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Comparison of carbon footprints of school lunches in Dangriga, Belize, and Northwest Arkansas

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Abstract

The original purpose of this study was to investigate differences in carbon footprints of school lunches by comparing a school in Arkansas, USA, and a school in Belize. Due to complications imposed by the COVID-19 pandemic, the purpose was revised to gathering preliminary data about the school lunch program at a school in Northwest Arkansas; data were to be used to estimate CO2-equivalent emissions for cafeteria energy use, meal ingredients from the two most popular meals served, and food transportation at the last point in the supply chain (food service delivery to school). This study highlights the intersection of food systems and climate change. As the effects of climate change worsen, it is important to consider ways to reduce emissions in a variety of sectors, including the food sector, to reduce future effects of anthropogenic climate change and reduce risks related to food security. The study investigated the kg CO2-eq emissions of two popular meals served based on interviews conducted with cafeteria staff in a selected school in Northwest Arkansas. The methodology section outlines suggested data collection for when researchers can visit Belize to complete the study and describes methods for estimating CO2-eq values for different aspects of meal preparation and the supply chain. The absence of specific information for certain foods or distributors made it difficult to draw conclusions in some cases. Estimates from the study show the overall CO2-eq for the "beefy nachos" meal to be much greater than the chicken tender meal, likely due to the larger carbon footprints of beef and cheese production compared to chicken and potatoes. Energy use estimates to prepare each meal were small relative to the estimated overall carbon footprint of each meal. Most of the carbon footprint related to the production of the food itself. To perform more detailed calculations in the future, it is recommended that data collection be conducted on site for both schools, and for researchers to use programs such as SimaPro or OpenLCA to find

more specific data values to perform calculations. Ultimately, this will allow for more accurate comparisons of lunches at both schools that will be beneficial in finding ways to reduce emissions of lunches where possible.

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Introduction

Background and Need

Virtually everything humans do has an impact on the planet; this includes travel habits, morning commutes, charging cell phones, and even choices at the grocery store. Some refer to this as a "carbon footprint". According to the Merriam Webster Dictionary, a carbon footprint is defined as "the amount of greenhouse gases and specifically carbon dioxide emitted by something (such as a person's activities or a product's manufacture and transport) during a given period" (Merriam-Webster, n.d., Dictionary section). People's everyday choices and consumption habits affect their carbon footprint, with food being one of those choices. For example, in a comparative study, it was found that a healthy vegetarian diet reduced overall greenhouse gas emissions by about 32% compared to a baseline American diet (Hitaj et al., 2019). Although transportation of food has less of an impact on greenhouse gas emissions than production for traditional diets including animal products, transportation still plays a role in fossil fuel combustion which still accounts for 56% of the emissions in the baseline American diet according to the same study (Hitaj et al., 2019, Figure 1). Atmospheric concentrations of greenhouse gas emissions are the central antecedent of global climate change, and the food system has significantly contributed to those emissions (Xu, Z., et al., 2014). Collectively, greenhouse gas emissions contribute to the warming effect, which has several consequences that many people experience today including changes in weather, challenges in agriculture, and food security.

The Intergovernmental Panel on Climate Change (IPCC) report predicts "Reductions in projected food availability are larger at 2°C than at 1.5°C of global warming" for various regions of the world (Hoegh-Guldberg, et al., 2018, p. 180). The IPCC report validates that anthropogenic climate change will further exacerbate issues of food security, however, there are already many disparities in food security around the world today. Elkins (2021) suggested in a recent article that erratic weather brought on by climate change has already reduced expected crop yields and may have a future impact on our ability to grow enough food, especially in Europe and Africa. Numerous studies have reported that climate changes have significant impacts on agricultural land which directly affects food security (IPCC, 2007; Liliana, 2005 World Bank, 2016). While the global population continues to grow, the rates that climate change and production of food have been increasing are not equal.

Disparities in food security are evident when comparing the food insecurity in Belize and in Northwest Arkansas. For instance, based on a survey sample of the population by Harris (2018), it was estimated that approximately 22.73% of the general population (n=22) and 36.36% of farmers (n=38) in Dangriga, Stann Creek, Belize reported experiencing food insecurity within 12 months of the survey. In Northwest Arkansas, 14% of the population is food insecure (Fitzpatrick, 2018). According to the USDA, rates of food insecurity in Belize and Northwest Arkansas are higher than the United States average, which is 10.5% of households (United States, 2020). Research cited above (Hitaj et al., 2019, Hoegh-Guldberg, et al., 2018 Xu, Z., et al., 2014) supports the connections between food production and climate change. Although food insecurity today is not caused by climate change alone, existing food insecurity and issues of soil health will be exacerbated by climate impacts. The future perils of food insecurity and the environment are inherently related, therefore interwoven solutions can be used to thwart the worsening effects of both concerns.

Various studies have explored climate impacts of crop yields, consumption habits, and supply chain, particularly in areas such as Sub-Saharan Africa (Masipa, 2017), but few have focused on food systems of school lunch programs (Ribal, etal., 2016, Saarinen, et al., 2012, Sottile, et al., 2016). School lunch programs provide meals to students around the world. The main priority for some schools is simply to provide access to food for students without concern for being environmentally conscious. However, minimizing environmental impacts of these meals where feasible (sustainable farming practices, reduced transportation of good to the end user, and reduced waste) could add up to a substantial decrease in greenhouse gas (GHG) emissions, therefore contributing to the effort to prevent worsening climate change and to decrease food insecurity in the future.

These data will provide a new perspective by comparing countries of two different levels of HDI development. According to the United Nations, the United States has a Human Development Index (HDI) score of 0.926 and is ranked 17th in the world, while Belize has an HDI score of 0.716 and is ranked 110th in development (United Nations, n.d.). Although some GHG reduction methods may not be applicable to schools worldwide, a comparison of school lunch programs in a more developed country with those of a less developed country might highlight key differences that affect the overall carbon footprint of a lunch. Data could eventually be used to strategize ways to reduce the GHG emissions of lunches where possible.

Although some solutions may address food security or food emissions separately, long term food security is influenced by many factors, one being climate change-causing emissions from the food systems. This project is significant as it analyzes economic, ethical, and environmental factors simultaneously by comparing communities which vary in levels of development, food security, and potentially environmental impact; this allows for the potential that data collected in this study can be used by both countries to learn from each other and tackle complex problems simultaneously, taking steps toward a more sustainable and secure food system.

Problem Statement

As climate change becomes increasingly apparent, food security is increasingly threatened. Food production and consumption habits and the food supply chain directly impact the planet. Current agricultural practices are not sustainable for achieving food security in the face of climate change and a growing population. For example, models for soil degradation estimate one-quarter of land on Earth to be highly degraded, and in the face of climate change, the potential for agricultural productivity will likely continue to decrease, presenting a major threat to food security (Gomiero, 2016, section 1.4). Liliana (2005) reported that by the year 2025, approximately 66% of Africa's arable land is likely to be lost due to lack of rainfall and increased drought, decreasing agricultural production. Extremes may soon resonate around the world.

There are evident disparities in both the agricultural production as well as the carbon footprint of citizens of Belize of the United States as explored in the background and need. In addition, Americans are overconsuming and wasting food, as illustrated by the fact that food made up 24.14% of the waste sent to landfills in the United States in 2018 (*National Overview*, 2018), illustrating discrepancies in the supply chain, distribution, and use of food in the United States. As a consequence of an increasing population and the worsening effects of climate change, the food supply for students in Belize and the United States (and other areas globally as well) may become unstable. Elkins (2021) predicted decreases in crop yields, which demonstrates potential concerns for future food security.

Purpose of the Study

The original purpose of this study was to compare the accessibility and cost of fresh produce, as well as the carbon footprint of school lunches in Northwest Arkansas with school lunches at St. Matthew's Anglican School near Dangriga, Belize, which uses a school garden to supply fresh produce for lunches. However, due to COVID-19, the project purpose and objectives had to be modified. The purpose shifted to gathering data from Helen Tyson Middle School in Springdale, Arkansas to make preliminary determinations on what information will be most beneficial to collect once students can travel to Belize and make a comparison between schools.

Research Objectives – as altered by COVID-19

The following objectives guided the completion of this study:

- To identify two commonly served school lunches in Northwest Arkansas; Using ingredients provided, identify out-sourcing versus local food suppliers and calculating approximate miles of transportation,
- To survey energy consumption of appliances in the cafeteria facility used to prepare common meals
- To evaluate the food preparation process with considerations of number of students served, energy use, packaging, and food waste
- To propose a list of information which should be gathered to make accurate comparisons between schools in the future.

COVID-19 Impact Statement

Two study abroad trips to Belize were cancelled due to COVID-19 during the time this research project was planned. Though the plan was to conduct a more comprehensive Life Cycle

Assessment of the foods used to make the school lunches both in Belize and Northwest Arkansas and an assessment of accessibility of fresh foods in Belize, the researchers ultimately had to pivot due to delays and complications from the COVID-19 pandemic. The research methodology was revised to be broader in scope and hypothesized the impact of the foods and lunches on the environment rather than quantifying the impact through detailed analysis of carbon dioxide equivalents. Institutional Review Board approvals were delayed due to COVID as well. Approval was granted on April 6, 2022 (approval letter in Appendix A), though the application was made in January immediately after knowing the trip to Belize was again cancelled. As a result, data collection was delayed which didn’t leave enough time to complete the study. The survey instrument previously created was modified to reflect the new goal and objectives of this study as originally proposed. The researcher would have liked to provide more quantifiable data but hopes another student will continue with this project to complete the goals and objectives originally proposed.

Literature Review

This section begins with general background information on each country in which data were collected, and then reviews recent sustainability initiatives regarding school lunches around the world. Food insecurity is defined and addressed for the local regions of Stann Creek, Belize and Northwest Arkansas, and accessibility of fresh foods is described Belize and the United States Next, the impact of carbon footprints on climate change and environmental dangers to the modern food system are discussed. Finally, the term carbon footprint is defined, various methodologies for assessing carbon footprint are explored, as well as the significance of using this tool as it relates to climate change.

General Statistics

In this section, demographic information for each country in which data were collected will be presented. Belize is a country located in Latin America. About 46% of residents in Belize live in urban areas, compared to about 83% of residents in the United States (Urbanization, 2018). The school in which data were collected is located in the Stann Creek Region of Belize. Stann Creek's total population in 2018 was 43,459, with 10,442 residents living in the city of Dangriga, and 33,017 residents living in rural areas (Annual Report, 2019). The Stann Creek District had an average unemployment rate of 11.9% in 2018 (Annual Report, 2019) compared to a 6.1% unemployment rate in Arkansas in 2020 (Unemployment Rates for States, 2020). More specifically the city of Springdale, Arkansas, the location of the school used in this study, had a poverty rate of 20.7% (Springdale City, 2019), and 14.39% of Belize's population was living in extreme poverty in 2019 (Global Extreme Poverty, 2019). The life expectancies in each country are relatively similar, with Belize and the United States having life expectancies of 74.6 and 78.9 years respectively (Life Expectancy, 2019). However, the countries differ when it comes to nutritional deficiency. In 2019 Belize had a child iron deficiency rate of 20.2 %, compared to 6.1% in the United States (Micronutrient Deficiency, 2017).

Sustainable School Lunch Initiatives

A variety of initiatives around the world are looking into making school lunches more sustainable. One study developed a methodology for assessing the sustainability of school gardens in Kenya (Sottile, et al., 2016). This school garden project not only minimized food transportation, but also sought out research that could reduce other environmental impacts of the gardens such as water use, agricultural inputs, etc. In addition, a case study in Europe set out to design lunch programs which were climate friendly, economically conscious, and nutritious

(Ribal, et al., 2016). Another European study which took place in Finland also explored climate and eutrophication impacts of a variety of school lunches and home-made lunches. Saarinen, et al. (2012) found that choice of protein source made a major difference in environmental impact, and that based on the sample, home-made lunches in Finland had greater environmental impacts than school lunches due to raw material and energy consumption. Although various environmental impacts of school lunches have been explored in these studies, there is a lack of literature which relates this topic to both varying levels of development and food insecurity.

Food Insecurity in Belize and Northwest Arkansas

In addition to the challenges presented by climate change, many people presently experience food insecurity worldwide. The Food and Agriculture Organization states that "a person is food insecure when they lack regular access to enough safe and nutritious food for normal growth and development and an active and healthy life" (FAO, n.d., What is food insecurity? section). In the Stann Creek region of Belize, which is near the school used in this study, the percentage of the population experiencing food insecurity is about 10% greater compared to the global percentage, and about 4% higher compared to the region of Latin America and the Caribbean (Harris, 2018; Smith & Meade, 2019). Food insecurity of Northwest Arkansas is experienced at a lower rate than globally, but at about a 2% higher rate compared to North America, and 3.5% higher rate compared to the United States (Fitzpatrick 2018; Smith & Meade 2019; United States Department of Agriculture, 2020).

Accessibility of Fresh Foods

People who are considered food secure can still lack access to fresh foods. People in the United States experiencing a lack of food that is both nutritious and reasonably priced live in locations called food deserts (Ver Ploeg, Nulph, & Williams, 2011). According to the USDA, a significant number of residents in multiple census tracts in Fayetteville and Springdale, Arkansas, are considered both Low Income and Low Access, and also lack vehicle access; this means that residents live in a low-income area where groceries are greater than one mile away for urban dwellers and greater than 10 miles away for rural dwellers (Measuring Access to Food, n.d.) In Dangriga, Belize, a survey of 22 members of the general population found that “over 95% of [adults] reported having access to meat each day, while 85.71% revealed they had access to fresh fruits and vegetables” (Harris, 2018, p. 21). Prices of food can also challenge access to fresh and nutritious foods. In Belize, 38.11% of the population cannot afford a healthy diet, while only 1.5% of the population could not afford a healthy diet in the United States in 2017 (Food Prices, 2013). Data shows that the cost of a healthy diet per day in Belize is just slightly less than the cost per day in the United States. However, the portion of average spending required to pay for a healthy diet in Belize is much higher at 118.74%, compared to the United States which requires spending 42.41% of average spending to pay for a healthy diet (Food Prices, 2013). Although the international equivalent dollar amount required to pay for healthy food is less in Belize, the cost of healthy food is still much higher relative to average income in Belize than in the United States.

Threats to Today’s Food System

Current food systems have become remarkably complex and interconnected. Food systems have a life cycle of production and processing starting with farming, harvesting, packaging, transportation to grocery stores, consumption, and finally waste (Xu, Z.,et al., 2014). Although food begins with agriculture, popular farming methods have led to excessive deforestation, scarcity of arable land, and soil degradation, leaving humans with a limited foundation for continuing future crop production (Gomiero, 2016). In addition to the challenges of degraded lands, the effects of climate change such as more frequent and intense storms, weather extremes, and water scarcity will likely put the security of the food system in jeopardy (Hoegh-Guldberg, et al., 2018).

Threats to potential food production are not the only weakness of today's food systems. The final stage in the food supply chain also impacts climate change, since nearly one-quarter of landfills in the United States are composed of food waste, releasing a comparably more potent greenhouse gas, methane (National Overview, 2018). A study on food waste in Brazil showed that fruit and vegetable losses often occur post-harvest due to transportation, improper hygiene, and lack of proper food infrastructure to store the produce (Santos, et al., 2020). Even if adequate food is grown and has the capacity for transport, much produce is wasted and does not reach communities in need. The fact that food is being thrown away demonstrates telling issues in the food system.

Carbon Footprints of Food and Climate Change

A carbon footprint is a tool used to compare relative greenhouse gas emissions of different industries, energy sources, or products (Merriam-Webster, n.d.). Carbon footprints are established using a variety of different calculations and methodologies. For example, when calculating the carbon footprint of a particular food, energy consumption and emissions are taken into account throughout the various stages of agricultural production including farmland and machinery emissions, processing and packaging, power and transportation, and even enteric fermentation and emission from manures for animal products (Xu, X. & Lan, Y., 2016).

Carbon footprints of animal-based foods have a significantly greater impact on the environment largely due to methane emissions, animal feed production, and land use, and therefore, are a preeminent contributor to climate change in comparison to most plant-based foods (Xu, X. & Lan, Y., 2016). Switching to a vegetarian or plant-based diet can assist in lowering atmospheric greenhouse gas concentrations and may reduce the potential impacts of climate change (Hitaj, 2019). When calculating the carbon footprint of food, food contributes significantly to emissions globally. Based on data from 2001, Hertwich found that the food supply chain, as an anthropogenic source of emissions, was responsible for about one-fifth of total global emissions (Hertwich, 2009). Anthropogenic greenhouse gas emissions are considered to be the most prominent driver of climate change (Xu, X. & Lan, Y., 2016). As atmospheric greenhouse gas emissions continue to rise, the need to reduce overall emissions becomes increasingly apparent, and reductions in the food and agricultural sector have the potential to make a powerful contribution to lowering overall emissions (Xu, Z., et al., 2014).

The intersection of agricultural practices, climate change, and food security is evident. Calculating a carbon footprint is beneficial for identifying areas of the food system that could be improved to simultaneously address food security and greenhouse gas emissions. In regions such as Stann Creek and Northwest Arkansas, which both suffer from greater food insecurity compared to their respective surrounding regions, analyzing local food systems, and assessing the carbon footprint would be especially helpful from both an environmental and nutritional perspective.

Methodology

This section provides details on the type of study chosen and justifies the approach by providing examples of studies using a similar approach. In addition, the rigor of the study is addressed to ensure that adequate steps were taken to provide accurate and meaningful data within the constraints of time and access to the schools during COVID-19. The methods for collecting data are described along with the process of calculating carbon footprints at each school. Specifics regarding the two locations of potential data collection are also provided. Extenuating circumstances due to COVID-19 meant that the original methodology intended for this study could not be fully carried out within the time constraints. Therefore, the methodology section outlines methods for future researchers to complete data collection and wrap up the study, and describes the process used to estimate energy usage at Helen Tyson Middle School.

Research Design

This study used a quantitative non-experimental comparative research design. Comparative research involves a systemized process for identifying key differences and similarities of items of interest for a specific purpose and has been used for "educational exchanges" and "curiosity about other cultures" (Bukhari, 2011). A comparative research design was selected to support the analysis of environmental impacts of school lunches in the United States and Belize, which have many distinctions including different levels of development, food security, and different methods of sourcing school lunches. A comparative research design was previously used in a case study investigating greenhouse gas emissions of construction methods, where the emissions of two sites using different methods were quantitatively compared to determine possible methods of greenhouse gas emission reduction (Mao, et al., 2013). The construction study had a similar goal to this study, comparing emissions of two different sites to find potential ways to reduce overall emissions. The comparative design for this study supported the goal of the study which was to allow researchers to analyze differences and share methods that can potentially benefit both Belize and Northwest Arkansas in the aspects of sustainability and food accessibility.

Rigor

Within this study, an expert on the lunch program from each school was to be contacted. Each school was to be asked to provide the same information related to their school lunch programs. The requested information was reviewed by mentors for content validity to ensure the information requested aligned with the objectives of the study. The same information was to be requested from both the St. Matthew's Episcopal School and the chosen school in Northwest Arkansas to limit potential experimental biases.

Initially, several public elementary schools from a district in Northwest Arkansas were asked for consent to participate in this study, from which five schools that were willing to participate within that district would have been selected. After reviewing the proposal, the district was not willing to participate in the study for unspecified reasons. Therefore, the Helen Tyson Middle school was selected by convenience sample based on connections with a 6^{th} grade teacher at the school who was able to secure permission. St. Matthew's school was also selected by convenience sample due to accessibility and proximity during travel in Belize for an on-going service-learning project. Data from Belize were to be collected only from St. Matthew's school due to accessibility and proximity to the research location in Belize, as well as the time constraints of the study. The same data were to be collected from the cafeteria staff at each school. To calculate the carbon footprint of a lunch which is commonly served at each school, the same emissions values for specific foods and transportation methods, which are explained in the Instrumentation section, were to be used for each school to maintain consistency in calculations and an accurate comparison. Methods from other carbon footprint calculation methods were consulted and reviewed before preparing the methodology for this study.

Instrumentation

The information unique to each school and their lunch programs was to be gathered through communication with the respective staff at both schools being studied. Information was requested from the school in Northwest Arkansas including two commonly served meals, list of ingredients and portion sizes for each meal, and transportation method or food supplier used. This information was intended to be used to calculate the carbon footprints of each school lunch using Life Cycle Assessment (LCA) data. LCA data provide emissions values for various stages of the supply chain including raw material production, processing and packaging, storage, transportation, etc. for various products but can also be used for food production, processing, use, and waste evaluations (Design for the Environment, 2020). A similar process for calculating the carbon footprint of a meal was used for restaurants in a study (Pulkkinen, 2016), which included the use of LCA data, but used a simplified, less comprehensive assessment by mainly focusing on the raw material production and processing stages of the supply chain due to limited resources and data availability.

For this research project, it was intended that carbon footprints be evaluated by comparing carbon dioxide equivalent values or kg of CO2-eq. CO2-eq is a measure which considers emissions of carbon dioxide in addition to other greenhouse gases such as methane based on the potency of each greenhouse gas in relation to climate change, resulting in a total kg CO2-eq which demonstrates the total climate warming impact (How do I get Carbon, n.d.). A variety of LCA methodologies in literature often differ based on data limitations (Pulkkinen, 2015). Detailed LCA studies often use flow charts to define "system boundaries", or parts of the supply chain are included in the assessment (Tillman, et al., 1993); typically, the stages of an LCA study consist of an inventory of the impacts (raw materials acquisition, manufacture, processing, distribution and transportation, use, reuse, maintenance, recycling and waste disposal), an impact analysis that characterizes the effects on human health and the environment, and an improvement analysis to make changes to the life cycle based on findings (Levy, M., 2017). It was intended that calculations in this study would be primarily based on kg CO_2-eq from the raw material production stages (including land use change and farm stages) and transportation stages due to limited availability to data from other aspects of the supply chain such as energy use for specific preparation methods and appliances, packaging specifics, and food waste estimates which may not be reliable. Concentrating on these stages of the life cycle was supported by the fact that more than 80% of emissions for most foods comes from land use and farm stage emissions (Ritchie, 2020). Most other stages of the supply chain (e.g., packaging, retail) usually account for a smaller proportion of total emissions (Ritchie, 2020).

The working unit to be used to calculate carbon footprints at each school was a "typical" school lunch, or a representation of each of two commonly served meals, based on information gathered from cafeteria staff at each school. Originally, the aim was to use data collected from cafeteria staff to calculate the average carbon dioxide equivalent emissions for each meal (if possible).

Data Collection

This study was approved by the University of Arkansas IRB (protocol #2110367337) prior to collecting data and interacting with human subjects. Data for the school lunch program at Helen Tyson Middle School were collected through Zoom audio calls with the head cafeteria staff due to COVID-19 precautions, however, doing in-person site visits of the cafeterias would yield more complete information, especially with regard to the appliances used on a daily basis. The initial interview was conducted on March 16, 2022. Before beginning the interview, the researcher explained the project and the research participant's rights and received consent from the research participant. The research participant then provided information by answering interview questions regarding the existing school lunch program including two commonly served meals, a list of ingredients for each meal, portions of each ingredient per meal served, average number of students served per day, and methods and frequency of food deliveries. The interview also included questions pertaining to the disposal of leftover food and food scraps, food storage, preparation, and facility energy use. The Zoom audio call was recorded and transcribed for content analysis. After the initial interview, qualitative information from the recordings was organized in a Word document and quantitative data were categorized into an Excel spreadsheet. A follow up interview was conducted to clarify on March 26, 2022, to fill in missing data for certain food ingredients and clarify some information regarding most popular meal components. Additional phone and email correspondence occurred after the follow up interview to relay and clarify additional information used during the estimation processes.

School lunch program information for St. Mathew's school was intended to be collected on site while in Belize in January 2022 (a trip which was cancelled by the university). However, it is now intended that in-person interviews be conducted by a future researcher, as Zoom audio interviews were not possible with faculty at St. Matthew's school within the time constraints for this study.

Methods for Future Researchers

Future researchers should collect data from St. Matthew's School in Belize, and additional data collection from Helen Tyson Middle School in Springdale would be beneficial for making more accurate estimates and comparisons. Procedures and interview questions should be based upon the original interview transcript used for Helen Tyson Middle School to keep interviews consistent for each school, although differences in the lunch programs and the need for additional data may lead to different questions during the semi-structured interview. Additional interview questions for both schools should aim to gather more specific information regarding distributor warehouse locations, frequency of deliveries, and location of farms/ food producers for different ingredients before the food arrives at the distributor warehouse. Further questions and analysis of proportions of meals served per month or per school year at each school which include beef, another meat, or no meat would help illustrate protein options offered for other meals served at each school. Interviews should be recorded for content analysis. Future researchers should ask for permission to follow up with the research participants for additional information. Researchers should conduct on-site visits to better understand each school lunch program, record dimensions and brands of appliances, and take of photos appliances and food packaging, if possible, to aid in content analysis.

Future researchers should consider the meals they are comparing across schools. For example, choosing to compare chicken-based meals and how often they are served at each school may reduce experimental biases. A similar Excel spreadsheet to the one used to create Tables 1A and 1B in Appendix B for Helen Tyson Middle School should be used to organize quantitative data for two common meals such as serving size, preparation, storage, delivery, and packaging of each ingredient used in the meal. With additional data collection, it is hoped that future researchers can perform a more detailed Life Cycle Assessment of meals at each school by using programs which offer comprehensive emissions datasets such as SimaPro or OpenLCA. Additional data collection and comparison could be used to formulate a framework for school lunch programs to help reduce emissions while still meeting dietary requirements. To ensure this information is distributed well, future researchers should investigate the authorities which are responsible for regulating and deciding what lunches get served at each school.

Results and Discussion

In this section information gathered through interviews with a staff member at Helen Tyson Middle School is presented. First, basic information about the school lunch program will be described including food delivery schedules, food preparation practices, and facility energy use. Then, more detailed information about two common meals and the meal components are specified.

Helen Tyson Middle School in Springdale Arkansas

Helen Tyson Middle School's cafeteria serves 6^{th} and 7^{th} grade students. Approximately 530 students are served a variety of meal options for lunch each day. Quantities of meals are prepared based on counts the cafeteria receives each day. There are five main components (including a protein or main dish, several side options, and a drink) offered for each meal, and the students must take at least three of those options including at least one serving of a fruit or vegetable and a choice of 1% milk to drink.

All the food is delivered to the school via delivery trucks from several different suppliers. Local produce makes up a very minimal portion of lunches. The only local produce is a "fruit or vegetable of the month" which gets delivered once per month from a local farm that is roughly 300 miles away from the school. Produce is delivered by KT Produce in Rogers, Arkansas once per week. Commodities are delivered by Tankersley Foods, located in Van Buren, Arkansas. Food is delivered from Van Buren to the school's warehouse in large quantities every few months, and then more frequent deliveries are made from the school's warehouse to the school. The rest of the foods are delivered by Ben E. Keith, a distributor located in Little Rock, Arkansas, which makes deliveries from their warehouse in Van Buren weekly. The milk cartons are delivered by Hiland Dairy, located in Fayetteville, Arkansas. The frequency of deliveries is specified in Table 4A in the Appendix B.

The cafeteria facility at Helen Tyson houses a variety of industrial sized appliances to store, preserve, and prepare foods. Food ingredients are stored in a storeroom for non-perishable items. The cafeteria also has a reach-in industrial refrigerator, a Hussman walk-in refrigerator, a Hussman industrial sized freezer, and a Beverage Air USA refrigerator for the individual milk cartons. Appliances used to prepare the meals and keep the meals warm include four gas convection ovens, two electric Cleveland brand steamers, three electric Crescor brand warmers, and a gas braiser.

Packaging generally depends on the type of food. Most produce is delivered in cardboard boxes, but most other products come in some form of plastic. Some commodity ingredients such as flour and sugar used to make the dinner rolls are packaged in large paper bags.

It was estimated that less than 10% of food is wasted according to the head of the cafeteria staff at Helen Tyson. The cafeteria staff cooks in batches according to the head counts of the number of students the cafeteria receives from the administration each day. Extra food that has already been prepared but not served, such as chicken tenders, can be saved and reheated one time. If food cannot be reheated or does not get eaten, it goes in the trash along with food scraps from the meal preparation process. However, all the cardboard that the food is delivered in gets recycled.

According to cafeteria staff, two common meals (which were thought to be most popular meals) at Helen Tyson Middle School are chicken tenders with mashed potatoes, usually prepared for 340 students for one day, and beefy nachos with chips which is usually prepared for

230 students for one day. The chicken tender meal is served once weekly while the beefy nacho meal is served once monthly. There are a variety of side options and toppings served with each meal from which the students can pick. For both meals analyzed in this study, students usually select 4-5 components. A common combination for the chicken tender meal includes chicken tenders, mashed potatoes with gravy, a roll, fruit, and milk. For the beefy nacho meal, a student will typically have corn tortilla chips, cooked beef, nacho cheese, a choice of fruit, and milk. To simplify analysis, only the typical combination of main meal components was used in the calculations and is presented in Appendix B. The serving sizes, storage methods, preparation, packaging, and delivery information for the ingredients in each meal are shown in Appendix B (Tables 1A and 1B). These data can be used by future researchers to conduct a more comprehensive quantification of carbon footprints for each meal. Kilograms of CO2-eq estimations for energy use are provided in Appendix B (Tables 2A and 2B) and compared in Appendix C (Figures 1 and 2). Overall kg CO2-eq per meal based on meal components, and kg CO2-eq/kg estimations for transportation are also located in Appendix B (Tables 3A through 4B) and compared in Appendix C (Figures 3 through 6).

CO2-eq Estimates for Lunch Components

Although data for the GHG emissions of meal ingredients specifically for the food production stage was not assessed within the resource and time constraints of the study, the overall kg CO2-eq/ kg of each ingredient from existing sources were used to estimate kg CO2-eq for the two common lunches at Helen Tyson Middle School. The values reported include multiple stages of the supply chain including land-use change, farming, animal feed, processing, transport, retail, and packaging (Poore & Nemecek, 2018). If emissions values for an ingredient differed across sources multiple sources, kg CO2-eq/kg of product values were averaged. If data for the exact products were not available, kg CO2-eq/kg of product values for a similar product were used for estimations.

To calculate the emissions for each ingredient, the individual serving sizes (in ounces) were multiplied by the number of students served to estimate the total emissions for the typical number of students served for each particular meal. Total ounces were converted to kilograms, and kilograms were multiplied by kg CO2-eq values from existing literature (Poore & Nemecek, 2018) to estimate kg CO2-eq each meal. Cafeteria staff at Helen Tyson reported that the typical batch size for the beefy nacho meal was 230 servings for one school day, and 340 servings per school day was the typical batch size prepared for the chicken tender meal. Kilograms of CO2-eq for both batch sizes were calculated for each meal to compare estimated emissions. The chicken tender meal is served once per week, and four times per month. The beefy nachos meal is served once per month. Estimates for both batch sizes were multiplied by 36 and 9 for the chicken tender and beefy nacho meals, respectively, to estimate the kg CO2-eq values of each meal for a nine-month school year. Only ingredients from the common combinations of meal components were used in these calculations, and kg CO2-eq emissions from extra toppings were omitted, as these components are optional and offered in small quantities.

CO2-eq Estimates for Energy Use

In the absence of an accurate source for energy emissions data, appliances using electricity or gas were used to estimate energy used and convert that to kg CO2-eq to compare greenhouse gas emissions at each cafeteria facility. Information regarding cafeteria facility appliances collected during interviews such as number of each type of appliance, appliance type or brand, and number of hours used per day that a specified meal is prepared aided in energy use estimations. Based on information provided, the following assumptions were made to perform calculations for lunches at Helen Tyson Middle School in Springdale, AR:

1. All ovens are used to bake chicken tenders and rolls
2. Rolls are baked for 20 minutes (Fleischmann's Yeast)
3. All steamers and warmers are used during preparation and serving of each lunch; food generally stays in the steamers/warmers for one hour unless specified otherwise
4. Storage appliances such as refrigerators and freezers run 24 hours per day for nine months out of the year
5. The chicken tender meal is served approximately one time per week, approximately four times per month, and approximately 36 times per school year
6. The beefy nachos meal is served approximately one time per month, and approximately nine times per school year
7. Meals are prepared only once per day which serves both lunch shifts

Based on the type and quantity of each appliance, energy use data (in Btu or kWh) were found online by searching the manufacturer's website and used to calculate the energy used to prepare each specified meal per day the meal is served. Since the exact models were not known, an average of the models presented was chosen for the calculations. Using this information, emissions from appliance energy usage for preparation of each meal were calculated in kg CO2-eq for a single day that the meal is served, and cumulatively (per each individual meal) for the school year. Energy use was calculated only for the two meals analyzed in this study, although there are five lunches served weekly.

CO2-eq Estimates for Food Transportation

To estimate emissions from food transportation, kg CO2-eq/ ton-km values for trucks were used from existing literature shown in Table 4B (Wakeland, et al., 2012). Data for the weight of goods carried on each truck were not provided, so emissions estimates were done using distance traveled and frequency of deliveries in units of kg CO2-eq/ton of goods being transported. Based on information from interviews on food suppliers and warehouse locations, the kg CO2-eq per ton were estimated based on distance (miles) that a shipment from each supplier would travel, which was estimated by using the fastest route from each warehouse location to the school using Apple Maps. Distance traveled for a delivery for each food supplier was converted to km, and then multiplied by kg CO2-eq/ton-km to get kg CO2-eq/ton for deliveries from each food supplier. Due to the varying frequency of delivery for each supplier, the kg CO2-eq per ton for transportation was estimated for deliveries from each supplier based on a nine-month school year. For food distributors which deliver weekly, it was estimated that there are 36 weeks in 9 months to calculate the transportation emissions for a nine-month school year. Future additional research should estimate the weight of goods carried in delivery trucks to produce a more accurate estimate of GHG emissions.

The process of estimating kg CO2-eq for energy use and transportation supported the overall objectives of the study to compare the carbon footprints of school lunches by using available data for processing and different stages of the supply chain. In the absence of emissions data specific to individual stages of the supply chain, the research objectives support the process of estimating overall kg CO2-eq emissions (including several stages of the supply chain) for each meal and its components. While the study cannot comprehensively quantify the entire life cycle of the school lunches, focusing on a few known sources of emissions can still provide valuable information for comparison.

Calculated Results

Data from emissions estimates can be used to contrast the two most popular meals and contrast emissions from energy use and transportation with the overall carbon footprint of each meal. Energy use emissions estimates for each meal show that emissions were approximately equal (Figures 1 and 2), and therefore equal kg CO2-eq emissions were produced during preparation for both meals on a daily basis and per nine-month school year (data from Tables 2A and 2B).

The total kg CO2-eq estimates for energy used in the cafeteria to store and prepare the meals (based on a single day a meal is served) were small relative to the overall kg CO2-eq estimates based on food components (included land use change, farming, packaging, processing, etc.) shown in Tables 3A and 3B, and Figures 3 and 4. For example, the estimated kg CO2-eq produced from energy use each time the chicken tender meal was served was 0.0335 CO2-eq (Table 2A), compared to 581.06 kg CO2-eq (Table 3A), which is the estimated overall emissions for the typical batch of 340 servings of chicken tender meals. The estimated kg CO2-eq energy produced each time the beefy nachos meal was served was 0.0335 kg CO2-eq (Table 2B), compared to 1277.34 kg CO2-eq (Table 3B) produced for a typical batch of 230 servings. Kilograms of CO2-eq estimates for energy use each time a meal was served compared to overall kg CO2-eq estimates for a typical batch size indicated that energy use from preparation, storage, and warming were responsible for a relatively small proportion of total kg CO2-eq for both lunches. The relatively small kg CO2-eq estimates for energy use compared to overall kg CO2-eq for each meal is supported in the literature by the fact that the largest portion of food emissions reportedly comes from the food production stage (Ritchie, 2020). When performing calculations, it was assumed that meals were prepared only once per school day which serves the entire school. If meals were to be prepared separately, it would change energy use estimates, likely by doubling the original estimates in this study.

For overall kg CO2-eq estimates based on meal components, the beefy nacho meal produced less kg CO2-eq emissions per school year compared to the chicken tender meal, shown in Figure 4, based on data from Tables 3A and 3B. Yearly emissions for beefy nacho meal were less than that of the chicken tender meal because the beefy nacho meal is served only once per month, compared to the chicken tender meal which is served once per week. However, the beefy nacho meal had greater total kg CO2-eq emissions on a daily basis (1888.25 kg CO2-eq per day meal is served) compared to the chicken tender meal (581.06 kg CO2-eq per day meal is served) for meals prepared for 340 students as shown in Figure 3, based on data in Tables 3A and 3B. This is likely because the main components for the beefy nacho meal had much greater CO2-eq values per kg of meal ingredient compared to the chicken tender meal. The kg CO2-eq/kg of gravy was not available and therefore not included in calculations, excluding a potential source of emissions which might increase overall emissions for the chicken tender meal. Although an individual serving of beef (2 oz) was less than half of the serving size of chicken tenders (5.5 oz), the emissions for a serving of beef were approximately 3.6 times greater than a serving of chicken tenders, (Figure 5, Tables 3A and 3B). A high carbon footprint of beef relative to other foods is supported by calculations which estimated beef to have the greatest carbon footprint compared to all other animal products in the study (Xu, X. & Lan, Y., 2016). The estimated kg CO2-eq per individual serving of nacho cheese was greater than that of chicken tenders, despite the cheese having a smaller serving size than chicken tenders (Figure 5, Tables 3A and 3B).

Estimates for the cheese were not exact since values were estimated with available data for cheese, rather than for each ingredient used to make the nacho cheese mixture at Helen Tyson. High emissions from the cheese relative to the chicken is supported by various studies that demonstrated milk products produced greater GHG emissions per gram of protein (Hitaj, et.al, 2019), and cheese having greater kg CO2-eq per kg of product (Ritchie, 2020) compared to certain meats such as chicken and pork. Although an average of milk products was estimated to have greater GHG emissions per gram of protein compared to chicken and pork (Hitaj, et al., 2019), Ritchie (2020) demonstrated that milk had much lower overall emissions (kg CO2-eq) compared to cheese. This supports the data in Figure 5, based on Tables 3A and 3B which show the relatively low CO2-eq estimate for milk compared to other meal components offered for both lunches.

Transportation related emissions of food products vary by distributor, but it is difficult to draw conclusions based on available data. According to estimates in Table 4A, Tankersley Foods travels a further distance than other distributors but makes less frequent deliveries, and therefore Tankersley would produce the least transportation emissions per ton per school year (Figure 6, Table 4A). However, actual kg CO2-eq per ton from Tankersley Foods could vary based on location and frequency of trips from the school's warehouse. Based on information gathered in interviews and assumptions, food delivered by Ben E. Keith would produce the greatest overall kg CO2-eq per ton per school year due to furthest distance traveled and weekly deliveries (Figure 6, Table 4A). Actual kg CO2-eq for foods delivered by all distributors could vary based on weight of food products being transported and possible discrepancies between actual and estimated delivery frequencies and warehouse locations.

Approximately 20% of global emissions caused by humans come from food systems (Hertwich, 2009). Although lunches served at Helen Tyson Middle School alone do not contribute significantly, meal offerings at school lunch programs around the world cumulatively make a larger contribution to overall emissions that feed climate change. Based on estimates in this study, it is evident that that the type of meal components offered (type of meat, dairy product, plant-based food, etc.) offered greatly impact the overall carbon footprint of a school lunch.

Assumptions and Possible Sources of Error

Upon calculating portions of each ingredient per serving size of a meal component (for components such as nacho cheese and dinner rolls), potential errors may have occurred, since the number of servings prepared for certain meal components can vary based on ingredient for the total number of meals served. For example, although the chicken tender meal is typically prepared for 340 students, the cafeteria staff may prepare fewer than 340 rolls since the students can choose their meal components within the dietary requirements. Possible errors in totals of amount of ingredients used may have resulted in errors in CO2-eq estimates for popular meal components.

Several assumptions were made in order to estimate kg CO2-eq for energy use within the time constraints for data collection and analysis. Energy use estimations could have been overestimated due to the assumption that all ovens in the facility were used in the preparation process for both the chicken tenders and dinner rolls. However, other errors could have resulted if meals were prepared separately for each grade level per day, or from unknown dimensions and brands for certain appliances.

Transportation estimates were calculated in terms of kg CO2-eq/ton based on distance that foods travel from warehouses to the school. Weight of goods transported may impact actual kg CO2-eq produced during transportation for each distributor, resulting in potential error in comparing emissions per school year from each distributor. Estimates for transportation did not include kg CO2-eq emissions produced for each ingredient to travel to warehouses of individual distributors from farms and processing plants. It was noted in interviews that Tankersley Foods delivers commodities from their warehouse to the school's warehouse every few months, and then more frequent deliveries are made from the school's warehouse to Helen Tyson's cafeteria. The location of the school's warehouse was unspecified, and so the kg CO2-eq estimations for Tankersley were calculated based on distance from Tankersley Foods in Van Buren, Arkansas to Helen Tyson Middle School. Cafeteria staff were unsure of exact locations of food distributor warehouses, so locations were determined from the websites of each food distributor along with information from interviews.

Conclusions and Implications

Although the COVID-19 pandemic prevented the researcher from gathering adequate data within the time constraints, the literature review and available data provide information for future researchers and demonstrates the need for the study. The literature review also explored methodologies of previous studies, and the methodology section provided a suggested outline for future researchers to continue data collection and perform more detailed, quantitative calculations.

The process of conducting the literature review and emissions estimates showed that LCA calculations have many potential opportunities of error, but still produce valuable estimates which quantify relative sources of emissions. Varying LCA methodologies and lack of existing data often make it difficult to compare LCA results across different studies. However, using a consistent methodology for both schools would still provide useful data to compare school lunches from each site, as well as cafeteria facilities. Data collected may unveil ways that schools could decrease carbon footprints of school lunches.

Several conclusions can be drawn based on data collection and analysis from Helen Tyson Middle School (Springdale, Arkansas). The common meals served at Helen Tyson included processed or pre-prepared foods as some of the main components offered, which could influence energy use estimates and future comparisons with St. Matthew's school lunches in Belize, which may require different processing or preparation methods. In addition, common meals included meat or other animal products as a main component. Since animal products typically have greater carbon footprints compared to plant products (Xu, X. & Lan, Y. 2016), the typical meals served at Helen Tyson could have greater carbon footprints compared to St. Matthew's school depending what proportion of common meals served at St. Matthew's school contain animal products. Many meals in Belize consist of beans and rice. Some chicken is served, but little beef. However, future data collection is necessary to explore this idea.

Based on transportation emissions estimates for Helen Tyson, it can be concluded that making more efficient deliveries for non-perishable food items that can be stored long term could potentially reduce overall transportation emissions per school year. Cafeteria staff estimated that a small portion of ingredients used at Helen Tyson are produced locally, which may result in potential differences in carbon footprints of lunches since St. Matthew's school has a school garden on site. However, the proportion of lunch ingredients that come from the school garden and the distance that other ingredients travel would influence the overall transportation emissions for lunches at St. Matthew's in Belize. Additionally, the future installation of a poultry facility at

St. Matthew's may alter the overall carbon footprint of common lunches at St. Matthew's as they compare to common lunches at Helen Tyson.

Estimated overall CO2-eq for the beefy nacho meal was high (per one meal or per one patch of meals) compared to the chicken tender meal, although emissions from the beefy nacho meal were less than that of the chicken tender meal during a 9-month school year since beefy nachos were served less frequently. Estimated emissions from animal products were high (especially beef) compared to other lunch components. The comparatively high emissions of animal products implies that Helen Tyson could potentially decrease emissions of lunches by reducing the number of meals which include beef and replacing it with other lower GHG protein options such as fish, poultry or plant-based proteins. Since milk products often have higher emissions than poultry and plant-based products, offering alternative drink options besides milk could potentially lower overall emissions of meals. The proportionately low energy use emissions compared to overall emissions based on meal components also supports the idea that focusing on shifts in lunch component offerings could decrease overall emissions from meals served at Helen Tyson. However, it is important that if meal component offerings are replaced or removed, it is done in a way that does not compromise overall nutrition and dietary requirements of the students.

To quantitatively compare differences in greenhouse gas emissions of lunches, facility energy use, and locality of lunch ingredients, interviews should be conducted at St. Matthew's School in Belize, and more specific data from Helen Tyson middle school would be beneficial. Additional data should be collected on site at both schools to develop a more concrete understanding of packaging, as well as dimensions and brands of cafeteria appliances to compare cafeteria energy use emissions at each school and fill in gaps in transportation data that would increase accuracy of estimations. The researcher hopes that other institutions will consider doing their part by offering more environmentally conscious meal choices to ultimately reduce risks of food security brought on by climate change. Future researchers have the potential to synthesize materials accessible to other institutions to aid in the process of re-thinking meal offerings to reduce emissions. Overall, this study highlights the connections between food systems and CO2 emissions exacerbating climate change and provides guidelines for data collection for future researchers in hopes to formulate methods to reduce emissions from school lunches and therefore the overall food sector in the future.

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Appendix A

IRB Approval Letter

UNIVERSITY OF ARKANSAS

To:	Lisa S Wood
From:	Douglas J AdamsJustin R Chimka, Chair IRB Expedited Review
Date:	04/06/2022
Action:	**Exemption Granted**
Action Date:	04/06/2022
Protocol #:	2110367337
Study Title:	Comparing Carbon Footprints of School Lunches in Belize and Northwest Arkansas

The above-referenced protocol has been determined to be exempt.

If you wish to make any modifications in the approved protocol that may affect the level of risk to your participants, you must seek approval prior to implementing those changes. All modifications must provide sufficient detail to assess the impact of the change.

If you have any questions or need any assistance from the IRB, please contact the IRB Coordinator at 109 MLKG Building, 5-2208, or irb@uark.edu.

cc: Isabel M Whitehead, Investigator
Lauren Elizabeth Greenwood, Investigator

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Appendix B

Tables

Table 1A

Summary of Helen Tyson Middle School Interview Data for Popular Meal Components of Chicken Tender Meal

Popular Meal Component	Ingredients	Storage Method	Individual Serving Size (oz)	Prep	Delivery	Packaging
Chicken Tenders	Chicken Tenders	Freezer	5.5	Oven: 20 minutes at 425° F, then warmers 60 min	Ben E. Keith	Cardboard Box
Mashed Potatoes with Gravy	Mashed Potatoes	Storeroom	4.0	Made with Hot Water, then Steam Table 60 min	Ben E. Keith	Plastic Bag
	Gravy	Storeroom	1.0	Made with Hot Water, then Steam Table 60 min	Ben E. Keith	Plastic Bag
Dinner Roll	Dinner Roll	Storeroom	2.0	Oven: 20 min	Ben E. Keith and Tankersley	Most ingredients in plastic and paper bulk bags
Fruit Options (Choose 1)	Apple	Fridge	4.0 (1-Apple)	-	KT Produce	Cardboard Box
	Cantaloupe Pieces	Fridge	4.0	Chopping	KT Produce	Cardboard Box
Drink	1% Milk	Beverage Air Milk Box	8.0	-	Hiland Dairy	Wax-Coated Cardboard Cartons

Note. Cells with a dash indicate information was not specified or does not apply to that meal component/ingredient.

Table 1B

Summary of Helen Tyson Middle School Interview Data for Popular Meal Components of Beefy Nacho Meal

Popular Meal Component	Ingredients	Storage	Individual Serving Size (oz)	Prep	Delivery	Packaging
Beef	Beef	Freezer	2.00	Braiser: 60 min, then Warmers 90 min	Ben E. Keith or Tankersley	Plastic Casings in Cardboard Box
	Spices (Chili Powder, Cumin, Paprika)	Storeroom	-		Ben E. Keith	Plastic Bottle
Nacho Cheese (2 oz serving)	Powdered Milk	Storeroom	-	Steamers: 90 min	Ben E. Keith	Plastic Bottle
	American Cheese	Refrigerator	-		Ben E. Keith and Tankersley	-
	Water	-	-		-	-
Chips	Corn Tortilla Chips (Gran Sabor)	Storeroom	2.00	-	Ben E. Keith	Plastic Bags inside Cardboard Box
Fruit Options (Choose 1)	Bananas	Storeroom	4.00 (1 banana)	-	KT Produce	Cardboard Box
	Strawberry Cup	Freezer	4.00	Thawing	Tankersley	Plastic Cup
Drink	1% Milk	Beverage Air Milk Box	8.00	-	Hiland Dairy	Wax-Coated Cardboard Cartons

Note. Cells with a dash indicate information was not specified or does not apply to that meal component/ingredient.

Table 2A

CO_2-eq Estimates for Energy Use of Appliances for Chicken Tender Meal

Appliance	Energy Use (kWh)	Time Used/Day (hours)	Energy Use (kWh/day meal is served)	Energy Use/ Month (kWh)	Energy Use/ 9 Month School Year (kWh)	CO2-eq Each Time Meal is Served (kg)	CO2-eq for Meal/ School Year (kg)
4 Hobart Convection Ovens (chicken tenders)	58.62	0.33	19.34	77.38	696.41	0.0084	0.3015
Warmers (chicken tenders)	0.48	1.00	0.48	1.91	17.17	0.0002	0.0074
4 Hobart Convection Ovens (rolls)	58.62	0.33	19.34	77.38	696.41	0.0084	0.3015
2 Steamers (potatoes and gravy)	1.00	1.00	1.00	4.00	36.00	0.0004	0.0156
Reach In Refrigerator	0.06	24.00	1.36	5.44	48.96	0.0006	0.0212
Walk In Refrigerator	0.40	24.00	9.60	38.40	345.60	0.0042	0.1496
Industrial Sized Freezer	0.92	24.00	22.00	88.00	792.00	0.0095	0.3429
Beverage Air Refrigerator	0.17	24.00	4.13	16.52	148.68	0.0018	0.0644
		Totals	77.26	309.02	2781.22	0.0335	1.2043

Table 2B

CO2-eq Estimates for Energy Use of Appliances for Beefy Nacho Meal

Appliance	Energy Use (kWh)	Time Used/Day (hours)	Energy Use (kWh/day meal is served)	Energy Use/Month (kWh)	Energy Use/9 Month School Year (kWh)	CO2-eq Each Time Meal is Served (kg)	CO2-eq for Meal/ School Year (kg)
Braiser (beef)	1.59	1.00	38.10	38.10	342.90	0.0165	0.1485
2 Steamers (nacho cheese)	1.00	1.50	1.50	2.25	20.25	0.0006	0.0088
3 Warmers (beef)	0.48	1.50	0.72	0.72	6.48	0.0003	0.0028
Reach In Refrigerator	0.06	24.00	1.36	1.36	12.24	0.0006	0.0053
Walk In Refrigerator	0.40	24.00	9.60	9.60	86.40	0.0042	0.0374
Industrial Sized Freezer	0.92	24.00	22.00	22.00	198.00	0.0095	0.0857
Beverage Air Refrigerator	0.17	24.00	4.13	4.13	37.17	0.0018	0.0161
		Totals	77.41	78.16	703.44	0.0335	0.3046

Table 3A

CO2-eq Estimates for Lunch Components of Chicken Tenders Meal

Popular Meal Component	Individual Serving Size (oz)	Kg CO2-eq per kg produced	CO2-eq per individual serving	Kg CO2-eq/day (230 servings [c])	Kg CO2-eq/day (340 servings [c])	Kg CO2-eq/school year (230 servings [c])	Kg CO2-eq/school year (340 servings [c])
Chicken Tenders	5.5	6.00	0.936	215.17	318.08	7746.22	11450.94
Mashed Potatoes	4.0	0.40	0.045	10.43	15.42	375.57	555.20
Gravy	1.0	-	-	-	-	-	-
Dinner Roll [a]	2.0	0.04	0.002	0.54	0.80	19.56	28.92
Choice of Apple or Cantaloupe Pieces [b]	4.0	0.40	0.045	10.43	15.42	375.57	555.20
Drink (1% Milk)	8.0	3.00	0.680	156.49	231.33	5633.62	8327.96
		Totals	1.709	393.07	581.06	14150.55	20918.21

Note. Cells with a dash indicate information was not specified or does not apply to that meal component/ingredient.

[a] Estimated using CO2-eq for loaf of bread, assuming 1 loaf of bread ~12 rolls

[b] Either choice has the same CO2-eq per kg value

[c] Daily batch size used in estimation

Table 3B

CO2-eq Estimates for Lunch Components of Beefy Nachos Meal

Popular Meal Component	Individual Serving Size (oz)	Kg CO2-eq per kg produced	CO2-eq per individual serving	Kg CO2-eq/day (230 servings [b])	Kg CO2-eq/day (340 servings [b])	CO2-eq per school year (230 servings [b])	CO2-eq per school year (340 servings [b])
Beef	2.0	60.00	3.402	782.45	1156.66	7042.02	10409.94
Nacho Cheese	2.0	21.00	1.191	273.86	404.83	2464.71	3643.48
Corn Tortilla Chips	2.0	3.20	0.181	41.73	61.69	375.57	555.20
Choice of Banana or Strawberries [a]	4.0	0.88	0.099	22.82	33.74	205.39	303.62
Drink (1% Milk)	8.0	3.00	0.680	156.49	231.33	1408.40	2081.99
		Totals	5.554	1277.34	1888.25	11496.10	16994.24

[a] Estimated using average CO2-eq per kg of strawberries and bananas
[b] Daily batch size used in estimation

Table 4A

CO2-eq/ton Estimates for Transportation per School Year by Distributor

Distributor	Warehouse Location	Distance Traveled (km)	Kg CO2-eq/ton per one delivery	Delivery Frequency	Kg CO2-eq/ton per school year
Tankersley	Van Buren, AR	96.56	173.81	Every few Months (~3x per school year)	521.43
Ben E Keith	Little Rock, AR	320.26	576.47	1x per week	20752.81
KT Produce	Rogers, AR	17.70	31.87	1x per week	1147.14
Hiland Dairy	Fayetteville, AR	20.92	37.66	-	-

Note. Cells with a dash indicate information was not specified or does not apply to that meal component/ingredient.

Table 4B

Kg CO2-eq per ton-km used for Estimates in Table 4a.

	MegaJoules per ton-km	Kg CO2-eq per ton-km
International water-container	0.2	0.14
Inland water	0.3	0.21
Rail [a]	0.3	0.18 [a]
Truck [b]	2.7	1.80
Air [c]	10.0	6.8

Note. Utilization and backhaul rates will affect all figures. From "Food transportation issues and reducing carbon footprint", by W. Wakeland, et al., 2012, *Green Technologies in Food Production and Processing*, Table 9.1, (https://doi.org/https://doi.org/10.1007/978-1-4614-1587-9_9). Copyright 2012 by Her Majesty the Queen, in Right of Canada.

[a] May depend on whether diesel or electric power is used

[b] Depends on size and type of truck, power source

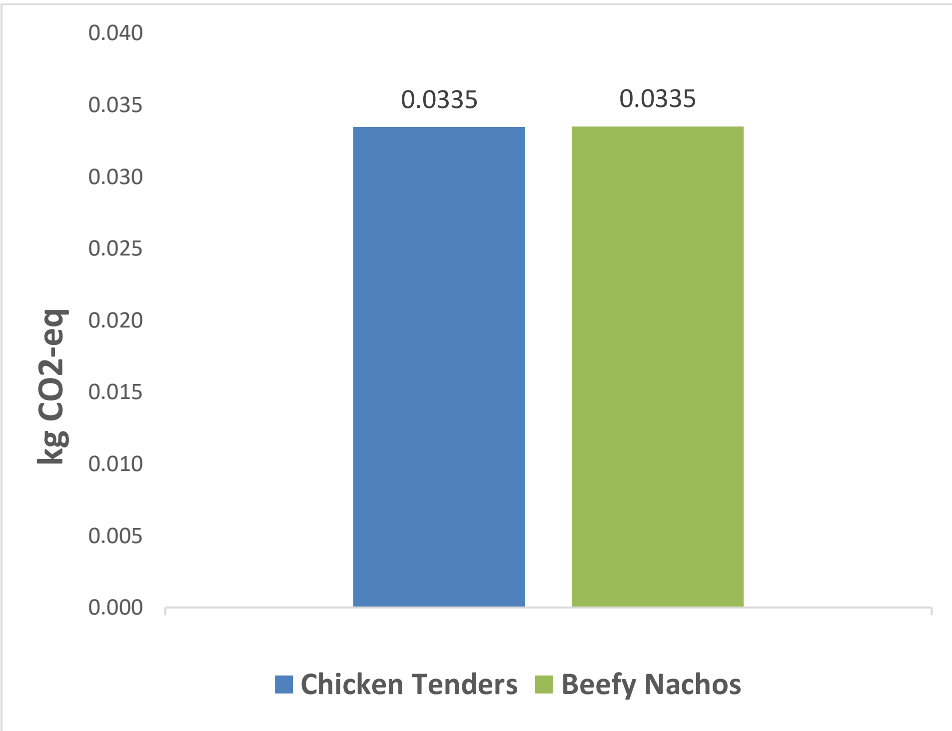
[c] Includes effects from radiative forcing

Appendix C

Figures

Figure 1

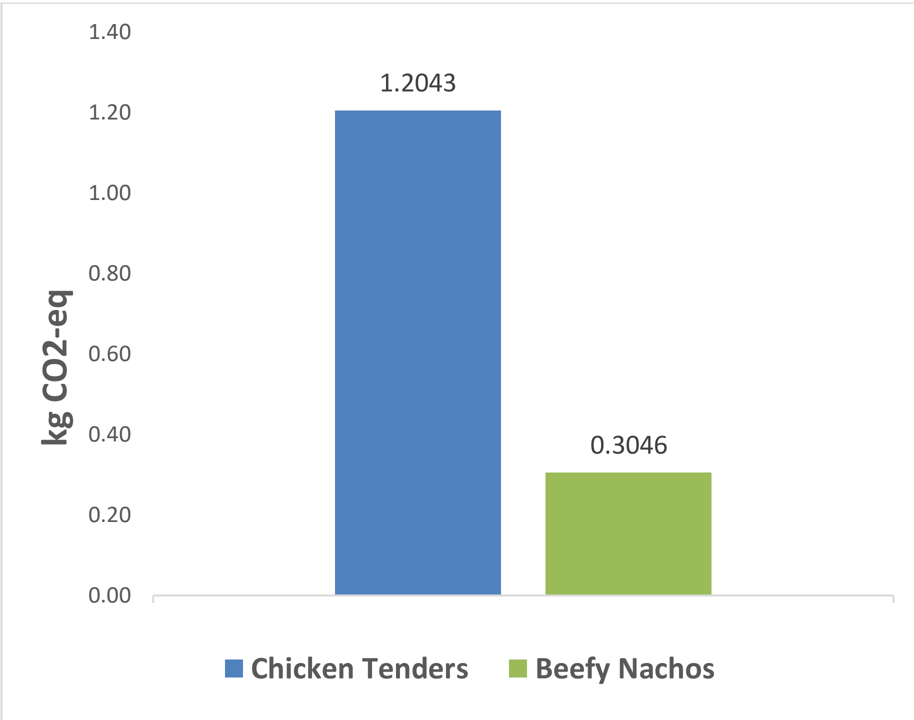
Estimated Energy Emissions for Common Meals/ Each Time Meal is Served



Note. Figure adapted from Tables 2A and 2B in Appendix B.

Figure 2

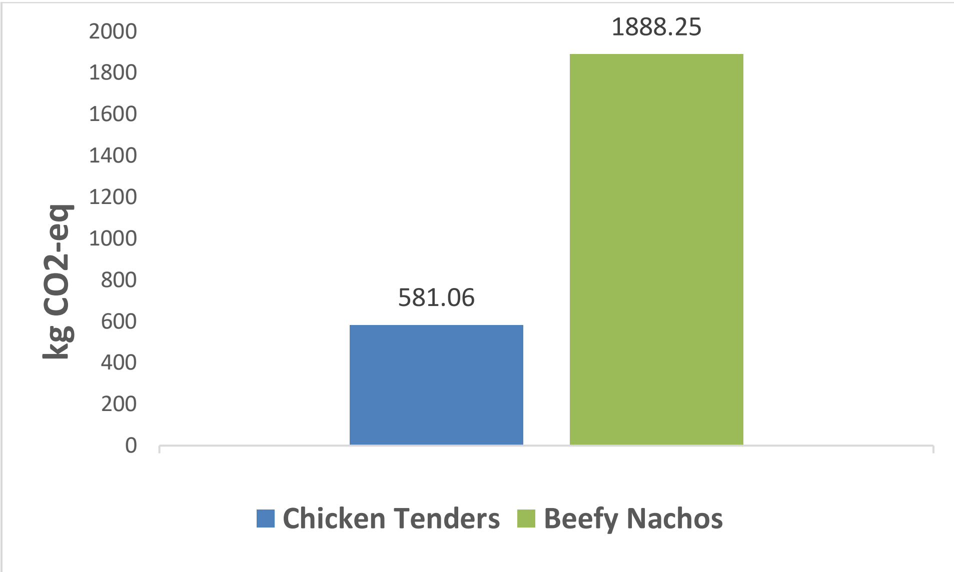
Estimated Energy Emissions for Common Meals/ School Year



Note. Figure adapted from Tables 2A and 2B in Appendix B.

Figure 3

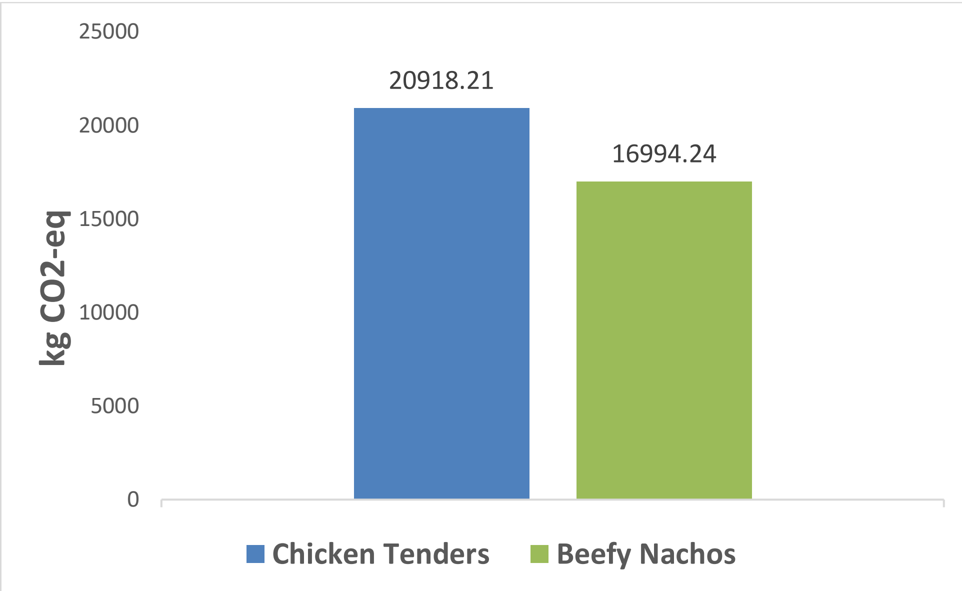
Estimated Overall Emissions for Common Meals/ Each Day Meal is Served



Note. Estimates are based on batch size of 340 servings for both meals. Figure adapted from data in Tables 3A and 3B in Appendix B.

Figure 4

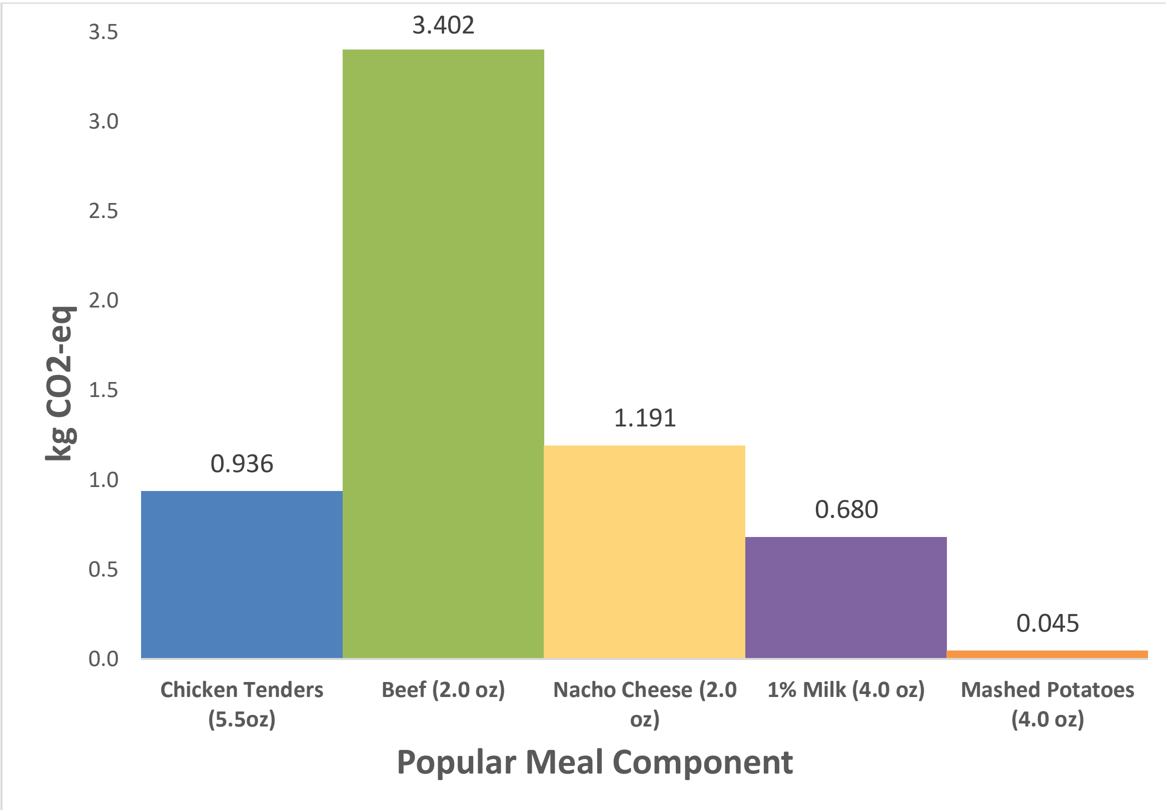
Estimated Overall Emissions for Common Meals/ School Year



Note. Estimates are based on batch size of 340 servings for both meals. Figure adapted from data in Tables 3A and 3B in Appendix B.

Figure 5

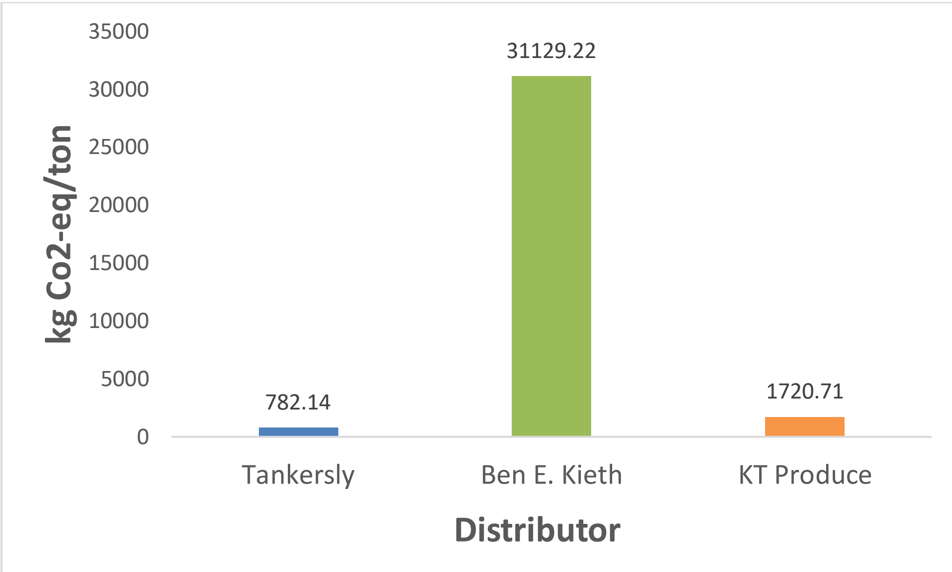
Estimated Overall Emissions for Popular Meal Components/ Individual Serving



Note. Figure adapted from data in Tables 3A and 3B in Appendix B.

Figure 6

Estimated Transportation Emissions/ton per School Year



Note. Figure adapted from data in Tables 4A in Appendix B.