBC did purchase organic apples, but they also said that conventional ones were purchased as well. They did not know exact percentages of these two categories. As such an accurate estimate of estimations may fluctuate based on these two totals.

Scenario Evaluation/Limitations

At the beginning of our project we held meetings with our community partners Victoria Wakefield and Lillian Zaremba to in order to get their perspective on the project and what they hoped to see at the end.

One limitation of this study was the availability of data related to UBC Food Services Purchases. Particularly in the area of whole fresh produce. The available data on the quantities of produce entering the UBC Food System via Food Services focused heavily on processed products. The available data on processed products presented an additional challenge. Information about production and transportation prior to arrival at a processing facility was not available. Either facilities did not have this information or were unwilling to share it. Because of this the number of figures directly based on the activities that brought a given produce product to UBC Food Services were limited.

Another challenge we faced was the lack of standardization in the literature in the measurement of GHG emissions associated with different produce item. Research results were reported in different units for example some studies used Global Warming Potential while other used carbon dioxide equivalents. This made it very difficult for used to assess how the different values compared with each other without doing several mathematical conversion step. In addition, results were reported in different units because each researcher determined their own functional unit. Some reported their emission factors in terms of one kg of processed product while other used per tonne of product at the farm gate. Because the estimated emission factors varied greatly in the literature, our final results are open to error.

Our project highlighted the different factors that have to be taken into account when analyzing the environmental impacts of the different produce items purchased by UBC Food Services. We also

identified that there are many knowledge gaps in the field of vegetable Life Cycle Assessments and have suggested ways to bridge these gaps in the future. We shared our findings through a class presentation and were able to generate discussion about how minimizing food-related GHG emissions for an institution such as UBC entails more than just reducing the distance between the site of production and the site of consumption. We have also produced a detailed report for the community partners that could not make it to our presentation that highlights the most important outcomes and suggests steps that can be taken to build a more sustainable food system.

Recommendations for future LFS students.

- Choose specific popular produce items and explore the most sustainable source. As discovered from the results, certain food items contribute more to UBC's total emissions because they are consumed in greater amounts rather than because they have a high GHG emission per kg of product. Future students can choose the most consumed items for further analysis.
- Do comprehensive LCAs on the most important produce items to identify GHG emission 'hot-spots'. This will help them identify the stages of an item's journey from the farm to the table that contributes the most GHG. Once the hot-spots have been identified, the necessary changes can be made where possible.
- Have more than one group concentrate on estimating GHG emissions of the 10 most consumed produce items. From our results, we found that amount consumed highly influences total GHG emissions.
- Work with partners outside UBC in order to obtain specific information such as amount of fuel used per acre for various farm processes, water use, distance from farm to processing plants to retailers, sources of fresh produce for processed items and amounts of fertilizer, herbicide and pesticide used.

- Start the project early in order to define the focus of the project. This will allow adequate time for modifying the project should issues arise.
- Holding regular consultations with the teaching team and community partner will also help students stay on track through out the term.

Recommendations for Community Partner

- To create a cost effective strategy choose produce for purchase based on popularity and sustainability
- When possible try to form partnerships with local producers to cut down on transportation emissions.
- Sell foods that are low in GHG emissions. This would require purchasing of fresh produce and less frozen premade products.
- In addition to distance between the site of production and the site of consumption, different indicators must be used to assess environmental impacts of purchased produce items. As stated before, emissions due to transportation may not be a significant contributor to total GHG emissions associated with a particular item. UBC Food Services must consider all the different steps associated with the finished product. In some case, it may be much better to import crops grown in an area with suitable climate than buying local produce grown in energy intensive facilities that try to recreate normal growing conditions e.g. heated and lighted greenhouses.
- The difference of emissions produced versus what emissions are produced should be an eventual focus for the UBC food services. Often there can be small amounts of emissions which can have a more harmful effect on the local ecosystem of an area.

Recommendations for the teaching team

- Design a scenario that will focus on doing a detailed LCAs of 100% organic produce items in Canada. There are currently major information gaps in the field of organic production in terms of emissions associated with production. The few studies that are available are inconclusive and different researchers report different results. This project can be designed to use UBC farm as a resource in terms of acquiring specific production information related to energy use, irrigation and organic fertilizer use. Records can be kept for particular crops for several growing seasons and then the data can be used to make estimations for total GHG emissions associated with production.

Conclusion

In our investigation we found that tomatoes were the most GHG intensive item in our study. The agricultural production of one kilogram of tomatoes yields 0.771 kg of carbon dioxide. The processing of tomato products increased the final product GHG emissions by an average of 35%. Ketchup was found to be the most intensive processing product with an emission factor of 1.324kgCO₂/kg ketchup. This was followed by tomato juice, diced tomatoes, and tomato paste with emission factors of 1.122kgCO₂/kg, 0.866kgCO₂/kg, and 0.860kgCO₂/kg respectively. The production of apples is less than nine times that of tomato production, with an emission factor of 0.080 kgCO₂/kg fresh apples. Potatoes were rated as having an emission factor of 0.044 kgCO₂/kg potatoes. The processing of potatoes to produce french fries was emits over four times the GHGs used in the agricultural production of potatoes with an emission factor of 0.233 kgCO₂/kg french fries. Fries consumed at UBC in 2011 contributed a total of 297.7 kg of CO₂ whereas the whole potatoes purchased by UBC Food Services were associated with 0.121 kg of CO₂ emission. Carbon emissions for processed tomato products purchased by UBC Food Services during 2011 are 2264 kg CO₂ emitted for tomato juice, 8346.0 kg CO₂ emitted for diced tomatoes, 7955 kg CO₂ emitted for tomato paste, and 1933 kg CO₂ emitted for ketchup.

Literature cited

1. Roy, P., Daisuke, N., Takahiro, O., Qingyi, X., Hiroshi, O., Nobutaka, N. and Takeo, S. (2009). A review of life cycle assessment (LCA) on some food products, *J Food Eng.* 90(1) ;1-10, Retrieved from (<http://www.sciencedirect.com/science/article/pii/S0260877408002793>)
2. Roy, P., Nei D, Okadome H, Nakamura N, Orikasa T, Shiina T. (2008). Life cycle inventory analysis of fresh tomato distribution systems in Japan considering the quality aspects. *J Food Eng.* 86; 225-33. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0260877407005110>
3. Andersson, K. and Ohlsson, T. (1999). Including environmental aspects in production development: a case study of tomato ketchup. *Lebensmittel-Wissenschaft Und-Technologie.* 32,134–141
4. Andersson, K., Ohlsson, T. and Olsson, P. (1994). Life cycle assessment (LCA) of food products and production systems. *Trends in Food Science and Technology,* 5(5),134–138. Retrieved from <http://www.sciencedirect.com/science/article/pii/092422449490118X>
5. Foster, C., Green, K., Bleda, M., Dewick, P., Evans, B., Flynn A., Mylan, J. (2006). Environmental Impacts of Food Production and Consumption: A report to the Department for Environment, Food and Rural Affairs. Manchester Business School. Retrieved from <http://www.ifr.ac.uk/waste/Reports/DEFRA-Environmental%20Impacts%20of%20Food%20Production%20%20Consumption.pdf>
6. Hartz, T., Miyao, G., Micklar, J., Lestrangle, M., Stoddard, S., Munez, J. and Aegerter, B. (2008). Processing tomato production in California. University of California Vegetable

- Research and Information Center. Retrieved from
<http://anrcatalog.ucdavis.edu/pdf/7228.pdf>
7. European Chemical Industry Council. (2011). Guidelines for Measuring and Managing CO2 Emission from Freight Transport Operations. Retrieved from <http://www.cefic.org/Documents/IndustrySupport/Transport-and-Logistics/Best%20Practice%20Guidelines%20-%20General%20Guidelines/Cefic-ECTA%20Guidelines%20for%20measuring%20and%20managing%20CO2%20emissions%20from%20transport%20operations%20Final%2030.03.2011.pdf>
 8. World Tomato Processing Council. (2006). Tomato processing in Canada. Retrieved from <http://www.wptc.to/pdf/Canada%202006.pdf>
 9. McCain food. (2011). Retrieved from <http://www.mccain.com/GoodBusiness/Corporate%20Responsibility/Pages/energy.aspx>
 10. Agriculture and Agri-Food Canada. (2006). Crop Profile for Greenhouse Tomato in Canada. Retrieved from http://publications.gc.ca/collections/collection_2009/agr/A118-10-24-2006E.pdf
 11. Fritz, K.B., Song, J., Streif, J. (2012). Physiological Impacts of Fruit Ripening and Storage Conditions on Aroma Volatile Formation in Apple and Strawberry Fruit: A Review. HortScience; 47(1), 4-10.
 12. University of Minnesota (2008). Before you Start an Apple Orchard. Retrieved from <http://fruit.cfans.umn.edu/apples/beforeyoustart.htm>
 13. Transport Canada (n.d) Retrieved from <http://www.tc.gc.ca/eng/menu.htm>
 14. Food and Farming Canada (2011) Apples - Organic or Conventional?. Retrieved from <http://www.foodandfarmingcanada.com/2011/06/28/apples-organic-or-conventional/>

15. UBC Sustainability Office. (2010). UBC Climate Action Plan 2010-2015. Retrieved from <http://sustain.ubc.ca/sites/sustain.ubc.ca/files/uploads/pdfs/Plans%20and%20Reports/UBC%20Vancouver%20CAP%20Final.pdf>
16. Kim, I., Deurer, M., Sivakumaran, S., Huh, K., Green, S., Clothier, B. (2011). The impact of soil carbon management and environmental conditions on N mineralization. *Biology & Fertility of Soils*; 47(6), 709-714.
17. Carlsson-Kanyama, A. (1998). Food Consumption Patterns and Their Influence on Climate Change: Greenhouse Gas Emissions in the Life-Cycle of Tomatoes and Carrots Consumed in Sweden. *Ambio*. 27(7), 528-534. Retrieved from <http://www.jstor.org/stable/4314785>.
18. Morgan, D., Renzi,S., Cook, R. and Radenovic, H. (2010). Seattle Food Enhancement Project: Greenhouse Gas Emission Study. University of Washington Program on the Environment; Staff

Appendices

- 1. LCA for Ketchup from Andersson et al (1998)**
- 2. Sources of emissions due to tomato production**