Life Cycle Assessment of Chili with Beans Comparing Packaging Scenarios

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Executive Summary

This document reports the results of a life cycle assessment that was commissioned by Truitt Brothers, a manufacturer of food products, and their packaging supplier, Ampac. The goal of the LCA was to evaluate the life cycle impacts of Truitt Brothers' beef chili with beans packaged in a new shelf stable retort pouch design, and to compare those impacts with two other packaging scenarios, where the chili is packaged and frozen or made from scratch.

The results show that the vast majority of the impacts occur upstream from the manufacturing process, at the farm. As a result, there is little variation among the different scenarios for most impact categories on a per serving basis.

Food waste in restaurants and cafeterias is a significant cost driver, and the shelf-stable retorted pouch has the potential to save waste because the contents can be heated to be ready to serve without opening, then if there is not enough demand, cooled and reheated another day. Other packaging options typically require that the contents be discarded if not served. The analysis indicates that the total environmental impacts per serving of chili served using the retorted pouch was decreased by over 50% in the case where the number of servings required is uncertain and the risk of preparing excess chili is high.

The full eco-profile for the Truitt pouched chili is shown below. Units are per serving.

Table 1: Truitt Pouched Chili - Life Cycle Impacts per serving

Impact category	TOTAL	Unit
Climate Change	**1.5**	kg CO_2 eq
Acidification	**2.1**	mol H+ eq
Respiratory effects	**0.3**	g PM10 eq
Eutrophication	**10**	g N eq
Ozone depletion	**44**	µg CFC-11 eq
Ecotoxicity	**0.39**	CTUe
Smog	**120**	g O_3 eq
Land use	**580**	m^2-years
Water	**100**	Liters

Upstream environmental impacts are dominated by the production of beef. All the packaging over the lifecycle of the product combined

proved to be a very small proportion of the product environmental impacts.

Overall the study illustrated the importance of managing food waste. Although the environmental impact of the packaging was small, the potential impact of reducing food waste through improved packaging is quite large, substantially reducing overall environmental impacts.

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Terms and Abbreviations

BPA: Bonneville Power Administration

ecoinvent: ecoinvent centre, Swiss Centre for Life Cycle Inventories

ERS: Economic Research Service of the USDA United States Department of Agriculture.

GWP: Global warming potential

HP: horsepower

IERE: Institute for Environmental Research & Education

IPCC: Intergovernmental Panel on Climate Change

kWh: Kilowatt-hour

LCA: Life cycle analysis

LCI: Life cycle inventory

LCIA: Life cycle impact assessment

NOx: Nitrogen oxides

OECD: Organization for Economic Co-operation and Development

PE: Polyethylene

PET: Polyethylene terephthalate

PM 10: Particulate Matter < 10 micrometers in diameter

Pouch: retorted pouch for shelf stable foods; the scenario describing this product system

PP: Polypropylene

Scratch: food prepared from fresh and semi-finished products and served directly.

TRACI: Tool for the Reduction and Assessment of Chemical and other Environmental Impacts

USDA: United States Department of Agriculture

US-EI 2.2: USLCI Ecoinvent hybrid database

USLCI: U.S. Life Cycle Inventory database

Introduction

Truitt Brothers is an Oregon based manufacturer of shelf stable food products for retail and foodservice customers. They have a long history of leadership in the field of developing and educating about sustainable foods, and over the last five years they have been using life cycle assessment (LCA) as a tool to better understand the environmental sustainability of their products and processes, and to communicate their environmental performance to their customers. In partnership with Ampac, their packaging supplier, they retained the Institute for Environmental Research & Education to conduct a life cycle assessment of their pouched all natural chili with beef product packaged in three different scenarios: (1) shelf stable Retort Pouch, (2) Frozen, and (3) Served immediately without packaging (chili 'from scratch').

IERE is a not-for-profit with a mission to undertake and disseminate comprehensive, fact-based research for use in the development of responsible environmental policy, programs and decisions.

Goal & Scope

The goal of this study is to better understand the environmental impacts of the Truitt Brothers Natural Beef chili in relationship to its packaging and to evaluate the potential for shelf stable retort pouch packaging to decrease waste and related environmental impacts. The scope of the analysis was a cradle to grave environmental assessment that evaluated the differences among three packaging scenarios (shelf-stable pouch, frozen and scratch). All portions of the packaging life cycle are covered, including waste disposal at end of life. The impacts of human waste are ignored, as are the impacts of providing and maintaining tableware for serving. The audience is primarily Ampac and Truitt Brothers' customers and internal personnel: the study is intended to support Ampac and Truitt Brothers' sustainability claims and to be published. No comparative assertions are intended. This study was performed in accordance with the ISO 14044 standard[i].

System function and functional unit

The function of the system under review is the provision of hot chili to the end consumer. The functional unit is the USDA definition of a serving, 8 ounces (226.8 g)[ii]. Although the customers for these products are food service organizations, e.g. cafeterias and restaurants, the function is to serve consumers of the chili.

Review

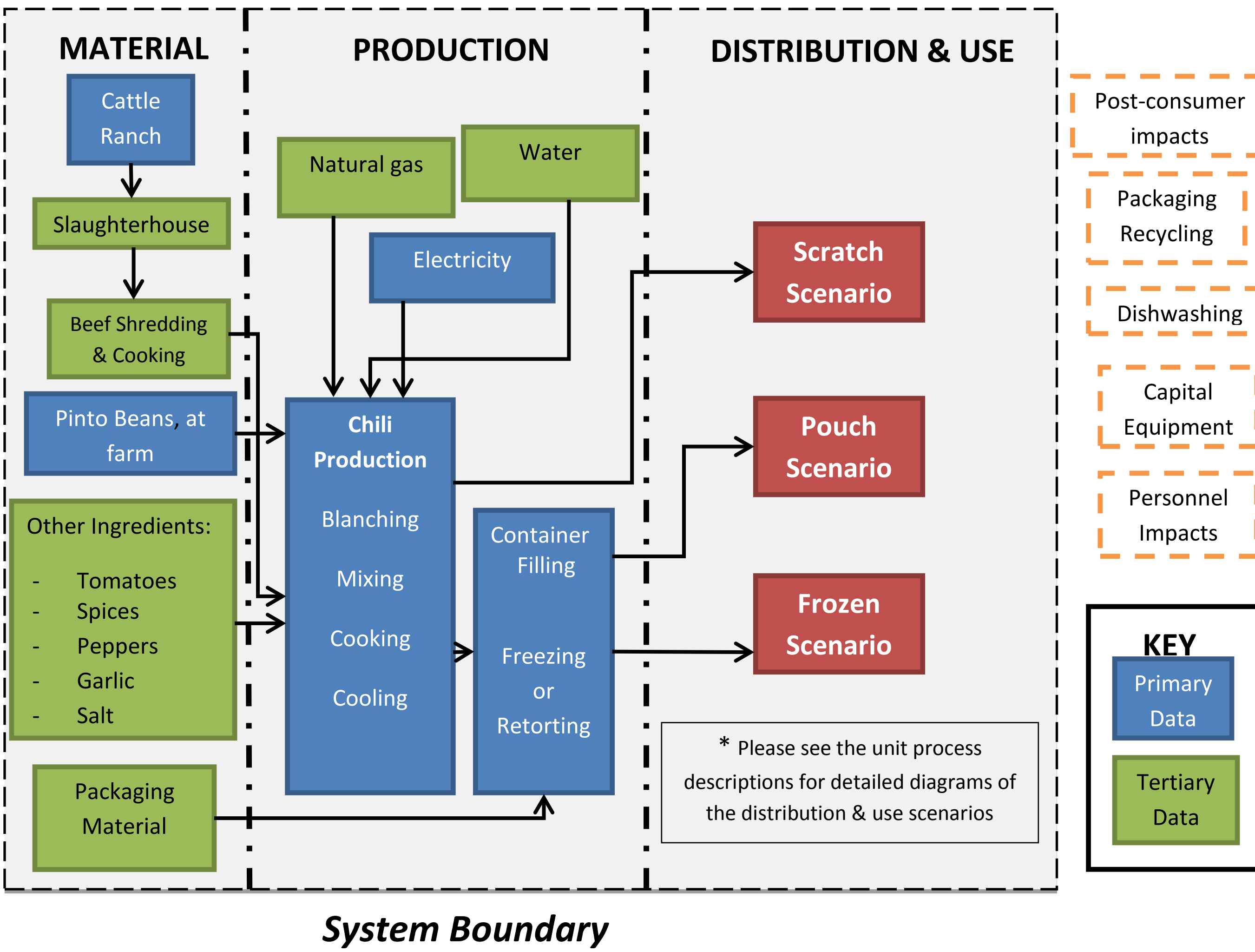
This report was reviewed by a team of three: Tom Gloria, LCACP Industrial Ecology (an independent LCA Certified Professionals; Mike Levy, American Chemistry Council, a foodservice packaging industry trade association expert; and Salil Arora, Archers Daniels Midland, a food industry expert and an LCA Certified Professional.

System Boundaries

This study is a cradle-to-plate analysis. It includes all life cycle stages up to serving the chili. This includes the extraction and production of primary inputs, their packaging and transportation, chili production, chili packaging, distribution and preparation. The end of life treatment of the chili after human consumption is not included, however the treatment of any pre-consumer wasted chili is included.

The system boundary excludes the production and disposal of capital equipment, but includes the operation of the equipment. The manufacture, use and cleaning of utensils, pots and dishes are excluded. The personnel impacts (travel to & from work; lunchroom operations and sanitary water treatment) are excluded. The office operations are excluded. All materials sent to recycling leave the system boundary.

Figure 1: System Boundary



Data Quality, Sources and Cutoff Rules

The intent of the data collection was to gather primary data from all unit processes under the direct control of the producer, and to seek as much primary data as possible from upstream suppliers. This represented 60% of the dry weight of the product. When primary data was not available, processes were taken from the USLCI[iii], ecoinvent[iv], USLCI-ecoinvent hybrid database[v], and a Danish LCA of food database[vii]. Nearly all the data were either primary data for production in the United States or US specific secondary or tertiary data.

We used region specific process LCI data whenever possible. This included the creation of an electrical grid mix to represent the current supply of the Bonneville Power Administration (BPA)[v]. This was used whenever we were certain that BPA supplied the electricity for a particular process. When region specific processes were not available, we employed process LCI data that represented US averages, and was no more than 10 years old. When US specific data was not available, we used data from OECD countries that have been modified to incorporate US electricity production (US-EI 2.2)[vi].

At least 95% of all mass and energy and all known toxic materials are included in the analysis. No flow representing more than 1% of the total mass or energy of the system was excluded.

Impact Categories

Life cycle impacts were calculated using the latest version of the US EPA Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI 2 V4.00. The TRACI model takes the life cycle inventory results and converts them to potential impacts for the following impact categories.

Climate change is the result of the anthropogenic addition of greenhouse gases into the atmosphere. These gases trap heat in the atmosphere, leading to a wide diversity of effects, including sea level rise and extreme weather events such as hurricanes, tornadoes, droughts and floods. Greenhouse gases are released primarily through combustion processes. Ruminant enteric fermentation and other biological processes also contribute to these emissions. Climate change ultimately yields effects such as crop failure and increased incidence of disease leading to human mortality and losses of species and ecosystems. The majority of greenhouse gases are derived from combustion, and all products include combustion in their value chains, even if only for the purpose of transportation.

The midpoint indicator of climate change is the amount of infrared radiative forcing, commonly referred to as Global Warming Potential (GWP), which is measured in mass of CO_2 equivalents. CO_2 is used as the reference because it is the most common and important (in terms of fraction of the greenhouse effect) greenhouse gas. The lifetime of CO_2 in the atmosphere varies, but a weighted average is near 100 years, and thus the 100 year time horizon is selected. The characterization factors are derived from the Intergovernmental Panel on Climate Change's most recent 100-year horizon global warming potentials[vi]. In addition to CO_2, N_2O and CH_4 are major drivers of climate change. Minor drivers of climate change include many refrigerants and some industrial chemicals. All of them must be accounted for in estimating the climate change impact.

Acidification causes the destruction of aquatic and terrestrial ecosystems through the wet and dry deposition of strong acids and ammonia. The acidification of soils mobilizes the aluminum in the soils and this has direct toxic effects on fish and other species, as well as an indirect effect through inhibition of uptake of potassium by plants, leading to loss of forest ecosystems. Acidification also affects the built environment, causing the slow dissolution of buildings. We have chosen the stoichiometric gram equivalents of hydrogen ion for emissions of oxides of sulfur and nitrogen, ammonia, HCl, HF, H_2SO_4, and H_3PO_4.

Respiratory effects can results from the release of criteria pollutants into the atmosphere. These pollutants, such as particulates, stress the respiratory systems of humans and other living creatures. Children, the elderly and people with heart and lung disease are especially at risk. Life cycle emissions that impact respiratory health are measured in units of PM 10. PM 10 represents particles less than 10 micrometers in size that are most likely to become lodged in the respiratory systems of animals.

Eutrophication is the overgrowth of biomass caused by the anthropogenic release of nutrients, particularly fixed nitrogen and phosphorus. The presence of these nutrients facilitates algal blooms, and subsequent increases in populations of microbes that subsist on decaying algae. These microbes consume oxygen during the decomposition process and deprive other respiring aquatic species. Many of the world's water bodies are subject to eutrophication seasonally. The most important causes of excess nutrient releases are agriculture, human and animal wastes, and combustion processes.

In the 1930's A.C. Redfield discovered that the ratio of carbon to nitrogen to phosphorus uptake in marine ecosystems was constant (Carbon:Nitrogen:Phosphorus = 106:16:1, on an atom basis) and subsequently this ratio was confirmed to be the same in freshwater systems. The Redfield ratio is the basis of all life cycle eutrophication impact models.

Ozone Depletion occurs when reactive and persistent substances interact with the beneficial ozone in the upper atmosphere, or stratosphere. This high altitude ozone filters out ultra-violet radiation that would be extremely harmful to life if it were able to reach the planet's surface. This impact category is measured in mass unit equivalents of CFC-11, a refrigerant and powerful ozone depleting substance.

Ecotoxicity represent direct effects of releases of toxic materials on humans and other organisms. There is a wide variety of sensitivity of organisms to different toxic materials and the results of this analysis should be evaluated with great care. We have used the USEtox[vii] model for ecotoxicity, with units of Toxic Unit (CTUe), as represented in the TRACI 4.0 version. This model is based on estimates of the concentration at which half of all organisms die. Of all the impact models shown here, the USEtox model has the highest uncertainty. Ecotoxicity can vary over 18 orders of magnitude, and the uncertainty of the results are very high. Any conclusion drawn from them must be done with great care.

Photochemical smog is produced when oxides of nitrogen and volatile organic substances are present in the lower atmosphere in the presence of sunlight. Ozone is formed, and this form of oxygen causes many direct effects, such as reducing crop yields, and increasing the occurrences of asthma and other respiratory effects. The production of ozone has been shown to be more related to the existence of oxides of nitrogen (NO_x) than to the release of volatile organic substances.
Measurements of smog were evaluated using the most recent U.S. EPA TRACI method, expressed in mass of ozone equivalents.

Land use is an important impact for all agricultural products. In the absence of a consistent model to measure the impacts of different land use regimes, this impact was calculated using the total land area occupied and has units of square-meter years.

Water is consumed during the production and use of the chili. There is currently no consensus on how to measure water resource depletion, so at this time, consumptive freshwater use shall be the indicator. Consumptive water use includes all the use of freshwater resources that leads to loss of the water from the watershed. Evaporation due to irrigation is an example of consumptive water use. Use of water that was sent to wastewater treatment and of water that appeared in the food itself was included. Rainfall was not included, but the amount of water consumed by cattle was included in the model (on the range, cattle drink from surface water sources).

Table 2 below summarizes these impact categories and the models used.

Table 2: Summary of Impact Categories

Impact Category	Model	Units
Climate Change	IPCC[vi]	Mass CO_2 equivalents
Acidification	Stoichiometric equivalents	Mass H+ equivalents
Respiratory Effects	TRACI 2 (v4.00)	Mass PM 10 equivalents
Eutrophication	Redfield Ratio	Mass N equivalents
Ozone Depletion	UNEP-SETAC 2000[viii]	Mass CFC-11 equivalents
Ecotoxicity	USEtox	CTUe
Photochemical Smog	TRACI 2 (v4.00	Mass O_3equivalents
Land Use	Inventory	Area-years
Water Use	Inventory	Volume of water

Life Cycle Inventory

The following section explains the processes that contribute to the chili life cycle. The processes are organized into the following life cycle stages: Chili Production, Ingredients (the on farm food production, and initial production prior to the Truitt factory), Packaging (all primary and secondary packaging as well as ancillary packaging such as pallets), Transportation (the transport of all components to the Truitt Brothers Facility), and Use (the shipping of the product from the factory, its storage and heating at the food service location).

Chili Production

The production stage begins with the receipt of the recipe ingredients. The upstream packaging consists of four materials: corrugated cardboard, polyethylene, Kraft paper, and steel strapping. All discarded upstream packaging materials are recycled and exported beyond the system boundaries. The packaged ingredients are shipped on wooden pallets.

The pinto beans are blanched and then all of the ingredients are mixed together and cooked. The chili is then jacket cooled and the packaging is filled and the packages retorted. After cooling and drying, the retorted packages are labeled and packaged for transport. The life cycle inventory data for chili production was provided by Truitt Brothers. It consists of process water, electricity and fossil fuel consumption; wastewater emissions; transportation & packaging of recipe ingredients; and a process scrap rate of one percent. Retorting the chili sterilizes it: no stabilizers or preservatives are added.

We have assumed that the chili was created in substantially the same manner for the other scenarios (frozen and scratch). As noted below the frozen scenario does not include retorting but does include freezing. We have estimated the energy for freezing and for retorting and they are approximately equivalent (less than 10% difference), so we have not made adjustments for this scenario. The made from scratch scenario has substantial differences from the retorted scenario. These are largely related to scale, because restaurant and food service production will be much smaller than the production in a factory. This means that the packages for ingredients are smaller, and the package to ingredient ratio will be greater. Lacking any information about these details, we have assumed that the ingredient packaging in both the frozen and the scratch scenarios are the same as those in the pouched scenario. This assumption provides a conservative estimate of these impacts.

Ingredients

Beef

The beef is sourced exclusively from a ranch in Oregon. The cattle are primarily pasture raised and grass fed, with some supplemental silage. Newborn cattle are weaned on a growth supplement for the first few months. Greenhouse gas emissions from enteric fermentation and manure management were calculated using the latest IPCC guidelines for performing greenhouse gas inventories from livestock[ix]. Cattle manure and urine contain nitrogen and phosphorus, two important nutrients for plant life that can have negative environmental impacts if they occur in high concentrations. The amount of nutrient run-off from cattle grazing depends on the grazing intensity, among other factors. Moderate grazing intensity (like the kind practiced at this cattle ranch) has been shown to have negligible effects on surface water nutrient loading when compared to ungrazed pastures[x]. Moderate stocking rates depend on the quality of forage, but range from 0.1 to 0.5 animal units per hectare[xi][xii]. In this study, the stocking rate was approximately 0.02 animal units per hectare. In light of this finding, we have omitted nutrient emissions to water from the cattle ranch inventory.

Cattle are sent from the cattle farm to a separate facility for slaughter. In the absence of primary data on the slaughtering process, a unit process from the Danish Food LCA[xiii] study was used with several modifications. Because the Danish slaughtering plants are much smaller than those in the US (with a concomitant lower efficiency), it is likely that this data overestimates the actual impact of slaughter. All input and output flows were adjusted in proportion to the average mass of cattle sent for finishing from the cattle farm. Finally, the relative economic value of meat, hide and offal were used to allocate the impacts of the slaughter process across the multiple outputs[xiv].

Beef leaves the slaughterhouse and is sent to an intermediate facility for further processing and cooking. The beef is shredded, packed into sterile plastic bags in 10 pound lots, and slow cooked for 10 hours at 190^{o} F. The cooked meat is then repackaged and shipped to the chili production facility. Attempts were made to collect primary data for this process with limited success. The energy intensity of grinding the meat was estimated from the specifications of a commercial meat grinder. The material of the plastic bags, transportation, and estimates of energy consumed during cooking are included in this process. We assumed that the plastic cooking bags were made from PET.

Assumptions & Missing Data

- Nutrient run-off from moderate cattle grazing is negligible.
- Tertiary data for the slaughterhouse process is an adequate representation.
- A 1 HP commercial grinder is used for the grinding process (~ 0.0014 kWh/kg).
- Beef is cooked in an electric oven (~0.00625 kWh/kg).

Beans

The beans are produced in Eastern Washington by a minimal-till grower. The fields were irrigated and this water use dominates the life cycle water use of the product. Primary data was collected from the producer. Unit process flows consist of land occupation, fossil fuel & electricity consumption, water use, pesticides, and fertilizer application. Data on the production of the fertilizers (nitrogen, phosphorus, & potassium) were for the year 2010 from a large global fertilizer producer[xv]. Energy consumption figures for fertilizer production were not disaggregated by energy source. Unless additional information was provided, the energy source was assumed to be natural gas.

Assumptions

- The primary energy source of fertilizer production is natural gas.

Tomatoes

Primary data for the production and processing of tomatoes was not available. According to the USDA, the vast majority (94%) of tomatoes produced for processing in the United States are grown in California's Central Valley, and the Truitt Brothers' tomatoes are sourced from California[xvi]. A review of the USDA National Agricultural Statistics Service database provided data on the inputs to California tomato production. Estimates of land occupation, water use, pesticides and fertilizer application were obtained for the year 2009. The fossil fuel intensity of tomato production was estimated by using the per acre consumption numbers from the bean farm primary data. This will likely overestimate the fossil fuel use because tomato production and harvesting typically rely more on manual labor and less on industrial farm machinery than crops like beans.

Assumptions

- Per acre fossil fuel use of tomato farming is equivalent to bean farming.
- Impacts of tomato processing are minimal and below the cut-off criteria.

Packaging

Information on the composition and amount of upstream packaging was obtained from Truitt Brothers. Processes for the production of corrugated cardboard, Kraft paper, and steel (for strapping) were taken from the USLCI database. Life cycle inventory data for the production of packaging materials from raw materials was not available (i.e. the production of a box from corrugated cardboard). All incoming packaging is recycled by the company and leaves the system boundary at the chili production facility. This is in contrast with the other wastes which are modeled as disposed (i.e., some to landfill, some to incineration).

Information about the primary container (the retorted pouch) was provided by its supplier, Ampac.

After the chili containers are filled, they are packaged for distribution. Downstream packaging information was provided by Truitt Brothers and consists of paper labels, corrugated cartons and dividers, corrugated slip sheets, and wooden pallets. To represent the potential for pallet reuse, an estimate of 6 uses per pallet was taken from a 2007 report conducted by Franklin Associates[xvii]. Primary data on the packaging composition of frozen products was unavailable, so the assumption was made that the packaging for distribution of the frozen containers is equivalent to the data provided for the pouches. Inventory data for packaging raw materials were obtained from the USLCI database.

The land use associated with forest product based packaging material (pallets, cardboard, and paper) was calculated using statistics from the National Forest Service for the year 2002[xviii].

Assumptions

- The secondary packaging material used for distribution is independent of the container type (frozen or pouch). This may underestimate the secondary packaging for the frozen product.
- Manufacture of secondary packages from packaging materials has minimal impacts and is below the cut-off criteria.

Transportation

The chili ingredients travel from their point of origin to Truitt Brothers by road and container vessel. Sources for all of the ingredients were provided by Truitt Brothers. Processes representing the transport of goods by truck and by container vessel were taken from the USLCI database. We assumed that the trucks made empty return trips 50% of the time. Land occupation associated with transportation infrastructure was calculated using highway extent and freight shipment data from the Bureau of Transportation Statistics[xix].

Assumptions

- Return trips by truck are empty 50% of the time.
- Return trips by container vessel are full 100% of the time.

Distribution & Use

The life cycles of the three scenarios under investigation are identical from raw material extraction to chili production. The variation in this analysis occurs once the chili has been prepared and is ready to be packaged or served. Up until this point, all of the data has been based on real world production processes at the Truitt facility. The distribution and use phase of this life cycle were modeled based on different scenarios of waste management. The following section outlines the methodological approach to the distribution and use phases and highlights the differences among the scenarios.

Pouch Scenario

The Truitt Brothers retorted pouch use scenarios are the focus of this comparative analysis. The amount of energy and water consumed during the filling and sealing of the pouch was only available aggregated with all the chili production process inputs. As a result, it is represented in the production phase of this analysis.

Each retort pouch holds 13 servings of chili. Data for the pouch material content, and process energy requirements were provided by the manufacturer. A production scrap rate of 14% was provided by Ampac, the pouch supplier, and this scrap rate was attributed equally across the three different types of plastics.

Table 3: Retort Pouch Material Composition

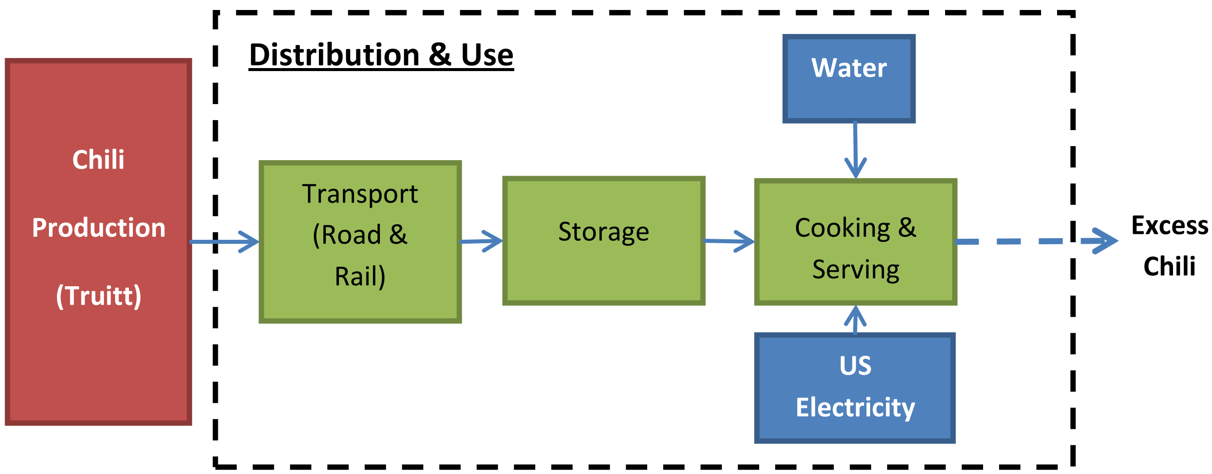
Material	Amount (g)
Polyethylene terephthalate (PET)	4.5
Nylon 6	7.8
Polypropylene (PP)	24.4
TOTAL	**36.7**

An estimate of the weighted distribution transport distance was borrowed from a previous study done for Truitt Brothers and includes both rail and road transport[xx].

Chili in the retort pouch is prepared by immersion in boiling water until it has reached a servable temperature. We have assumed that the amount of water required is approximately twice the amount of chili per serving, 0.5 liters. The energy required to reheat the chili in the pouch was determined by calculating the energy required for boiling water plus the energy required for heating the chili from room temperature (20^{o} C) to a servable temperature (75^{o} C)[xxi]. We have assumed that the chili has a heat capacity equivalent to that of water.

The energy efficiency of cooking can vary greatly depending on the fuel source, stove type and cooking vessel used. Without knowing exactly how the chili would be prepared, we have chosen to model the cooking phase as an electric stove with an energy conversion efficiency of 50%, assuming the U.S. average electric grid. Electric resistance heating coils heat through upwards conduction to the surface of the pot. About one-half of the energy is actually directed downwards. Although some of that heat is reflected upwards, we estimate that is reflection is small and likely offset by other losses (e.g. radiation from the surface of the pot). Several sources suggest that the efficiency of electric ranges are approximately equivalent to that of gas ranges[xxii]. We then performed a sensitivity analysis to assess the impacts of the efficiency assumption on the results. The carbon footprint of US average electricity is somewhat higher than the carbon footprint from using natural gas for heat, and so this is a conservative estimate of the energy ecoprofile. It may overestimate the environmental impact of cooking/reheating the chili.

Figure 2: Pouch Scenario Use Phase Process Flow



Assumptions

- Chili is prepared on an electric range using US average electricity mix.
- 0.5 liters of water per serving are required for reheating.
- Distribution network is equivalent to other Truitt Brothers products.
- The specific heat of chili is approximately that of water.

Frozen Scenario

The production phase of the frozen chili life cycle is very similar to that of the pouch scenario, however, instead of being retorted, the chili is packaged and then frozen. As was previously mentioned, the data provided by Truitt Brothers aggregated the energy used while retorting the pouches with all of the production processes. In the absence of detailed data for retorting or freezing, estimates of the energy required for both of the processes were calculated assuming that the amount of water required for retorting is three times greater than the amount of chili, and that the thermal properties of the chili are equivalent to water. It was found that the amount of energy consumed by freezing was approximately the same as the energy of retorting (0.3 MJ/ serving). Therefore, for the purposes of this report they were assumed to be equivalent.

Data for the mass of the packaging of frozen chili was obtained by sampling two equivalent products, a chili frozen in 5 pound quantities (10 servings) and another chili packaged in 4.5 pound quantities (13 servings, water added), with four examples of each product. This analysis provided a mean and standard deviation of the amount of packaging per serving of frozen chili. The packaging material was different for each product, and was not noted on the package. We analyzed the life cycle impacts assuming three different common plastic materials (nylon, polyethylene (PE), and polypropylene (PP)). The final life cycle results for each three material types were essentially the same: nylon had the largest impacts in some impact categories. However, the difference in impacts among the three materials was never more than 0.5% for the package itself and would result in an even smaller difference of the total life cycle impacts. PE had the lowest overall impacts and was chosen as a conservative reference material for the frozen packaging. All further analyses were performed assuming PE is the material for frozen chili packaging.

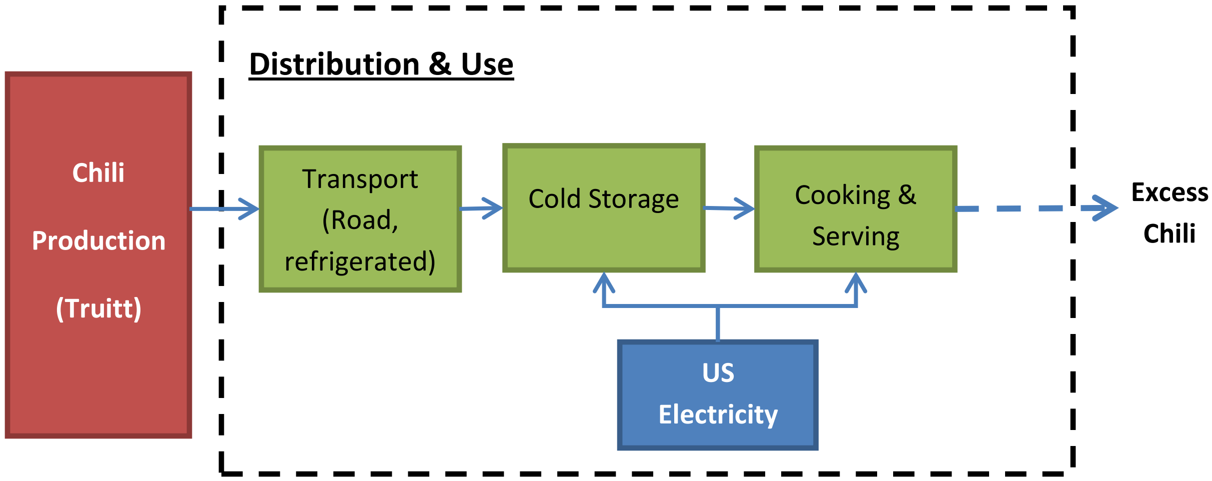
The transport distance for distribution is identical to the pouch scenario. Distribution of the frozen chili is performed entirely by refrigerated trucks. A literature review was conducted to determine the impacts of a refrigerated unit in relation to a standard truck, but provided only anecdotal information. Therefore, an assumption was made that refrigerated units consumed 20% more fuel per mile than non-refrigerated units[xxiii].

After distribution, the chili was modeled as being stored for 3 months in a commercial freezer. The freezer energy consumption was estimated using the minimum energy star rating requirement as the assumed performance. The storage period of 3 months was chosen because it is approximately half of the chili's recommended shelf-life[xxiv]. A sensitivity analysis was performed to assess the impacts of the storage period length on the results.

Although it was not evaluated here, it is likely that the shorter useful life of the frozen product versus the pouched chili would lead to higher losses due to past-date discards than the pouched chili, with concomitant increased environmental impacts.

The cooking phase was modeled in a similar fashion to the pouch scenario. However, in this case additional water is not used, and the chili is placed directly in the pot while still frozen, as per the manufacturers instructions. The energy required to heat the chili to a servable temperature from frozen was calculated assuming the chili has a heat capacity equivalent to water. A sensitivity analysis was performed to assess how different cooking efficiencies affect the final results.

Figure 3: Frozen Scenario - Use Phase Process Flow



Assumptions

- Chili is prepared on an electric range using US average electricity mix.
- Energy consumed during freezing is equivalent to the energy consumed during retorting.
- Distribution distance is equivalent to other Truitt Brothers products.
- All transportation is by refrigerated truck.
- The specific heat of chili is approximately that of water.
- Period of frozen storage is 3 months.
- Refrigerated trucks are 20% less fuel efficient than standard trucks.

Scratch Scenario

The scratch scenario represents a situation where chili is cooked from fresh ingredients and served immediately at the same location. There is no packaging or distribution after production. The smaller batch production of a scratch scenario is likely supported by increased packaging for smaller quantities of ingredients, but we were not able to identify data on this point and therefore have ignored this point. As shown below, the environmental impact of the complete packaging system is generally less than 5% of the total system environmental impact, and thus we anticipate that this represents much less than 1% of the total impacts of the scratch system.

There are as many recipes for chili made from scratch as there are cooks, so for simplicity and consistency the Truitt Brothers recipe and production life cycle inventory was also used for the scratch scenario. However, chili in the scratch scenario is not retorted or frozen. The estimate of the energy consumed during these processes (0.3 MJ/serving) that was discussed in the previous section was not included in the model of the scratch scenario.

The scratch scenario also does not have any post-production distribution. Furthermore, the chili comes out of the production process cooked and ready to serve, so an additional cooking process is not required.

The other two scenarios use electricity from the Bonneville Power Administration (BPA) during the production phase, and US average electricity for reheating prior to serving. The production of chili during the scratch scenario occurs immediately prior to serving and the location is uncertain. It is comparable to reheating during the use phases of the other scenarios. For consistency across the scenarios, the BPA grid mix used in the chili production has been replaced with US average mix for the scratch scenario.

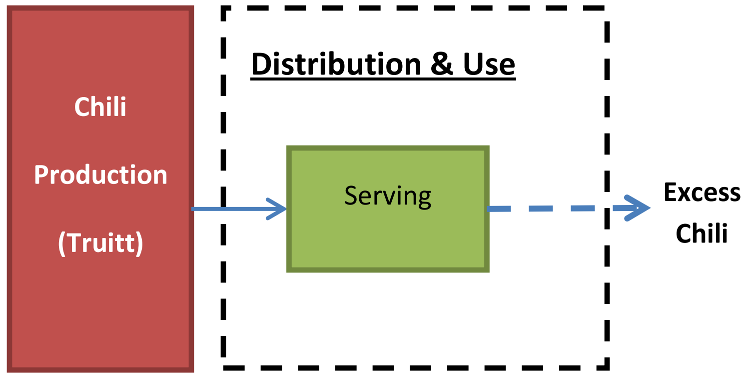
When chili is prepared from scratch there is a risk of over preparation. We assume that the excess food cannot be served again the next day, so it is discarded. The environmental impacts of the wasted food are not discarded along with it. Rather, they are attributed to the food that is consumed. Therefore it is important that the rate of food waste is properly incorporated into the model. A 2008 study of pre-consumer soup, chili and sauce waste conducted by LeanPath measured the proportion of waste generated in the cafeterias of two universities and high school for a year[xxv]. The findings of this study are summarized in Table 4.

Table 4: LeanPath Results

	Proportion Wasted	
	Mean	95% Confidence Interval
University A	9.0%	8.5% - 9.5%
University B	13%	12.2% - 13.7%
High School	7.6%	6.8% - 8.4%

The results of the LeanPath pre-consumer waste study show that two of the schools waste nearly a tenth of the chili prepared. University B is especially wasteful, consistently discarding over 12% of the chili. The mean of all three schools aggregated together is 10%, and this value was used as the assumed waste rate for the scratch scenario. School food service represents the situation where the number of diners is most predictable, and the number of food choices is most limited, and therefore these figures likely represent a low estimate of food waste due to over-preparation.

Figure 4: Scratch Scenario - Use Phase Process Flow



Assumptions

- Truitt production up to but not including packaging is used as a proxy for making chili from scratch. No transportation or storage.
- The proportion of pre-consumer waste is taken from the results of the LeanPath study.

Data Quality Assessment

This project attempted to collect as much primary data as possible. Detailed inventories were provided by Truitt Brothers as well as several key suppliers including the cattle ranch, bean farm, and pouch manufacturer. Data for 60% of the dry weight of the chili and packaging was provided by these sources.

All the remaining data met our data quality requirements. It was less than 10 years old, and was either North American sourced or based on OECD data modified for the U.S. situation by using the average U.S grid, as supplied by NREL.

There were several instances when data was not available, e.g. the energy use for preparing shredding beef and inventory data for growing spices. We have substituted dried onions for the missing dried spice data, and we have estimated the energy use for beef preparation from physical properties.

Summary of Unit Processes

Table 5 provides an overview of all the unit processes used in this analysis and includes information on geographic and temporal representativeness, sources, and an overall evaluation of the process data quality relative to the goal and scope of this study.

The fertilizer data from Potash Corporation represents from 30 to 70% of the total fertilizer production in North America primary facilities data was aggregated on a weighted average basis.

Table 5: Unit Processes

Process	Output	Data Level	Geography	Year	Data Quality	Source
Electricity, at grid, US/US – BPA Power 2010	Process energy	Primary	Northwest, USA	2010	Excellent, actual grid mix	Bonneville Power Administration[xxvi]
Natural Gas, combusted in industrial equipment/RNA	Process energy	Tertiary	North America	2008	Good	USLCI, Franklin Associates
Transport, combination truck, diesel powered/US	Transport	Tertiary	United States	2008	Good	USLCI, Franklin Associates
Transport, freighter, diesel	Transport	Tertiary	United States	2008	Good	USLCI, Franklin Associates
Unbleached Kraft Paperboard FAL	Packaging	Tertiary	United States	2011	Good	USLCI, Franklin Associates
Corrugated Cardboard FAL	Packaging	Tertiary	United States	2011	Good	USLCI, Franklin Associates
Cold rolled sheet, steel at plant/kg/RNA	Packaging	Tertiary	North America	2008	Adequate proxy for steel strapping	USLCI
Cattle Ranch	Beef Cattle	Primary	Oregon, USA	2010	Excellent, site specific inventory	Country Natural Beef (Vale, OR)
Slaughterhouse	Meat	Mixed	Denmark	2002	Good	LCA Food DK
Shredding & Cooking	Shredded Beef	Primary	Northwest, USA	2011	Poor, estimation of process energy requirements	BrucePac
Fertilizer production	N, P K fertilizer	Primary	North America	2010	Very good	Potash Corp
Pinto beans, at farm	Beans	Primary	Washington, USA	2010	Very Good, site specific inventory	Central Bean Company
Tomatoes	Tomatoes	Tertiary	Denmark	2010	Acceptable	LCA Food DK
Sodium Chloride, at plant /RNA	Salt	Tertiary	North America	2008	Good	USLCI, Franklin Associates
Sugar, wholesale	Sugar	Tertiary	Denmark	2006	Acceptable	LCA Food DK

Process	Output	Data Level	Geography	Year	Data Quality	Source
Maize starch, at plant/ DE with US electricity	Corn Starch	Tertiary	Germany	2010	Acceptable	US-EI 2.2
Onion, dried & stored	Onion & other dry	Tertiary	Denmark	2005	Acceptable	LCA Food DK
Retort Production	Pouch	Primary	USA	2010	Excellent	Ampac
Polyethylene terephthalate resin, at plant/RNA	Pouch	Secondary	USA	2010	Good	US LCI
Polypropylene resin, at plant/RNA	Pouch	Secondary	USA	2010	Good	US LCI
Nylon 6, production mix, at plant	Pouch	Tertiary	Europe, with US Electricity	2010	Acceptable	US-EI 2.2 (US LCI)
Electricity, at grid, US	Use Phase Energy	Secondary	USA	2010	Good	USLCI

Life Cycle Impact Assessment

Results

This section presents the results of the various analyses performed for this project. Life cycle impact assessment results do not predict impacts on category endpoints, exceeding thresholds, safety margins or risks. They do provide estimates of potential impacts.

Process Contribution

Figures 5, 6, and 7 display the relative contributions of each life cycle stage to the total impacts for each impact category. The purpose of these charts is to visualize the proportion of the total impacts that are attributable to different life cycle stages. The bars are all the same height because they represent 100% of the impacts for each category, not the actual values. The total values of each category are provided in the tables at the end of this section.

With the exceptions of respiratory effects and ecotoxicity, these environmental impacts are dominated by the ingredients phase (in green). These impacts are primarily incurred on the farm. The packaging portion of the life cycle (in reddish brown) is quite small in every case.

The contribution of different stages of the life cycle to the overall environmental impacts of the three scenarios is shown below. The bars for each impact are set at 100 percent, and the results are shown as the Use phase (distribution, storage and heating); Transportation (transport to the point of manufacture); Production; Packaging (all primary secondary and ancillary packaging); and Ingredients (the farm production and initial production of the food components)

Figure 5: Impact Process Contribution – Pouch Scenario

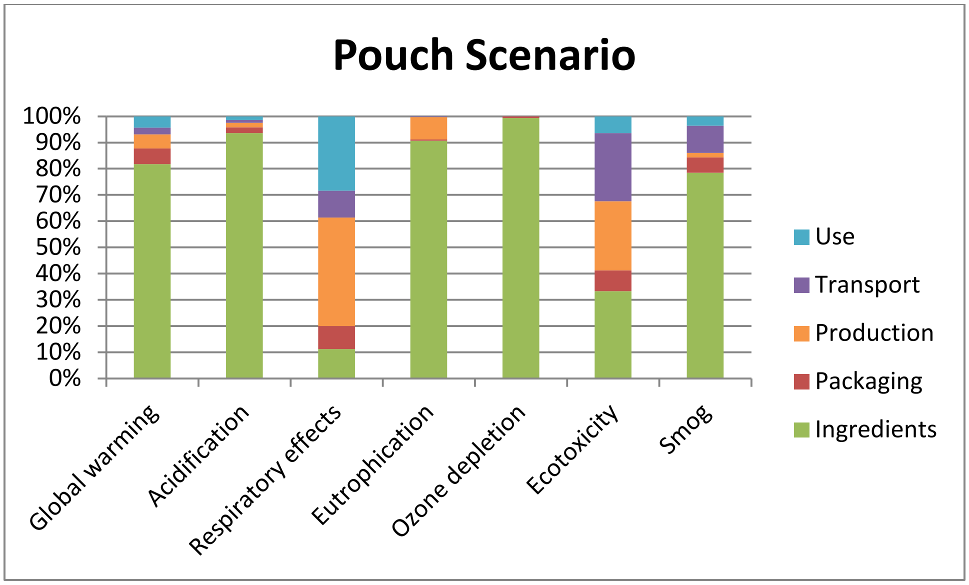
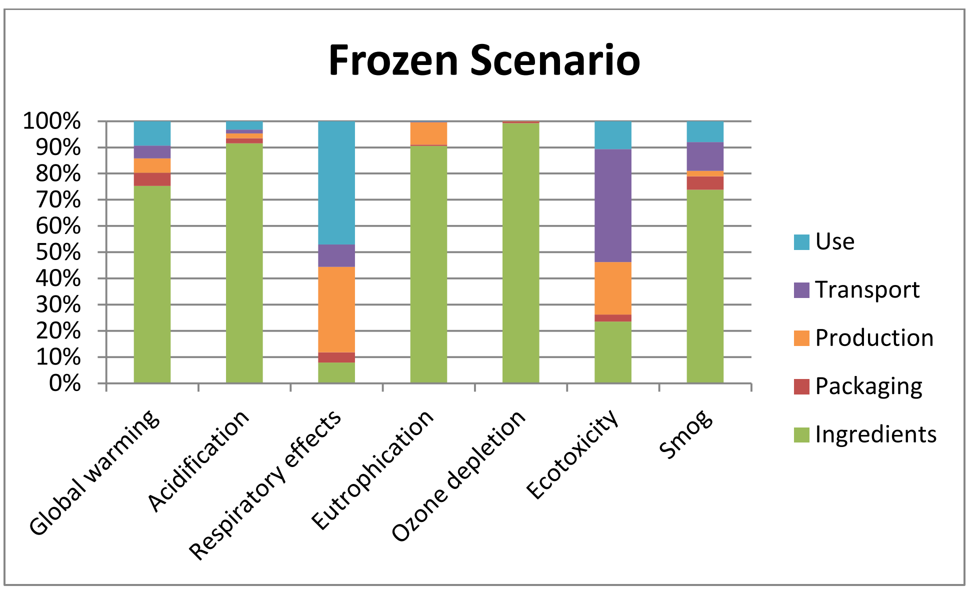
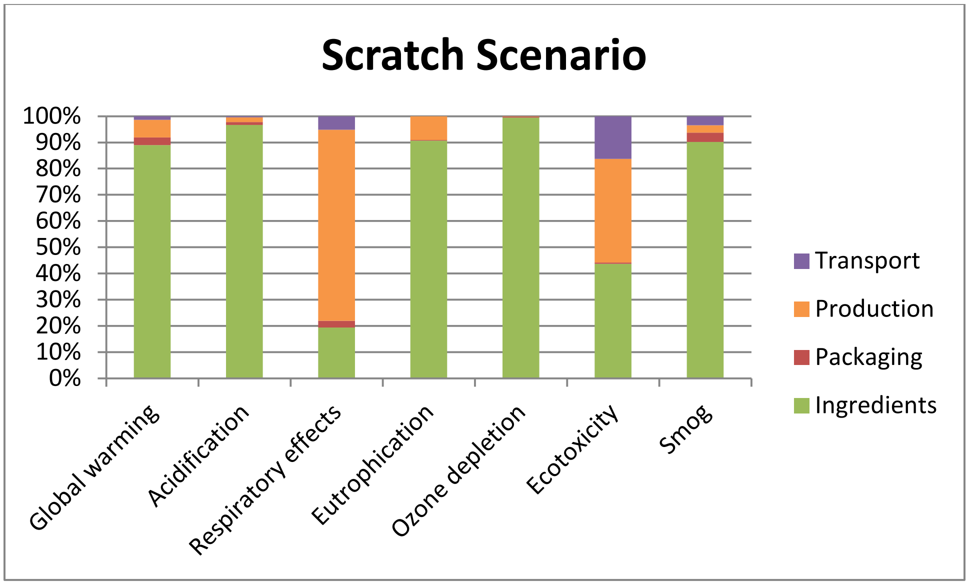


Figure 6: Impact Process Contribution - Frozen Scenario



The contributions of the pouch and frozen scenario are very similar across most of the impact categories. The production of ingredients dominates the environmental impacts for all but the respiratory effects and ecotoxicity categories, which are dominated by the use of fossil fuels. The packaging represents a small portion of the environmental impacts never exceeding 9% of the total for any impact category. The use phase of the frozen scenario contributes a larger proportion to global warming, respiratory effects, ecotoxicity, and smog because of the additional electricity consumed during refrigeration.

Figure 7: Impact Process Contribution - Scratch Scenario



The scratch scenario does not have a use (re-heating) phase or distribution so the ingredient inputs dominate the impacts categories even more so than the other two scenarios.

Figure 8: Pouch Scenario - Process Contribution to Global Warming Potential

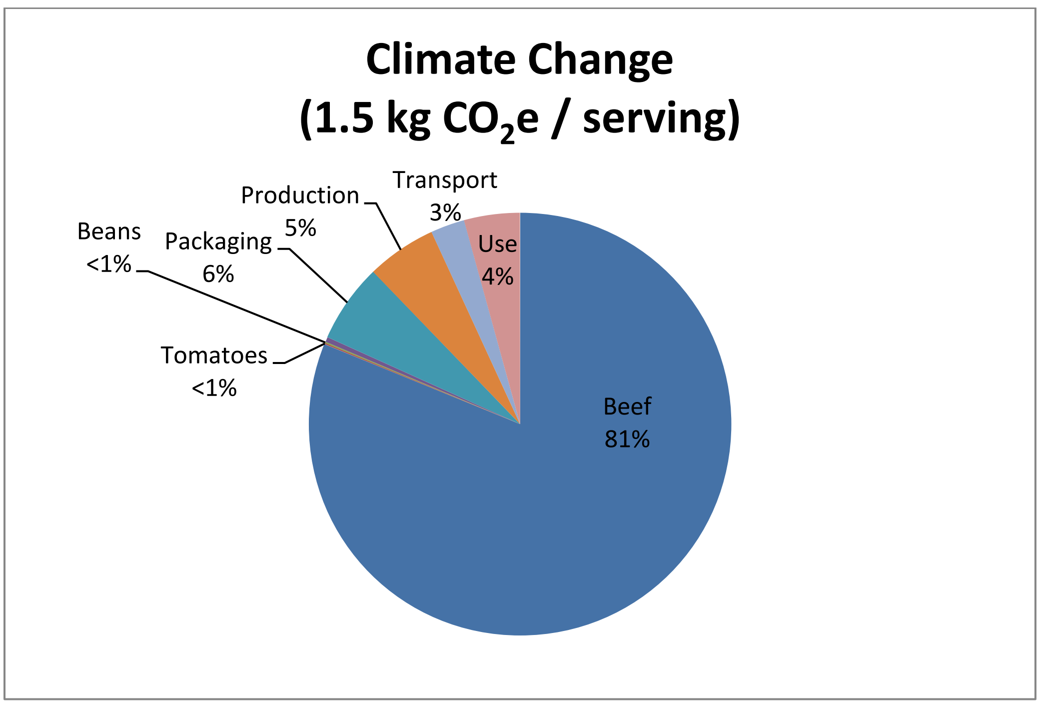
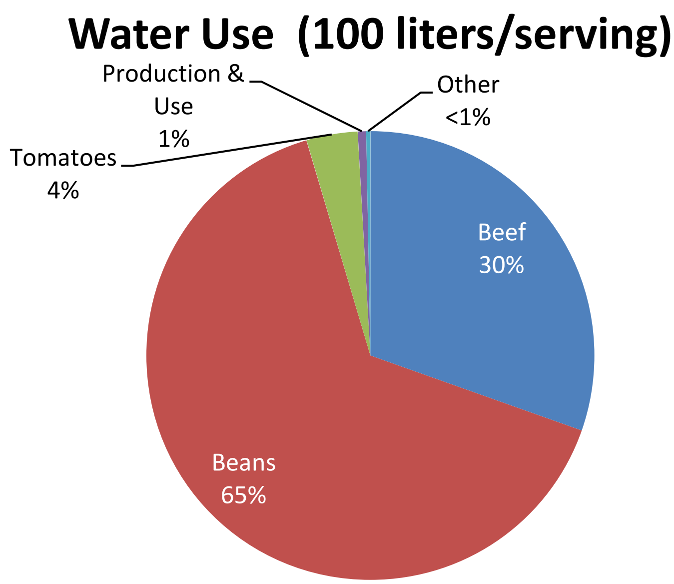


Figure 8 shows another view of the sources of climate change for the pouch scenario. This chart disaggregates the ingredient inputs category to show the contributions of individual inputs. The production of the beef dominates the global warming potential for the pouch scenario. This is largely due to direct enteric emissions from the cattle and manure management. After beef production, the largest contributors to climate change are packaging, production, use, and transportation. It is important to keep in mind that, in reality, the impacts from transport and use will vary depending on the location and method of final preparation. The total per-serving climate change impact is about 1.54 kg of CO_2 equivalent per serving. In the US, the average climate change impact per person-day is about 75 kg of CO_2 equivalent[xxvii].

Figure 9: Pouch Scenario - Process Contribution to Water Use



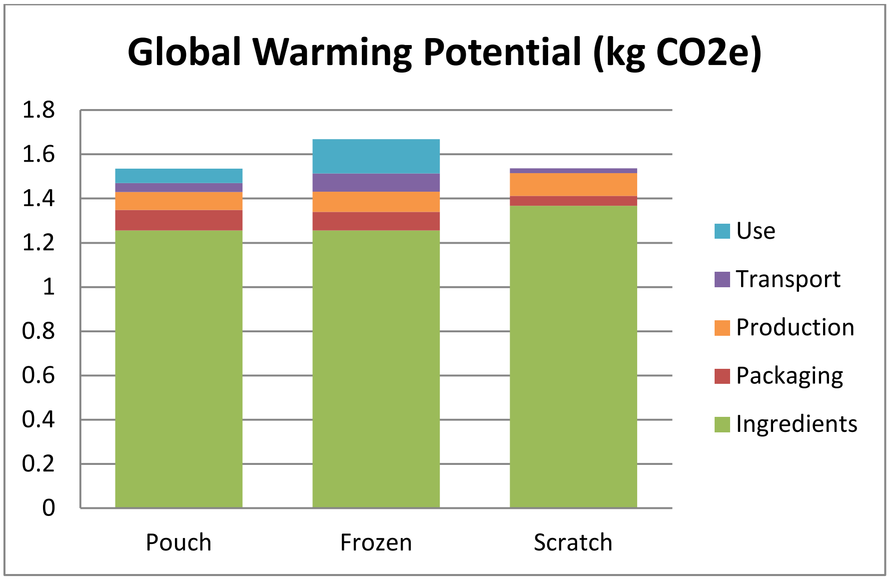
Agricultural products contribute the most to the life cycle water use of the chili. Combined, the beans and beef constitute over 90% of the total water freshwater consumed (see figure 9). The majority of the water consumption comes from irrigation of the beans. The majority of the water consumption attributed to the beef is surface water consumed by cattle at the ranch.

Over 99% of the land occupied over the life cycle of all three scenarios occurs during the production of ingredient inputs, especially the beef. The ranch utilizes over 50,000 hectares of public and private land for its operations. Other agricultural processes contribute to land use, as do transportation infrastructure and packaging materials made from forest products. However, the relative contribution to total land use is very small when compared to the beef production.

Scenario Comparison

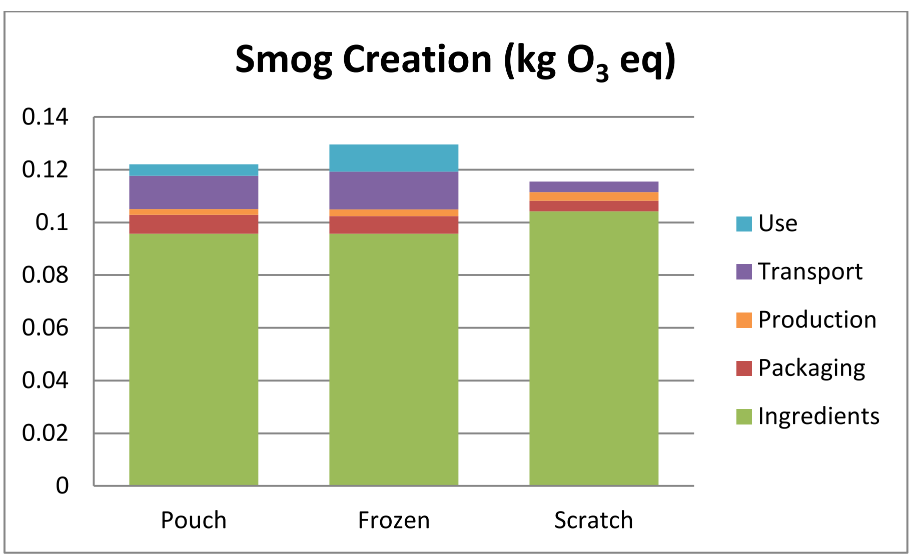
This section presents and compares the life cycle impact results of each scenario. The charts highlight a select group of impact categories. Complete impact results for the pouch, frozen and scratch scenarios are provided in Tables 6, 7, and 8, respectively.

Figure 10: Pouch - Global Warming Potential



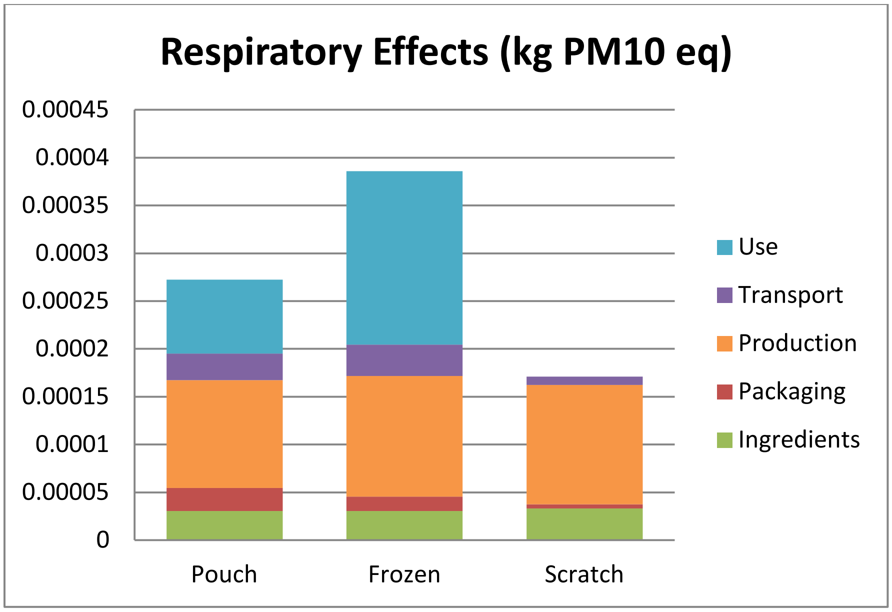
There is not a significant difference in the global warming potentials of the three scenarios. The frozen scenario has a slightly greater impact than the pouch in use and transportation because of the need for refrigeration and the lack of rail transport in the distribution. The higher waste rate of the scratch chili compared to the frozen or pouched chili is the cause of the higher contribution of ingredient inputs for this scenario.

Figure 11: Pouch - Smog Creation Potential



The differences between the scenarios are not significant for smog creation either. Unlike the pouch and frozen scenarios, the scratch scenario does not have distribution after production. The use phase is the main source of difference between the pouch and frozen scenarios for this impact. This is likely due to the use of a US average energy mix which includes electricity from coal power plants. The use phase impacts for all scenarios would be less in areas with cleaner energy production.

Figure 12: Pouch - Respiratory Effects



Ecotoxicity and respiratory effects shows a greater contrast among the scenarios' impacts. These impact categories are also the only categories that are not completely dominated by the farm inputs. Again the use phase is the main source of difference between the pouch and frozen scenarios for respiratory effects. As was the case with smog creation, these impacts originate from electricity generation and will vary depending on the actual energy mix.

While this data has allowed us to model certain aspects of the life cycle with some confidence, this study shows that the significant differences among the three scenarios (retorted pouch, frozen and made from scratch) occur almost entirely in the distribution and use stages. In this study, the impacts from these stages were based on the baseline estimates of the energy required to heat or cool the chili. In reality, the actual energy consumed by these stages will vary greatly depending on a number of variables, including the method of heating, and the planning decisions of kitchen staff.

Although not displayed here, land use is dominated by beef production. Over 90 percent of the land use is attributed to cattle production. This high number is due to the extensive (rather than intensive) ranching practices of the beef producer. The stocking rate was 0.02 animals per acre, compared to many animals per acre in intensive production . The ranching, and grass-fed practices may maintain the ecosystems in better condition than intensive cattle production on feed lots, but more land is required to raise the same amount of beef.

Complete Impact Results

The full life cycle impacts of each scenario are presented in the following tables (6, 7, and 8). Impacts are divided into life cycle stages to show the relative contribution of each stage to the total.

Table 6: Pouch Scenario Impacts

Impact category	Unit	Ingredient	Packaging	Production	Transport	Use	TOTAL
Climate Change	kg CO_2 eq	1.3	0.23	0.08	0.04	0.07	**1.5**
Acidification	mol H+ eq	2.0	0.11	0.04	0.02	0.03	**2.1**
Respiratory effects	g PM10 eq	0.03	0.23	0.11	0.03	0.08	**0.3**
Eutrophication	g N eq	9.3	0.11	0.87	0.02	0.01	**10**
Ozone depletion	µg CFC-11 eq	43	0.40	0.04	0.002	0.001	**44**
Ecotoxicity	CTUe	0.13	0.37	0.10	0.10	0.025	**0.39**
Smog	g O_3 eq	96	14.21	2.14	12.63	4.42	**120**
Land use	m^2-years	580	0.92	0.001	0.07	0.00	**580**
Water	Liters	99	0.0	0.10	0.0	0.50	**100**

Table 7: Frozen Scenario Impacts

Impact category	Unit	Ingredient	Packaging	Production	Transport	Use	TOTAL
Climate Change	kg CO_2 eq	1.3	0.08	0.09	0.08	0.15	**1.7**
Acidification	mol H+ eq	2.0	0.04	0.04	0.03	0.07	**2.1**
Respiratory Effects	g PM10 eq	0.03	0.02	0.13	0.03	0.18	**0.4**
Eutrophication	g N eq	9.3	0.04	0.87	0.03	0.02	**10**
Ozone Depletion	µg CFC-11 eq	43	0.24	0.06	0.004	0.003	**44**
Ecotoxicity	CTUe	0.13	0.015	0.11	0.24	0.059	**0.55**
Smog	g O_3 eq	96	6.7	2.6	14	10	**130**
Land use	m^2-years	580	0.92	0.001	0.7	0.0	**580**
Water	Liters	99	0.00	0.10	0.0	0.0	**99**

Table 8: Scratch Scenario Impacts

Impact category	Unit	Ingredient	Packaging	Production	Transport	Total
Climate Change	kg CO_2 eq	1.4	0.05	0.10	0.02	**1.5**
Acidification	mol H+ eq	2.1	0.02	0.04	0.01	**2.2**
Respiratory Effects	g PM10 eq	0.03	0.004	0.12	0.01	**0.2**
Eutrophication	g N eq	10	0.02	1.00	0.01	**11**
Ozone Depletion	µg CFC-11 eq	47	0.13	0.10	0.001	**47**
Ecotoxicity	CTUe	0.14	0.002	0.13	0.053	**0.33**

Impact category	Unit	Ingredient	Packaging	Production	Transport	Total
Smog	g O_3 eq	104	4.0	3.3	4.0	**120**
Land	m^2-years	630	0.59	0.001	0.014	**630**
Water	Liters	110	0.00	0.02	0.00	**110**

The packaging represents no more than ten percent of any environmental impact.   Note that the packaging includes all primary, secondary and ancillary packaging in the entire life cycle of the product. The retorted pouch represents less than three percent of the total packaging mass.

Transportation dominates respiratory effects, and ecotoxicity impact categories, but has little effect elsewhere. These impacts are driven by the emissions of diesel engines in trucks. Some of the ingredients were grown in India, but even so we see that the distance of travel via container vessel is not an important contributor to the overall environmental impacts of the product. The travelof the consumer to the restaurant was not included in this analysis.

The following table provides a side-by-side comparison of the total impacts for the three scenarios. For some impacts categories, there is very little difference among the three scenarios. In fact, the difference between the pouch and frozen scenario is not significant for any of the impact categories. The scratch scenario has greater impacts for some categories due mainly to the waste rate.

Table 9: Scenario Impact Comparison

Impact category	Unit	Pouch	Frozen	Scratch
Climate Change	kg CO_2 eq	1.5	1.7	1.5
Acidification	mol H+ eq	2.1	2.1	2.2
Respiratory Effects	g PM10 eq	0.3	0.4	0.2
Eutrophication	g N eq	10.2	10.3	11.2
Ozone Depletion	µg CFC-11 eq	44	44	47
Ecotoxicity	CTUe	0.39	0.55	0.32
Smog	g O_3 eq	120	120	120
Land	m^2-years	580	580	630
Water	Liters	100	99	110

Sensitivity Analyses

Sensitivity analyses test the change in the outputs of a model when the inputs are altered. They provide a way to identify how important variability in an input to a model (e.g. the amount of energy used for cooking) could affect the calculated results. They are an important tool in LCA and are required by the ISO 14044 standard.

Use Phase Energy Consumption

Energy consumption in the use phase occurs during the reheating of the frozen and pouched and chili, as well as in the storage of the frozen chili. Sensitivity analyses were performed to assess the effects of energy efficiency and storage life on the total life cycle impacts for these scenarios.

Cooking

The energy consumed while reheating the chili was calculated by first determining the minimum amount of energy required to reheat the chili based on its physical properties and then applying an energy conversion efficiency factor. A baseline efficiency of 50% was selected for the main analysis, however, in reality the conversion efficiency of stovetop cooking varies greatly depending on the circumstance. A minimum efficiency of 10% and a maximum efficiency of 90% were selected to show a wide range of variability. Below, the results of the analysis are presented alongside the baseline case. The effects of use phase energy consumption on water and land use are negligible and have been omitted from the sensitivity analysis.

Table 10: Pouch Scenario – Sensitivity to Efficiency of Reheating Chili

		Baseline (50%)	Low Efficiency (10%)		High Efficiency (90%)	
Impact Category	**Unit**	**Amount**	**Amount**	***% Change***	**Amount**	***% Change***
Climate Change	kg CO_2 eq	**1.5**	1.8	17%	1.5	-2%
Acidification	mol H+ eq	**2.1**	2.2	6%	2.1	0%
Respiratory Effects	g PM10 eq	**0.3**	0.6	113%	0.2	-13%
Eutrophication	g N eq	**10**	10	0%	10	0
Ozone Depletion	ug CFC-11 eq	**44**	44	0%	44	0
Ecotoxicity	CTUe	**0.39**	0.49	26%	0.38	-3%
Smog	g O_3 eq	**120**	140	14%	120	-2%

Table 11: Frozen Scenario – Sensitivity to Efficiency of Reheating Chili

		Baseline (50%	Low Efficiency (10%)		High Efficiency (90%)	
Impact Category	**Unit**	**Amount**	**Amount**	***% Change***	**Amount**	***% Change***
Climate Change	kg CO_2 eq	**1.7**	1.9	16%	1.6	-2%
Acidification	mol H+ eq	**2.1**	2.2	5%	2.1	0%
Respiratory Effects	g PM10 eq	**0.4**	0.7	79%	0.4	-9%
Eutrophication	g N eq	**10**	10	0%	10	0%
Ozone Depletion	ug CFC-11 eq	**44**	44	0%	44	0%
Ecotoxicity	CTUe	**0.55**	0.65	18%	0.54	-2%
Smog	g O_3 eq	**130**	150	13%	130	-1%

As shown in tables 10 and 11, the results of this analysis for both of the scenarios are very similar. In both cases, high energy conversion efficiency does not greatly reduce the impacts for any of the categories. However, a very low energy efficiency greatly increases the impacts from categories that are affected by power generation such as climate change, respiratory effects, ecotoxicity, smog creation, and, to a lesser extent, acidification. With the exception of the respiratory effects, however, this effect was not comparable to the decreased efficiency. This indicates that most environmental impacts are weakly linked to the reheating unit process.

Cold Storage

A unique aspect of the frozen scenario is that it includes 3 month period of refrigerated storage. This section presents the results of an analysis that varied the storage period from zero months to 6 months (the maximum useful shelf-life of frozen chili) and compares those results to the baseline case of 3 months of storage.

Table 12 Frozen Scenario Sensitivity to Storage Period

		3 Months	0 Months		6 Months	
Impact Category	**Unit**	**Amount**	**Amount**	***% Change***	**Amount**	***% Change***
Climate Change	kg CO_2 eq	**1.7**	1.6	-5%	1.8	5%
Acidification	mol H+ eq	**2.1**	2.1	-2%	2.2	2%
Respiratory Effects	g PM10 eq	**0.4**	0.3	-27%	0.5	27%
Eutrophication	g N eq	**10**	10	0%	10.3	0%
Ozone Depletion	ug CFC-11 eq	**44**	44	0%	44	0%
Ecotoxicity	CTUe	**0.55**	0.52	-6%	0.59	6%
Smog	g O_3 eq	**130**	120	-5%	136	5%

This analysis (table 12) shows that the length of storage for the frozen chili does not create significant changes in the total impacts for many of the impact categories. However, because this analysis is varied the amount of electricity consumed during storage, categories which are affected by power generation show the greatest variability.

The Effect of Excess Preparation

This analysis hypothesizes a situation where 100 servings of chili have been prepared using each of the three options: (1) Boiled in a retort pouch; (2) Frozen chili removed from packaging; (3) chili made from scratch. The goal was to determine how over-preparation effects the life cycle impacts per serving of chili consumed. We assume that any chili that has been unsealed and is not consumed must be discarded and cannot be eaten. This is the most likely scenario (per Truitt Brothers and Ampac): although the leftover frozen or scratch chili can be refrigerated and served within a day or two, this is unlikely to happen unless chili is a permanent menu item. As a result, the impacts associated with the production of wasted chili must be distributed across the chili that was actually served.

Figure 13 Climate Change (Global Warming Potential) Impact due to Waste

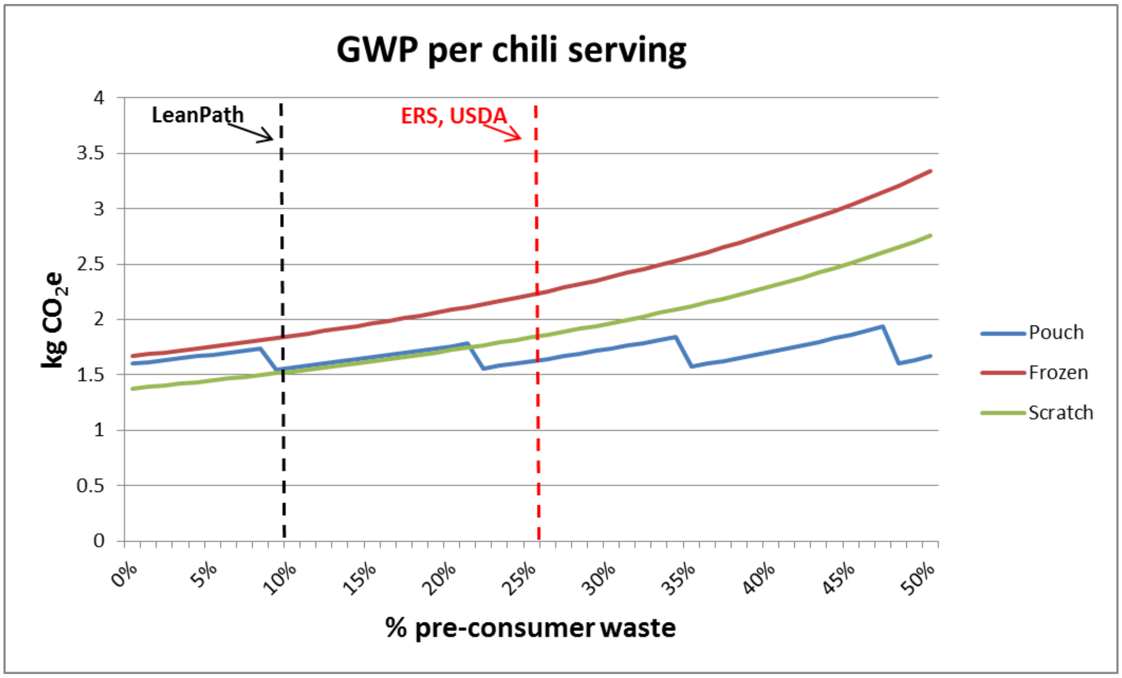


Figure 13 shows how climate change impacts (Global Warming Potential or GWP) per serving increase as more chili is wasted. In the frozen and scratch scenarios, we assume that once chili has been prepared it must be consumed or it is discarded. Both of the frozen and scratch scenarios show a continuous increase in Climate Change impact per serving as the number of servings consumed decreases. The jagged shape of the line representing the pouch scenario is a result of the pouch's ability to be saved for use another day. As long as a pouch's seal has not been broken, only the impacts of its reheating and not its production are attributed to the servings that are consumed. Each dip in this line is caused by the removal of a sealed pouch: the maximum waste is 12 servings of chili because the retorted pouch contains 13 servings.

The impact per serving of the scratch scenario is initially less than the other two. This seems to contradict the results presented in the previous section where the scratch and pouch scenario impacts are equal. This is because the main analysis assumed a waste rate in the scratch scenario of 10%, per the LeanPath results. In the chart above it is clear that the scratch and pouch scenario become equivalent at 10% waste.

The black and red dotted lines represent estimates of food waste from the LeanPath study (a minimum estimate, as discussed above) and the Economic Research Service of the USDA[xxviii], respectively. The ERS study included both production and post consumer (plate) waste. As the proportion of waste approaches the LeanPath line, the chili in the pouch has comparable impacts to the scratch scenario. As the amount of chili wasted increases to the USDA estimate of 26% of food wasted, the pouched chili has less impact than the scratch scenario. A recent study by Business for Social Responsibility (BSR) on behalf of the Grocery Manufacturer's Association (CMA) and the Food Marketing Institute (FMI) found that 12 to 20% (39.7 Million tons) of the food that leaves the farm is sent to disposal prior to consumption, with an additional 21 million tons diverted for use as animal feed[xxix]. These figures agree well with the Lean Path estimate.

At higher waste levels, the retorted pouch container can save half of the climate change impacts or more. Because the serving step (the last step in the life cycle assessment) is the point of waste, the effect of sparing environmental impacts over the life cycle of the wasted food will be the same in the other impact categories as well.

This analysis is sensitive to the relationship between the amount of servings initially prepared and the number of servings in each pouch.

The waste analysis showed that the pouch scenario begins to have a significant environmental advantage over the other two scenarios as the amount of chili that is not consumed approaches the USDA estimate of food waste. Another, more recent, report by the FAO suggests that the USDA estimate is not unrealistic. In fact, the report authors estimated that consumption waste rates in North America could be as high as 33%[xxx]. This rate is likely to be higher in food service because of the health requirements that mandate discarding food that is not consumed. Thus, the calculation of the differences among the scenarios based on food waste rising beyond 26% is not unreasonable, and may in fact represent the true situation in the majority of restaurants.

Conclusion and Discussion

The upstream impacts of growing the ingredients for the Truitt Brothers chili dominate the life cycle impacts of the chili for every impact category except respiratory effects and ecotoxicity. In this respect, the life cycle assessment is typical of the majority of food LCA studies[xxxi]. However, the food industry continues to evaluate the life cycle impacts of packaging independent of their contents, for example the recent IFEU[xxxii] (2012) study on the packaging in Europe.

Transportation represents a very small proportion of the total environmental impacts for every impact category except respiratory effects and ecotoxicity. This illustrates how food miles are not an important determiner of the environmental impact of food[xxxiii]. There are good social reasons for supporting local farms, such as community welfare and food security, but overall environmental performance is little affected by food miles.

Climate change impacts are dominated by the production of beef. This is because the enteric fermentation of these ruminants releases substantial amounts of methane, a potent greenhouse gas. Truitt Brothers could help decrease greenhouse gas production by promoting its vegetarian option chili over its beef containing chili.

Water consumption is dominated by the irrigation of beans, followed by the consumption of water by cattle. The use of water by cattle cannot be reasonably reduced, but it may be possible to support dry land farming of beans. However, the inevitable result of dry-land farming is that yields are lower, and it takes more land to grow the same amount of crops. This is a clear tradeoff between land use and water use, and it is a value judgment which one is better.

The impacts of the packaging systems evaluated here are never more than 9% of the total impact in any impact category, and usually much less. The impacts of the retorted pouches are an even smaller proportion of the total impacts of the chili life cycle.

The real environmental impacts of packaging can be seen in its ability to reduce food waste. Although the impacts of the packaging itself are quite small, the impact the packaging may have on the food waste can be quite large, decreasing the environmental impacts by as much as 50 percent or more in the case of very high waste. This is most evident in the case where the demand for the product is unpredictable. The pre-consumer food waste measured by LeanPath and reported here is about 10% for the case of school food service. This situation is likely to be the most predictable food service situation: the number of clients and their composition are consistent from day to day. Most restaurants have more variable clienteles.

The primary function of all packaging is to preserve the contents of the package in acceptable condition until they are used. While it is easy to point to packaging as an environmental burden, in fact the environmental impact of producing the contents of the package is typically much larger than the environmental impacts of producing and disposing of the packaging. Thus, the packaging with the largest impact is the packaging that fails, because not only is the package wasted, but the contents of the package (with all their imbedded upstream environmental impacts) are also wasted.

This does not mean that packaging manufacturers should ignore the opportunities to improve the environmental impacts of their packaging. Indeed the clear benefits of a shelf-stable retort package over a frozen package are shown in this report. It does mean that such environmental improvements are best viewed in the context of product protection.

This report highlights the environmental impacts of food waste and the retort pouch's ability to mitigate these impacts.

Acknowledgements

This study has an unusually high proportion of primary data included. This would not be possible without the generous sharing of data by both Truitt Brothers and by vendors to Truitt Brothers. We wish to thank the staff of Lean Path, Country Natural Beef, Central Bean, Ampac and Brucepac for assisting with data collection for this study.

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