Environmental Impacts of Foods in the Adventist Health Study-2 Dietary Questionnaire

Supplementary Information

This document is a resource to complement the main paper, and provides details of the assumptions made and data sources used in determining the environmental impacts of the foods considered in the life cycle assessment of the Adventist Health Study-2 dietary questionnaire.

1. Assumptions and data sources
   1. Agricultural production assumptions

We prioritized California and US production where possible and appropriate. Although we had data from UC Davis cost studies, we chose to use Ecoinvent 3 for apples, onions, and potatoes partially because these are foods that are produced in greater quantities outside of California. We also noticed large differences in estimated impacts between interpretation of UC Davis cost study data and Ecoinvent data for the US national average and decided it was better to use the Ecoinvent data in these cases. For other produce items where California is not the top producing state, we still used UC Davis data when available if there was not a large difference between it and the Ecoinvent data so that we had a better understanding and control over the data.

* 1. Agricultural production data

For the majority of produce and nuts, we used data from UC Davis cost studies expertly interpreted by Alfredo Mejia to estimate LCI data [1]. Fruit without UC Davis cost studies available or that California was not a top producing state for, such as bananas and apples, uses Ecoinvent 3 data [2]. Also, US average data is used where appropriate (e.g. apples), while global average data is used for other produce (e.g. bananas). Some foods included in the AHS-2 FFQ had no data available (e.g. persimmons), so we excluded these items. Other categories including grains, legumes, eggs, dairy, meat, poultry, fish, and products using these ingredients used data from several databases including Ecoinvent, Agri-footprint, and others. When certain products were available in multiple databases, we prioritized sources that were US and Canada specific. The main data source for production of ingredients is provided in *Supplemental Data.*

Many foods included multiple ingredients, and their composition had to be determined to estimate their environmental impacts. For these foods, we used recipes previously created by AHS-2 researchers to estimate the nutritional value of foods. These recipes were used in determining the weight of ingredients used. We prioritized the use of ingredients we already previously found data for in completing the LCI for these recipes, and if possible used California or US specific data sources. In some cases, ingredients comprising negligible portions of the total recipe weight (e.g. added vitamins and minerals) did not have data available, and were therefore excluded. If available, and in cases where the recipe was not clear regarding what specific ingredient was required, proxy ingredients with similar characteristics were used.

* 1. Energy for processing assumptions

For the majority of foods considered that required cooking, we assumed that this was done at home, and therefore that energy usage was outside of our system boundaries. Foods we assumed were prepared at home included soup, cooked grains, pasta, pizza, For foods that required processing prior to purchase (e.g. bread, we accounted for the energy used to do so. For example, we included the energy needed to process fruit juice, assuming the consumer was buying the juice rather than making it in this case. However, we did not include the energy for cooking pizza or pasta, as this was assumed to be cooked at home. For multiple industrially produced foods including some dairy products, sodas, and alcoholic beverages, we consulted with Rodrigo Matos to calculate the efficiency of throughput as well as energy requirements for processing. Specifically for soda, we used data from examination of an anonymous monograph describing the design of a soda manufacturing plant [3].

* 1. Energy for processing data

Table S1 outlines the energy usage assumed for processing different types of foods, and the data source for that information, for foods for which we needed to estimate the associated energy use. In cases where we could not obtain specific data for certain products, proxy data for similar products was used. In other cases, energy use for processing was already included in a LCI data source, and our estimate was not necessary. For some processing energy requirements, including for juices, we contacted extension services and used USDA documentation to estimate the necessary energy, and estimated the ingredients necessary to produce the juice based on the density of juice in each raw ingredient. For completing the LCI, electricity, natural gas, and propane were added as necessary from the Ecoinvent 3 database.

Table S1: Energy Usage for Processing Foods

|  |  |  |  |
| --- | --- | --- | --- |
| Type of Processing (1 kilogram of food) | Processing Energy – Natural Gas (cubic feet) *unless noted* | Processing Energy – Electricity (kWh) | Data Source |
| Bread | 0.23  Propane | 0.37 | Rodrigo Matos |
| Breakfast Cereals | 1.22 | 0.42 | [4] |
| Canned Burger | 3.72 | 0.65 | [5] |
| Canned Chunks | 6.32 | 1.09 | [5] |
| Canned Cold Cuts | 4.53 | 0.75 | [5] |
| Canned Links | 4.97 | 1.84 | [5] |
| Canned Minced | 3.72 | 0.65 | [5] |
| Canned Nuggets | 3.72 | 0.65 | [5] |
| Canned Patties | 3.00 | 1.23 | [5] |
| Frozen Burger | 4.25 | 0.75 | [5] |
| Frozen Cold Cuts | 4.15 | 0.52 | [5] |
| Frozen Links | 4.97 | 1.84 | [5] |
| Frozen Minced | 3.72 | 0.65 | [5] |
| Frozen Nuggets | 4.53 | 0.75 | [5] |
| Frozen Patties | 3.86 | 0.84 | [5] |
| Fruit Juices | 0.06 MJ natural gas | 0.02 MJ electricity | [6] |
| Salami | 0.02 kg Propane | 0.09 | Rodrigo Matos |
| Sausage | 0.18 kg Propane | 0.09 | Rodrigo Matos |
| Cottage Cheese | .0026 kg Propane | .0024 | Rodrigo Matos |
| Cream Cheese | .00154 kg Propane | .00121 | Rodrigo Matos |
| Imitation Cheese | .001521 kg Propane | .001521 | Rodrigo Matos |
| Cheddar Cheese | .0013 kg Propane | .00012 | Rodrigo Matos |
| Mozzarella Cheese | .00224 kg Propane | .00192 | Rodrigo Matos |
| Whipping Cream | N/A | .1 | Rodrigo Matos |
| Sour Cream | .001846 kg Propane | .01491 | Rodrigo Matos |
| Commercial Breakfast Cereals | 0.105537 Nm3 Per kg | 0.42 Per kg cereal | [4] |
| Juices | 0.05956 MJ Thermal Energy from Natural Gas Per kg Juice | 0.01492 MJ Electricity Per kg Juice | [6] |

* 1. Transportation assumptions

For the majority of foods studied, consideration of transportation was limited to the upstream processes necessary prior to the farm or factory gate, and therefore distribution of the final product was excluded. However, we made a partial exception to this in order to differentiate between in season and out of season produce.

We assumed that out of season produce was obtained by importing produce from other countries where it was most commonly produced. Although it is possible to store some produce, such as apples, for long term storage, the produce included in the out of season category of the FFQ was not typically suitable for long term storage, so we excluded this option and only considered imported produce. Transportation for out of season produce that originated outside the United States was assumed to be by oceanic freighter with cooling and/or refrigerated truck as necessary to be transported to one of two major ports of entry into the United States. Food shipped by ocean would arrive to the port of Los Angeles, California. Food shipped by truck would arrive to the port of Nogales, Arizona, the largest inland food port in the world [7].

We chose the country of origin for out of season produce based on data regarding the primary exporter to the US. Out of season produce imported to the US came primarily from Chile and Mexico.

Table S2: Country of Origin for Out of Season Produce

|  |  |  |
| --- | --- | --- |
| Food | Country of Origin | Source |
| Grapes | Chile | [8] |
| Peaches | Chile | [9] |
| Nectarines | Chile | [9] |
| Plums | Chile | [10] |
| Cantaloupe | Guatemala | [11] |
| Strawberries | Mexico | [12] |
| Blueberries | Chile | [13] |
| Raspberries | Mexico | [14] |
| Blackberries | Mexico | [15] |
| Sweet Cherries | Chile | [16] |

We assumed out of season produce was shipped internationally from Chile, Mexico, and Guatemala, depending on the specific produce type. For Chile, goods travelled by oceanic freighter with cooling from their port to the port of Los Angeles. For Mexico, goods travelled by refrigerated truck from Jalisco to Nogales.

* 1. Transportation data

For out of season fruit, we used the same production data as for seasonal fresh fruit, but added transportation to account for international shipping from locations where it would be produced when out of season. The distance that the produce must be transported was estimated based on either Google Maps or a reference for oceanic shipping [17]. Ecoinvent 3 was used for estimating oceanic shipping impacts, while USLCI was used for transportation by truck.

Table S3: International Transportation Distances by Mode

|  |  |  |
| --- | --- | --- |
| Origin | Boat Transportation Distance (km) | Truck Transportation Distance (km) |
| Chile | 8851 | - |
| Jalisco, Mexico | - | 1645 |
| Guatemala City | - | 3627 |

* 1. Packaging

We did not include packaging for the majority of foods in this study. Some foods included packaging data in their LCI database. Soda and coffee data were from an economic input-output database, and therefore included packaging. Canned tuna required packaging, which was estimated using the LCA Food DK database entry for canning fish. Packaging for meat analogues was based on previously collected data [5]. Databases used for tin can packaging for meat analogs include US-EI 2.2 and ELCD. Blister packaging data comes from Industry Data 2.0 and Ecoinvent 3 databases. Aluminum soda can packaging uses the Agri-footprint database. Coffee packaging is included in the US2002 input-output database used for coffee itself.

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