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The Environmental and Nutritional Dilemma of Beef Production and Consumption

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Abstract

Based on previous studies, it has been stated that beef production and consumption in the United States is detrimental to the environment. However, in depth studies analyzing the change of beef production and consumption, the environmental impacts, the external costs, the lifestyle implications as well as the nutritional, the social and the cultural aspects of beef have not been conducted. The goal of this study is to analyze the multiple aspects of the dilemma over beef production and consumption. This was done through an analysis of beef production and consumption data over the past 60 years to determine how it has changed in the United States. Life cycle assessments of varying cattle farming processes were completed to compare the varying impacts different processes have on the environment through impact analysis and external cost calculations. For the three cattle farming processes analyzed the top five impacts for all were: human non-carcinogenic toxicity, marine ecotoxicity, freshwater ecotoxicity, human carcinogenic toxicity, and global warming. It was found that cattle farming through the 'pasture and feedlot' process was the least environmental taxing due to the cattle being slaughtered at half the lifespan compared to the 'pasture' process and occupying less land than the 'pasture and proteic supplement' method. The lowest external cost was also associated with the 'pasture and feedlot' cattle farming process. Beef consumption amounts were altered from the average diet using a life expectancy calculator to investigate the impact on the human lifespan for changes in diets beginning at 1 year old, 30 years old, and 60 years old. A nutritional comparison was completed for beef and its alternatives, and social and cultural effects of beef production and consumption were researched. It was determined that beef consumption per capita has decreased due to triple the number of poultry being consumed on average per year from 1961 to 2018, as well as a larger increase in beef costs compared to other types of meat. Based on current popular beef alternatives in the market, beef has the same nutritional quality but also provides necessary vitamins that are not found naturally in the alternative protein sources. Reduction or depletion of beef production and consumption would not only impact diets, but also create issues within the economy and alternates to beef production byproducts would also need to be created for fertilizers and pet foods. While excess consumption of beef is not ideal for human health, based on current and past trends, the consumption and production of beef per capita will continue to decrease in the United States.

Authors' Contributions

The authors confirm contribution to the paper as follows: Introduction, The United States Beef Industry: Production and Consumption, Introduction to Beef Consumption Protein and Energy Efficiency: Stefano de Rosmini; Beef Nutrition, Cultural Effects of Beef Production and Consumption, and Conclusion: Brooke Lovan; Abstract, Impact Assessment of Varying Farming Cattle Processes, External Environmental Cost of Cattle Farming, Lifestyle Implications, Social Effects of Beef Production and Consumption: Hannah Swilling. All authors reviewed the results and approved the final version of the article.

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1. Introduction

Beef is one of the most popular types of meat for protein in the United States. It has been one of, if not the most, consumed types of meat between 1961 and 2017 (Ritchie and Roser). The production of beef has continuously increased over the last decades. The per capita consumption, however, has decreased over time. The decrease in the per capita consumption of beef in the United States between 1961 and 2018 can be attributed to a number of different factors such as increases in the per capita consumption of poultry, increases in the daily supply of calories per person per day, increases in the price of beef, and increases in the population of the United States. The impact that beef has on the environment has been a topic of great controversial discussion over the last few decades. Studies have shown that beef is potentially the biggest environmental impactful animal protein source. Many have suggested that one of the best ways to protect biodiversity and the environment is by reducing, or even completely eliminating, the production and consumption of beef (Selinske). For this reason, an environmental analysis was performed through a life cycle assessment, using data from Brazil, the second largest producer of beef in the world after the United States. An LCA was done for three different farming methods to compare how these affected the environment and which one was more sustainable. The farming methods analyzed for the production of beef were farming with pasture, farming with pasture and feedlot, and farming with pasture and protein supplement. Since many studies suggest that it would be best for the environment to reduce the consumption of beef, a nutritional comparison was done between a beef burger and a vegan burger, a common alternative, to determine which provides the best nutritional properties. Moreover, the social and cultural pay offs of beef production and consumption were examined for the future of beef in the Unites States. The objective of this article is to examine the environmental, nutritional, health, and social trade-off of beef production in the United States. The paper discusses how the production and consumption of beef has changed over time, the effects that different beef farming processes have on the environment and the nutritional differences between beef and its alternatives.

2. The United States Beef Industry: Production and Consumption

Over the past 60 years, the production of beef has more than doubled worldwide, increasing from 28.76 million tons per year in 1961 to 71.61 million tons per year in 2018. A similar trend has been followed in the United States where beef production has almost doubled from 7.43 million tons per year in 1961 to 12.22 million tons per year in 2018. Since 1961, the United States has been the world’s leading producer of beef followed by Brazil, China, Argentina, India, and Australia. As illustrated in Figure 1 below, in 2018 the United States made up nearly 20% of the globe’s beef production, surpassing Brazil, its closest competitor, by 2.32 million tons per year (Ritchie and Roser).

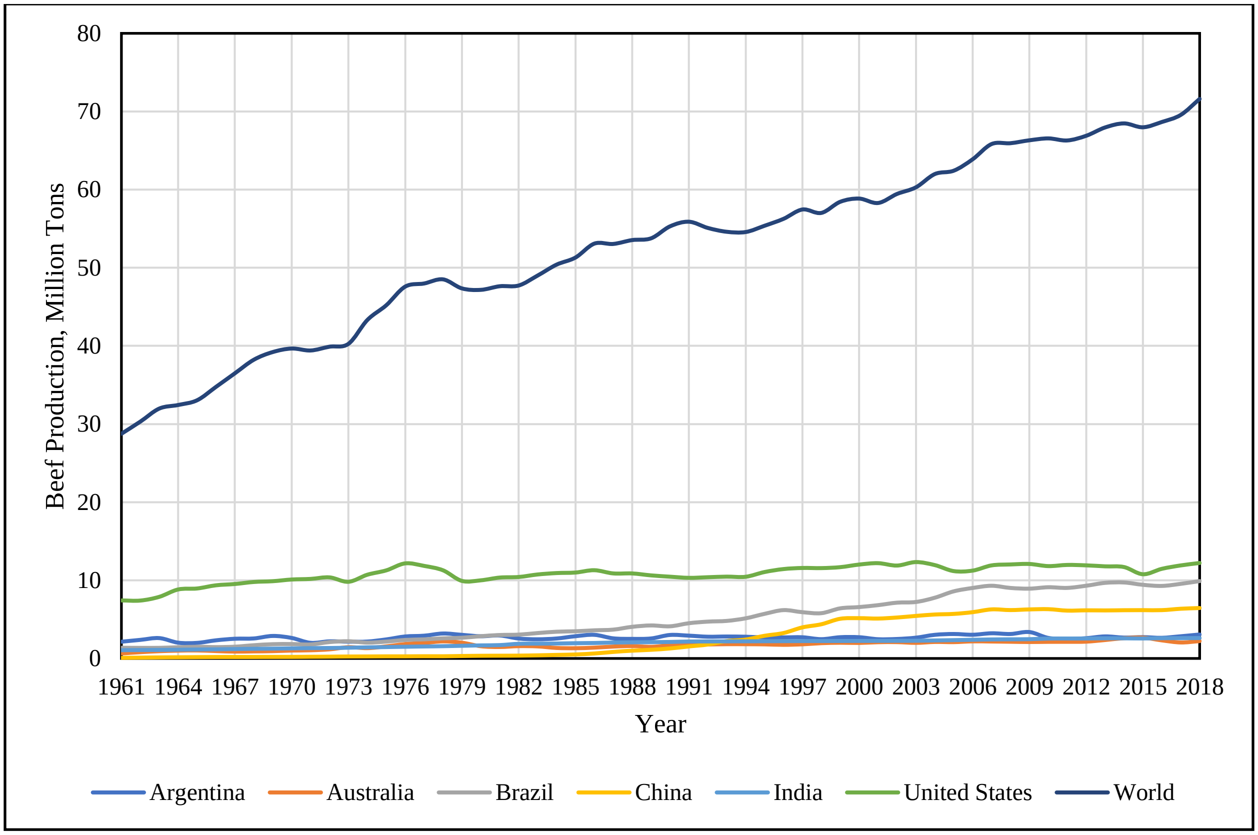

Figure 1. Global Beef Production, 1961 to 2018

While beef production has significantly increased, with a rapidly growing population in the United States, it is important to investigate how the consumption of beef has changed over time. The increasing trend in beef production in the United States shows that the consumption of beef is prevalent in people's diets. Between 1961 and 1992, beef was the most consumed type of meat in the United States. It was not until 1992 to 2018 that beef became the second most consumed type of meat only behind poultry. As shown in Figure 2 below, in 1961 the per capita consumption of beef was 41.22 kg/person/year. To put this into perspective, in that same year, the per capita consumption of all types of meats was 88.66 kg/person/year. This means that beef made up 46.5% of a person's total meat consumption diet. By 2017, the per capita consumption of beef decreased to 37.08 kg/person/year. In that same year, the per capita consumption of all types of meats increased to 124.1 kg/person/year; thus, beef went from making up 46.5% of a person's meat consumption diet in 1961 to making up 30% of a person's meat consumption diet in 2017. On the other hand, the per capita consumption of poultry more than tripled between 1961 and 2018. In 1961, the per capita consumption of was 16.44 kg/person/year. By 2017, this number increased to 55.68 kg/person/year and made poultry the most consumed type of meat in the United States. (Ritchie and Roser)

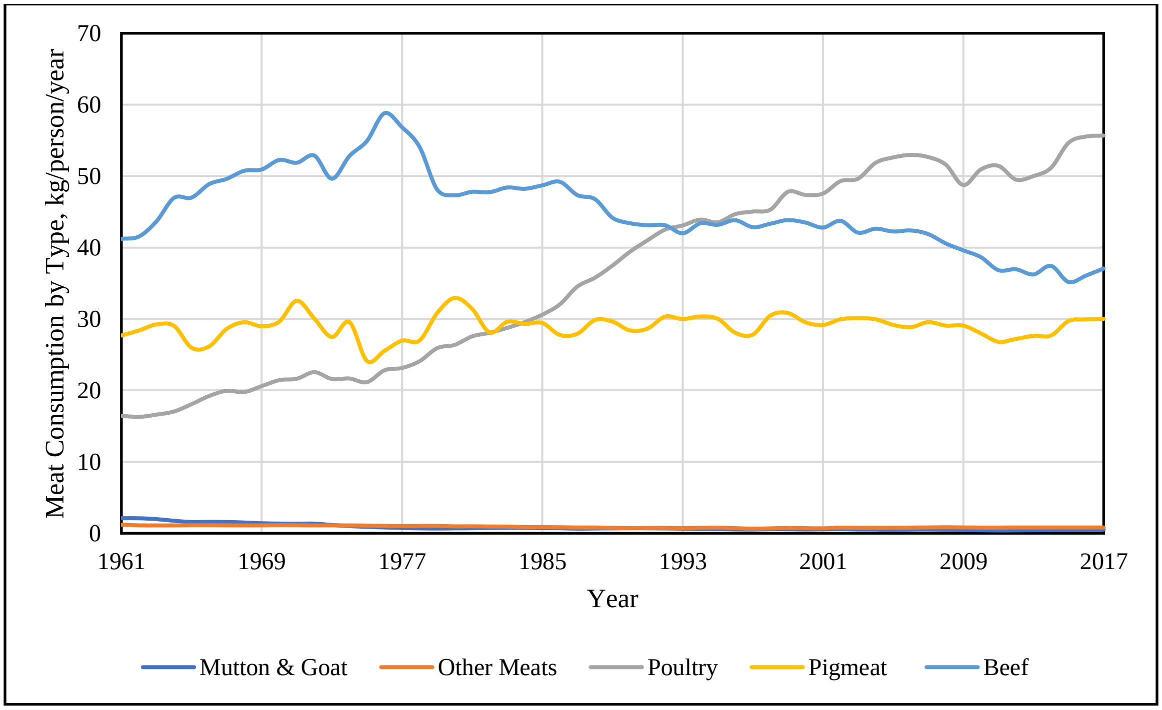

Figure 2. Per Capita Meat Consumption by Type in the United States, 1961 to 2017

There are several factors as to why the per capita consumption of beef decreased, while the production of beef increased in the United States between 1961 and 2018. Among these factors are the increase in the daily supply of calories per person per day, the increase in the per capita consumption of poultry, the increase in the price of beef, and the rapid growth of the population in the United States. As illustrated in Figure 3 below, the daily supply of calories per person per day went from 2,880 calories in 1961 to 3,782 calories in 2018 (Roser and Ritchie). The increase of nearly 1,000 calories per person per day between 1961 and 2018 can be attributed to the increase in the per capita consumption of poultry. The Unites States population, on average, consumed more than triple the number of poultry in 2017 than it did in 1961. The prices of the different types of meat in the United States have also drastically changed between 1980 and 2018. As can be seen in Figure 4 below, in 1980 the price of beef was $2.72/lb. By 2018, this price increased to $5.60/lb, an increase of $2.88/lb. On the other hand, in 1980 the price of poultry was $0.70/lb, and by 2018 the price increased to $1.59/lb, an increase of $0.89/lb. (Average retail food and energy prices, U.S. and Midwest Region) The difference of over $4/lb between the price of beef and the price of poultry in 2018 could be related to the reason why people chose to consume poultry over beef. The population of the United States has also grown at a rapid pace between 1961 and 2018. As can be seen in Figure 5 below, in 1961 the population of the United States was 189,569,843 and by 2018 it grew to 327,096,843, an increase of 73% (U.S. population growth rate 1950-2022). The factors stated above that the supply of calories per person per day increased by nearly 1,000 calories, the per capita consumption of poultry more than tripled, and the significantly greater increase in the price of beef compared to poultry in the United States between 1961 and 2018 have led the per capita consumption of beef to decrease, although the production increased.

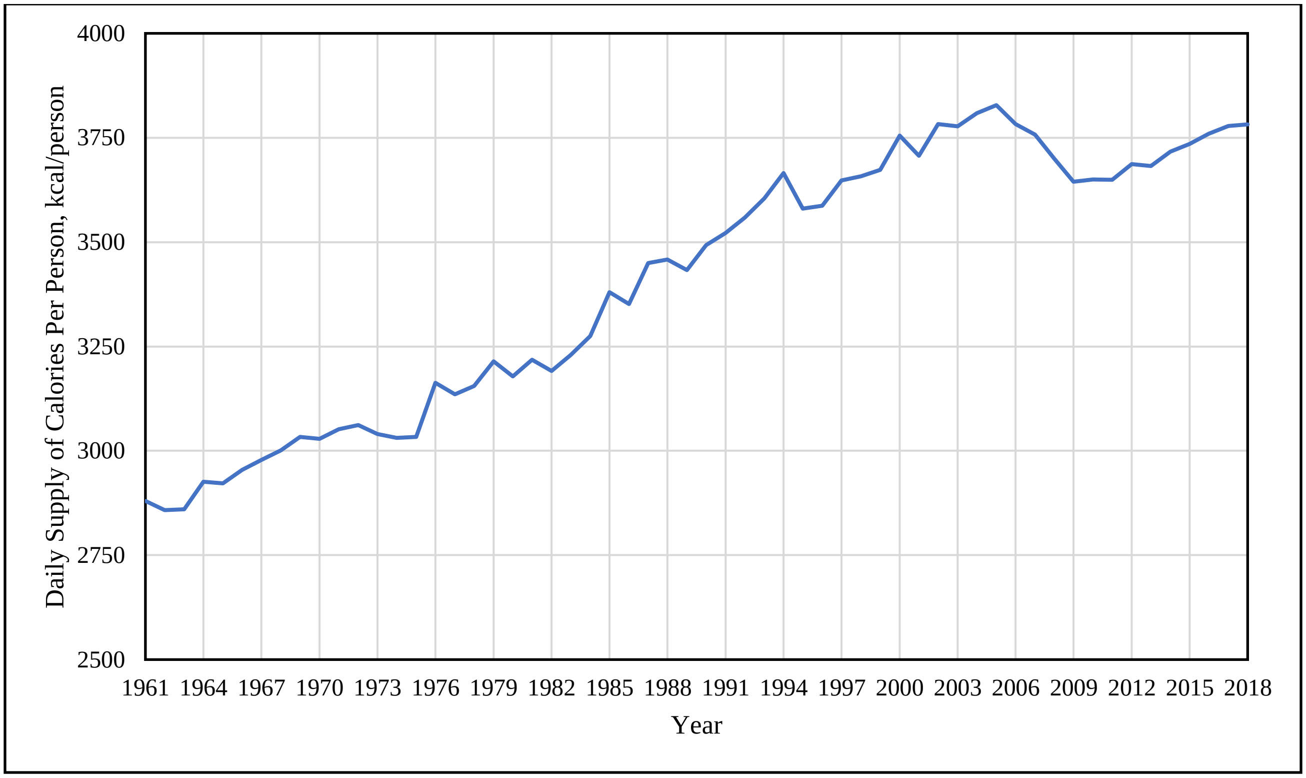

Figure 3. Daily Supply of Calories per Person in the United States, 1961 to 2018

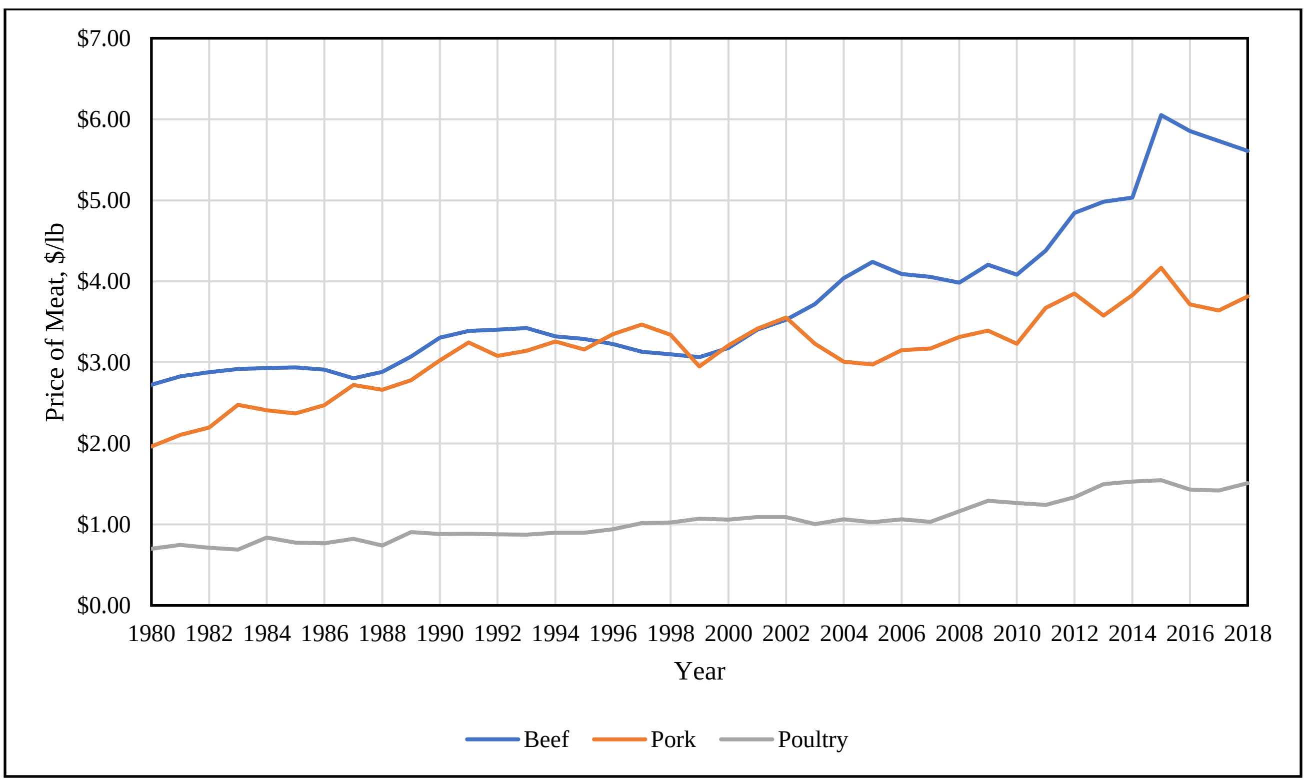

Figure 4. Prices of Meat in the United States, 1980 to 2018

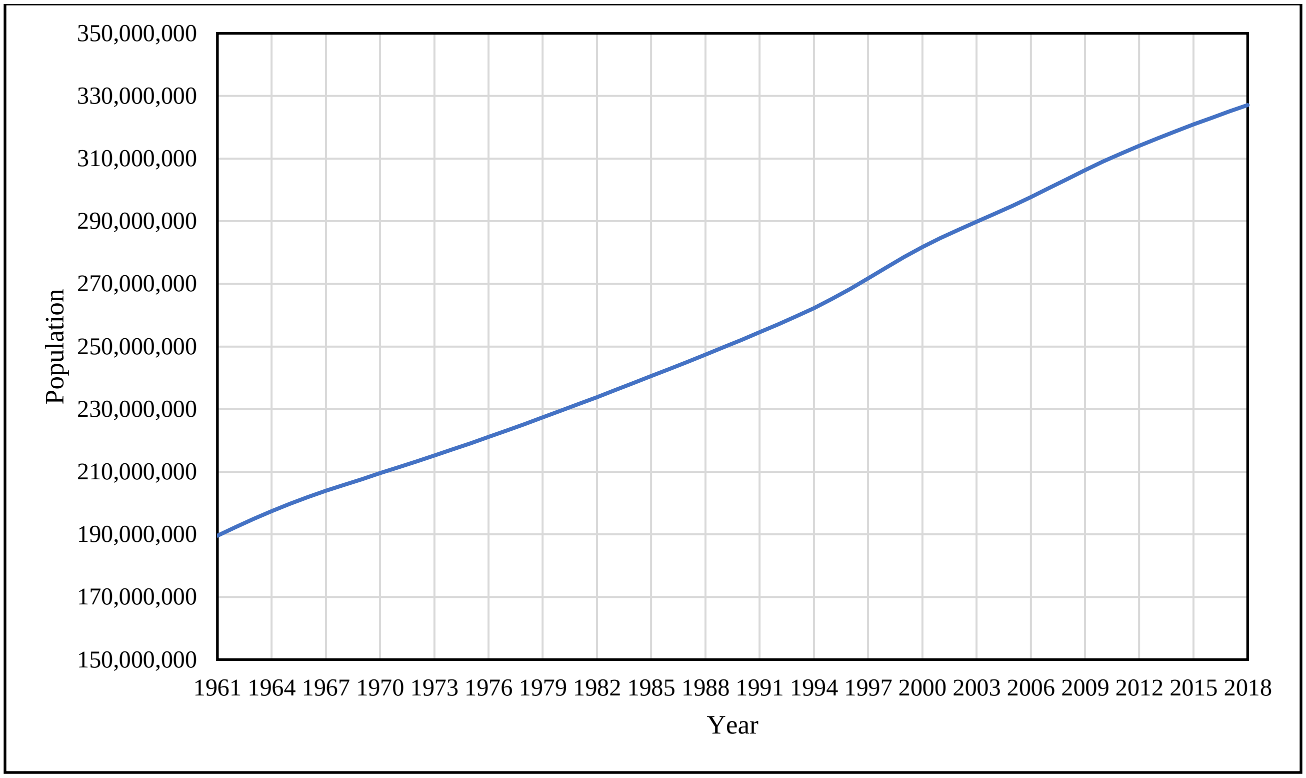

Figure 5. Population Growth in the United States, 1961 to 2018

Taking into account that the daily supply of calories, the per capita consumption of poultry, the price of beef and the population of the United States have all increased significantly in the past decades, it is comprehensible that the per capita consumption of beef decreased while the production increased between 1961 and 2018. The increasing trend in the production of beef shows that the consumption of beef is still common in people's lives. People's diets, however, have diversified between 1961 and 2018. To put this into perspective, in 1961 beef made up 46.5% of a person's meat consumption diet. By 2017, this number decreased to 30%. On the other hand, in 1961 the consumption of poultry was only 18.5% of a person's meat consumption diet, and by 2017 it rose to 45% of a person's meat consumption diet. Considering how widely popular the consumption of beef still is, it is important to analyze the environmental impact that the production and consumption of beef has in the United States.

3. Environmental Impact of Beef Production and Consumption

3.1 Introduction to Beef Consumption Protein and Energy Efficiency

To determine the environmental impact that the production and consumption of beef has in the United States, it is important to analyze the percentage of protein and caloric inputs as feed that are converted into animal products for consumption. As illustrated in Figure 5 below, beef is only capable of converting 3.8% of its total inputs of protein into animal product. This means that of the total amount of protein that is included in the cattle's diet, only 3.8% translates into protein into animal products that are used for consumption. In contrast, products like poultry, whole milk and eggs can convert upwards of 20% of its inputs of protein into animal product. Similarly, as shown in Figure 7 below, beef has the lowest energy efficiency as it is only capable of converting 1.9% of the caloric energy inputs as feed. On the other hand, products like poultry, whole milk and eggs are capable of converting up to 24% of their total caloric energy inputs as feed into animal products. (Ritchie and Roser)

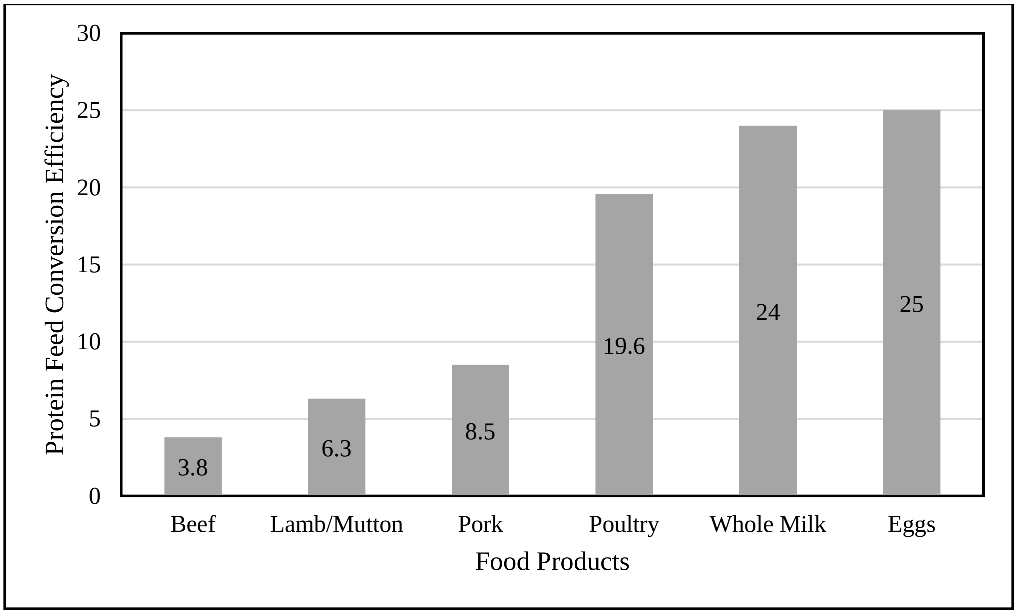

Figure 6. Protein Efficiency of Meat & Dairy Products

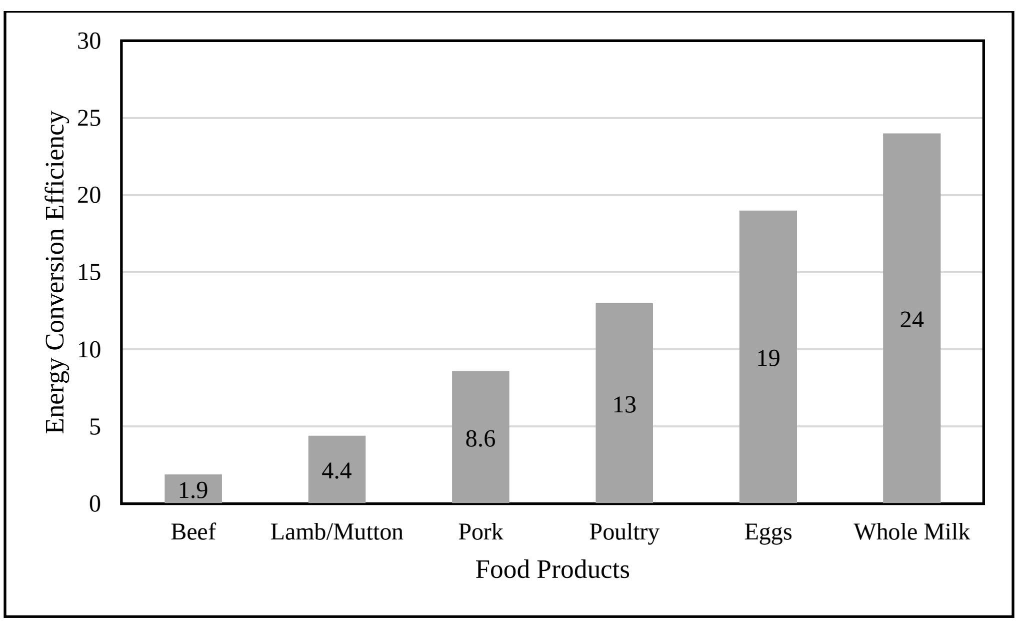

Figure 7. Energy Efficiency of Meat & Dairy Products

Although beef is among the most common types of meat consumed in the United States, its protein and energy efficiency are significantly low compared to other meats like poultry, and dairy products like whole milk and eggs. This raises questions as to how sustainable the production of beef actually is. For this reason, an impact assessment of varying cattle farming processes was performed on openLCA to analyze and examine the major impact categories affected by the production of beef.

3.2 Impact Assessment of Varying Cattle Farming Processes

With Brazil being the second highest producer of beef, impact assessments were completed for three different cattle farming processes to complete a characterization analysis. The three-farming processes analyzed were: pasture, pasture and feedlot, and pasture and proteic supplement. For all three farming processes, the basis was one kilogram live weight of beef cattle raised on a pasture farm until ready for slaughtering. Pasture fencing, pasture maintenance and replanting were all included in the inputs. Emissions from the pasture, organic fertilizer, and manure were all included. It was also assumed that the pasture was to be replanted every 20 years.

For the 'pasture' process, it was assumed that no protein supplement was given to the cattle aside from the grass on the pasture. The assessment included fat steers that were slaughtered after 42 months on a grazing pasture. For the 'pasture and feedlot' process, it was assumed that the steers were raised on a pasture for 20 months and on a feedlot for the 4 months prior to being slaughtered for consumption at 24 months. Aside from grazing the pasture, the cattle were also fed a proteic supplement composed of maize, soybean, urea, and salt during the first dry season. For the 'pasture and proteic supplement' cattle farming method it was assumed that along with hay the steers were fed maize, soybean, urea, and salt during the second and third dry season. The cattle were also slaughtered for consumption at 42 months of age.

The top five normalized impacts for all three farming processes, in order of highest impact, were human non-carcinogenic toxicity, marine ecotoxicity, freshwater ecotoxicity, human carcinogenic toxicity, and global warming. The impact assessment results can be seen in Figures 8, 9, 10, 11, and 12 below. The cattle that were raised for slaughter through the 'pasture and feedlot' process had the smallest impact on the environment for all five top impact categories. The cattle that were fed a proteic supplement had a lower environmental impact than those who were only fed from a pasture. Based on the results represented, it is concluded that from the three processes, the most sustainable way to raise cattle for slaughter is on a pasture and feedlot while also providing a proteic supplement. This is because when on the feedlot, the cattle occupy less land. The proteic supplement also promotes growth so that the cattle can be slaughtered after 24 months rather than 48. Because of this, the impact on the environment is lessened due to lower amount of methane being released.

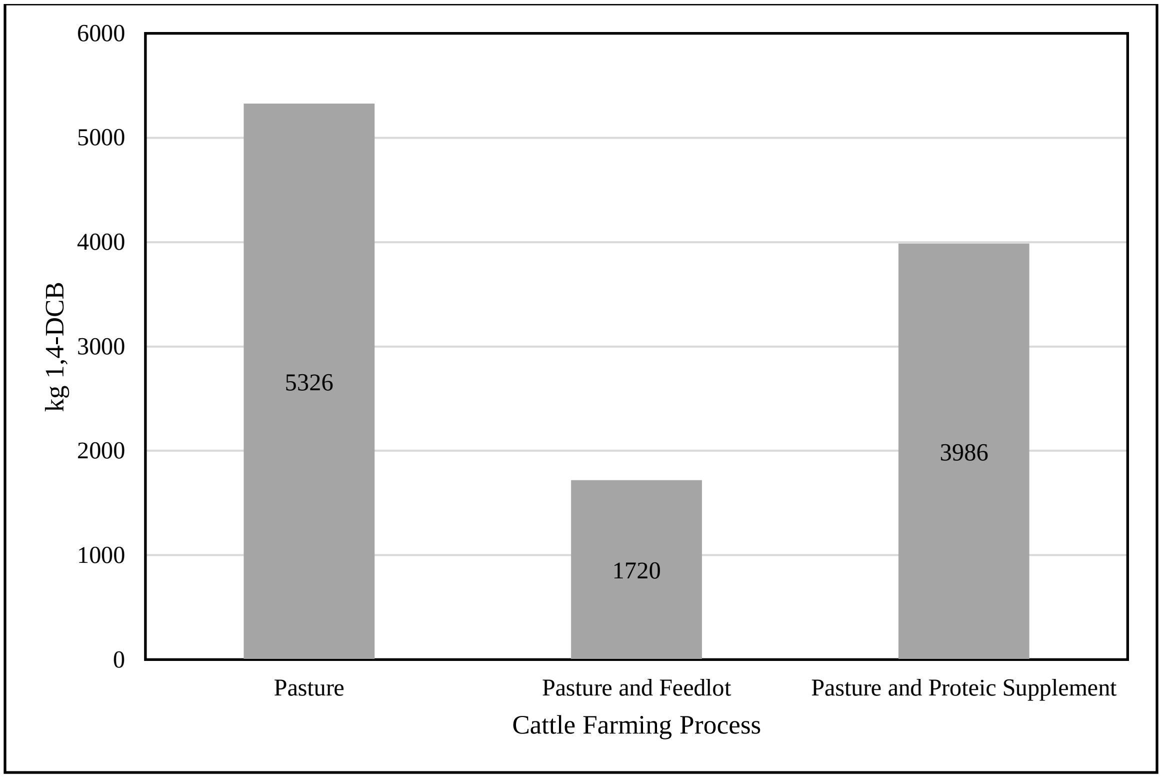

Figure 8. Human Non-Carcinogenic Toxicity

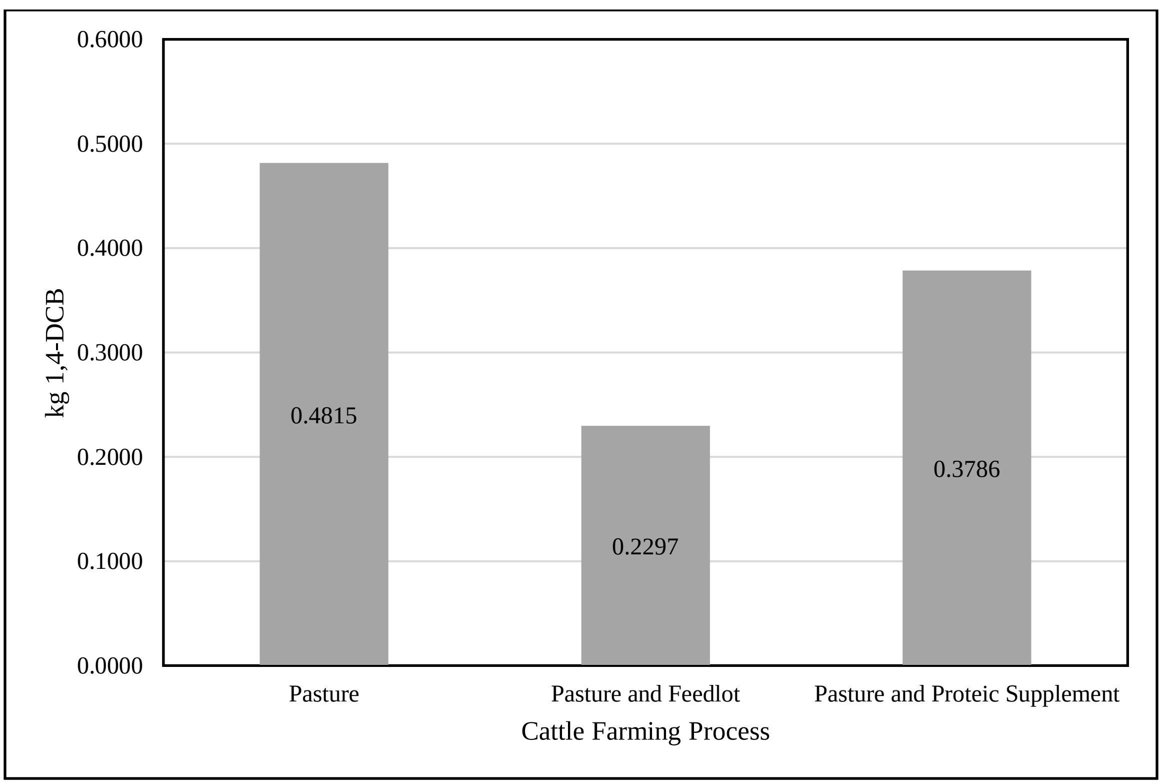

Figure 9. Marine Ecotoxicity

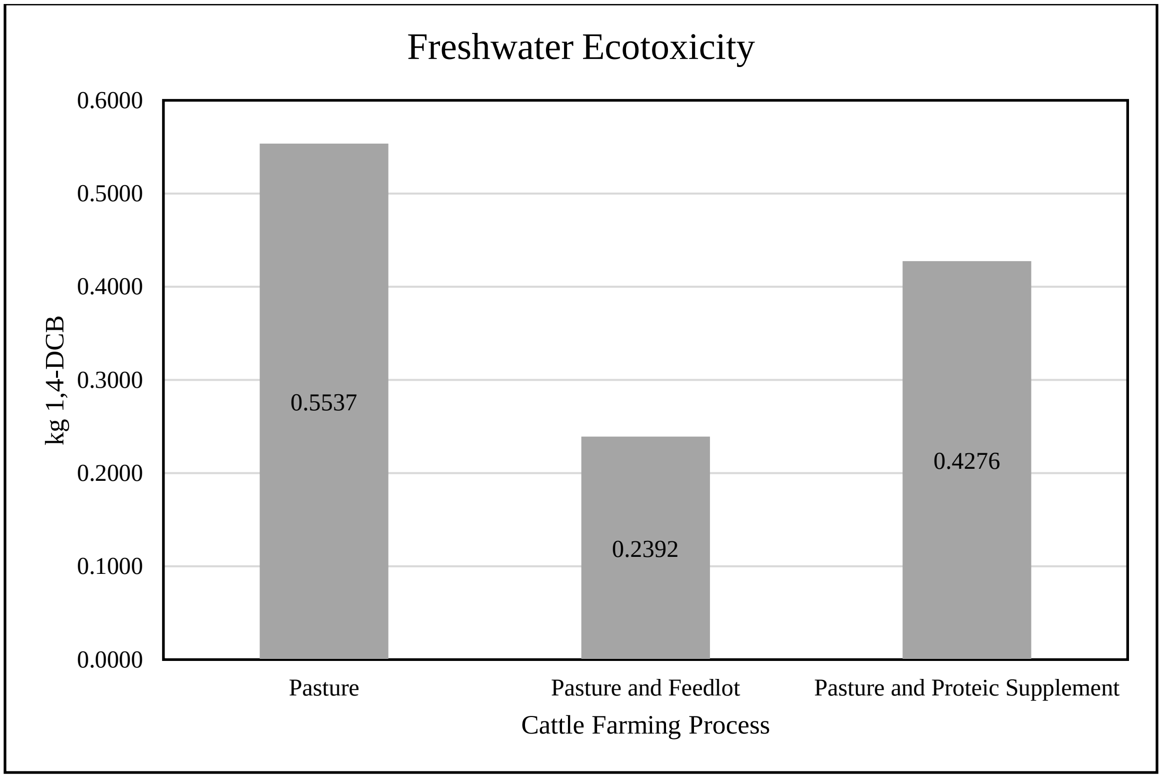

Figure 10. Freshwater Ecotoxicity

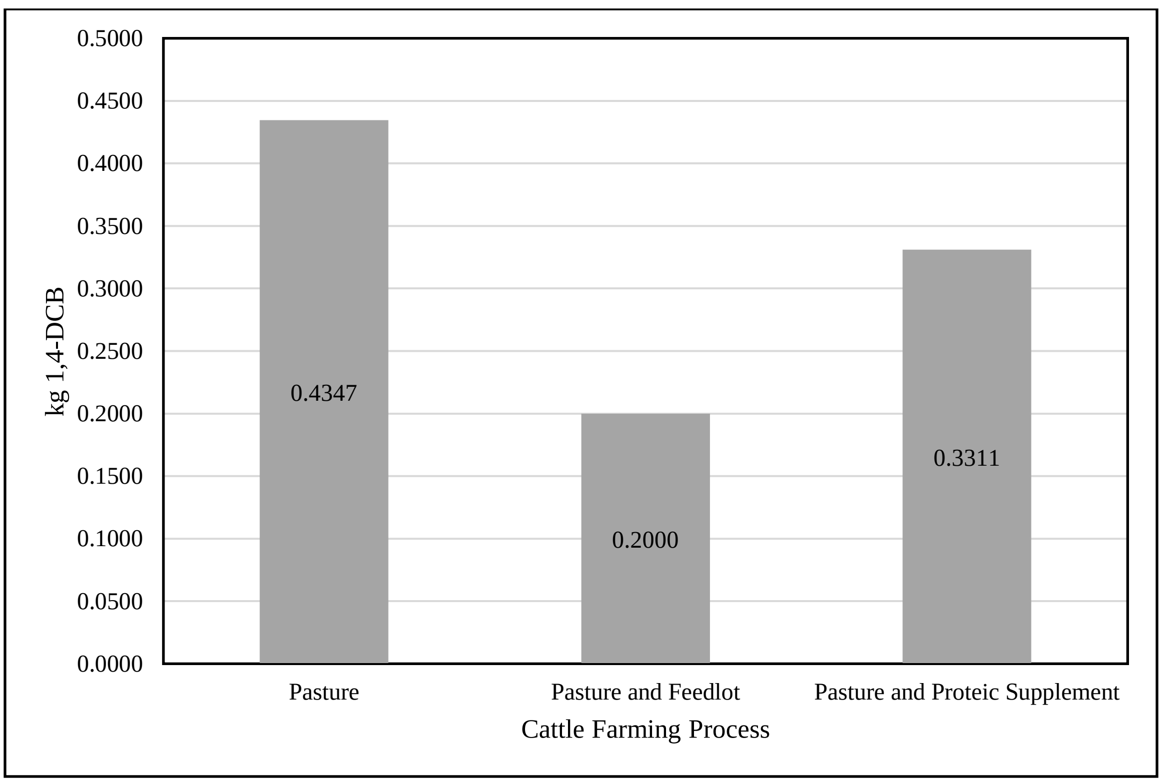

Figure 11. Human Carcinogenic Toxicity

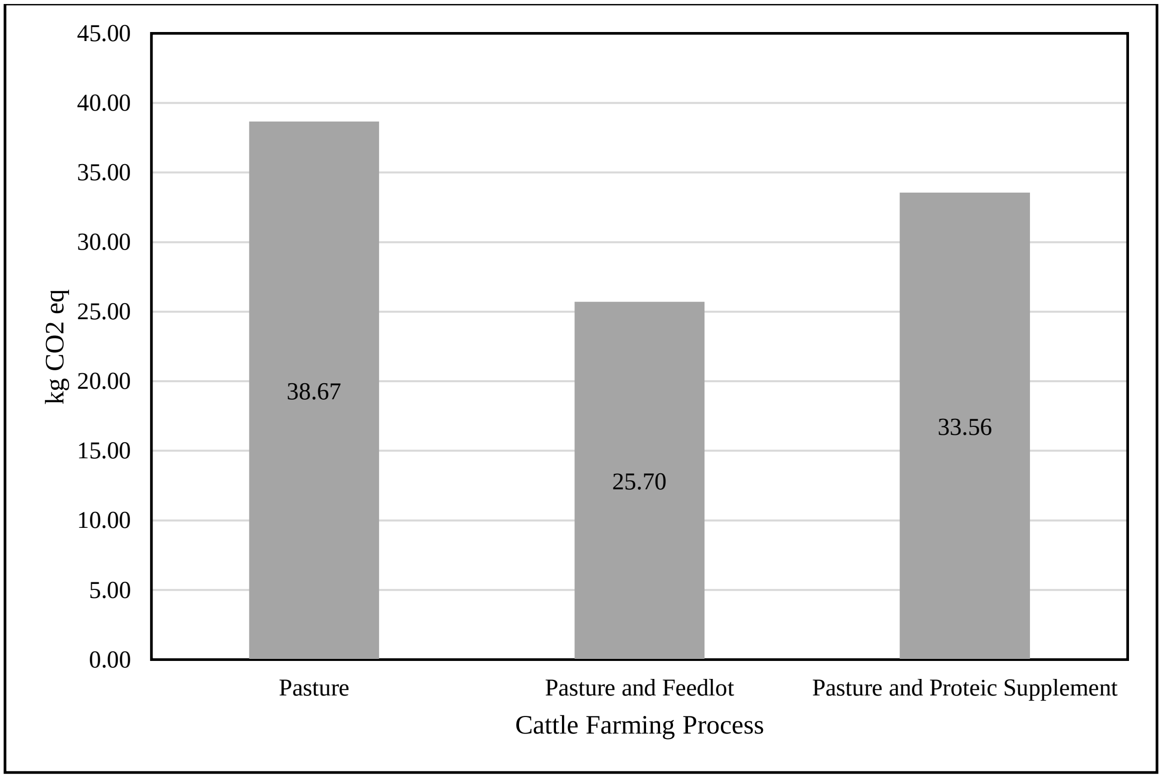

Figure 12. Global Warming

3.3 External Environmental Cost of Cattle Farming

The external cost is the cost related to the product that the consumer does not pay for. This is the cost that the individual or community will incur indirectly from the process such as from environmental impacts. External costs were calculated using the environmental indicator CEN+ method. The external cost for the three different farming processes are represented in Table 1 (Pasture), Table 2 (Pasture and Feedlot) and Table 3 (Pasture and Proteic Supplement) below. The cattle farming method with the lowest external cost was the ‘pasture and feedlot’ process. This is because it had the lowest amount of human non-carcinogenic toxicity released. This impact category had the largest effect on the external cost because its cost was over 400% higher than the other categories (718,317 $/CTUh) and it was the largest normalized impact. The external cost for the ‘pasture’ process had an external cost 194% greater than that of the ‘pasture and feedlot’ process. The ‘pasture and proteic supplement’ process had an external cost that was 122% higher than that of the ‘pasture and feedlot’ process. A large contribution of this is because that with the ‘pasture and feedlot’ farming process, the cattle were able to be slaughtered after 24 months rather than 48 months for the ‘pasture’ process.

Table 1. External Cost: Pasture Farming

Impact Category	External Cost
1. Human Non-Carcinogenic Toxicity	$44.50
2. Marine Ecotoxicity	$0.00
3. Freshwater Ecotoxicity	$0.02
4. Human Carcinogenic Toxicity	$0.06
5. Global Warming	$2.36
Total External Cost	$46.94

Table 2. External Cost: Pasture and Feedlot Farming

Impact Category	External Cost
1. Human Non-Carcinogenic Toxicity	$14.37
2. Marine Ecotoxicity	$0.00
3. Freshwater Ecotoxicity	$0.01
4. Human Carcinogenic Toxicity	$0.03
5. Global Warming	$1.57
Total External Cost	$15.98

Table 3. External Cost: Pasture and Protein Supplement Farming

Impact Category	External Cost
1. Human Non-Carcinogenic Toxicity	$33.31
2. Marine Ecotoxicity	$0.00
3. Freshwater Ecotoxicity	$0.02
4. Human Carcinogenic Toxicity	$0.04
5. Global Warming	$2.05
Total External Cost	$35.42

4. Nutritional and Lifestyle Implications of Beef Consumption

4.1 Beef Nutrition

Researchers and doctors specifically in developed countries started to warn others about the negative health effects of consuming red meat. Web MD, a popular website on human health, reports that red meats can lead to heart disease, and possibly cancer. Due to media coverage, the demand for red meat alternatives have increased, leading to vegan options being released to the market. Nutritionally, the comparison of these vegan burgers to livestock beef has not been investigated on many public platforms, leaving room for misinformation and assumptions about the difference in health impacts.

Beef, considered as red meat, is reported to contain many saturated fats, cholesterol, and sodium. Analyzing where the negative effect of beef originates from reveals that by substituting fatty red meats such as ribeye steak with a lean option such as a sirloin steak, can reduce the health impacts without eliminating red meat from a person's diet. Red meat can contain high amounts of lipids if not trimmed. Lean red meat that contains less fat, does not increase cholesterol levels, but consumption of uncut red meat could decrease life expectancy and potentially cause many long-term health effects. The increased consumption of red meat containing fat may be related to increased coronary heart disease, hypertension, and even cancer (Wolk). Red meat consumption is not necessarily the culprit, but rather the increased amounts of lipids that it can contain. Moreover, beef contains valuable vitamins that are unique to red meat such as zinc, B12, selenium, iron, niacin, B6, and phosphorus (Arnarson). These vitamins are important to incorporate into a diet and without the consumption of red meat would have to be artificially substituted. The recommended switch to lean white meat is still more beneficial than lean red meat due to the lower saturated fatty acids.

Another valuable alternative is switching from processed beef to organic beef. Due to processed beef dominating over 85% of the produced beef globally, organic beef is more expensive due to the lack of demand and being more difficult to produce (Processed Beef Market). Organic beef contains more beneficial omega acids, less cholesterol, and more antioxidants. Additionally, organically sourced beef omits the use of excessive antibiotics, growth hormones, preservatives, and feeds that are high in carbon emissions. Though organic beef is more beneficial nutritionally, it has a higher impact on the environment. (Organic Beef)

The marketed "impossible burger" and "beyond burger" are two new alternatives when cutting out red meat in a diet. These burgers are completely plant based, vegan, and also compare closely to a real burger. The vegan burgers have added vitamins and minerals that are originally only found in red meat such as B12 and zinc to mimic the health benefits of real beef. Unfortunately, vegan burgers are highly processed and have a significant amount of saturated fat. Saturated fat in red meat causes health problems and is the main reason for decreasing red meat in the diet. High saturated fat levels in a diet can led to heart disease and premature death. A nutritional breakdown of these burgers is attached below in Table 4.

Table 4. Nutrient Health of Plant vs Meat based Burgers

Burger Type (4 oz)	**Calories (kcal)**	**Fat (g)**	**Sat Fat (g)**	**Cholesterol (mg)**	**Sodium (mg)**	**Carbs (g)**	**Fiber (g)**	**Protein (g)**
Impossible Burger	240	14	8	0	370	9	3	19
Beyond Burger	230	18	5	0	390	7	2	20
85% Lean Ground Beef	240	17	6	80	80	0	0	21

Based on this nutritional analysis, the most beneficial health option is to consume lean organically derived beef, however organic meat results in a high impact on the environment.

4.2 Lifestyle Implications

To understand how the nutritional qualities of red meat play a part in the quality of life of an individual, an investigation of daily red meat consumption versus change in life expectancy was conducted. The daily diet was modified in terms of red meat consumption. The change in life expectancy varied based on what age the diet was modified from the average diet and how much it was changed. In this investigation, the average diet consisted of 50 grams of whole grains, 50 grams of fish, 50 grams of processed meat, 100 grams of red meat, 300 grams of milk or diary, 250 grams of vegetables, 200 grams of fruit, 500 grams of sugar from beverages, 150 grams of refined grains, 50 grams of eggs, 75 grams of white meat, and 25 grams of added oils. To balance the diet, it was assumed that when a lower amount of red meat was consumed, a higher amount of white meat was introduced into the diet in order to get the estimated total energy of the daily diet equal to 1,932 kcal/day. White meat was chosen as the alternative to red meat because increased amounts of white meat have no effect on lifespan.

Figures 13, 14, and 15 below present the data on the predicted change life expectancy based on different daily consumption amounts of red meat starting at 1 year old, 30 years old, and 60 years old (Fadnes and Haaland). In Figure 13 below, the change in life expectancy is displayed based on the varying amounts of red meat consumed from the age of 1 year old. Because 100 grams of red meat is consumed daily in the average diet, when amounts less than 100 grams were consumed, the expected life span increased up to 1.7 years for females and 2 years for males. However, when greater amounts of red meat were consumed, the expected life span decreased by up to 6.5 years for females and 7.5 years for males. The change in life span for an altered diet starting at 30 years old is shown in Figure 14. When red meat was removed from the diet at 30 years old, the lifespan increased by 1.6 years for females and 1.8 years for males. However, when the consumption of red meat increased up to 500 grams daily at 30 years old, the life expectancy decreased by 6 years for females and 6.6 years for males. At 60 years old (Figure 15) when red meat was cut out of the diet, the life expectancy increased by 1.2 years for both females and males, but when red meat was increased up to 500 grams, the life expectancy decreased by 4.3 years for females and 4.2 years for males. Based on the trends for the three age groups it is seen that when the daily consumption of red meat is decreased below 100 grams, the greatest change in life expectancy is seen when starting at a younger age. However, removing the consumption of red meat from the diet at 1 year old versus at 60 years old only has a difference in prolonged life of 0.5 years for females and 0.8 years for males. When increasing the amount of daily red meat consumption above 100 grams, the greatest decrease in lifespan is seen when amounts are increased from a younger age. When consumption is 500 g/day from 1 year old versus 60 years old, the life expectancy is 2.2 years shorter for females and 3.3 years shorter for males. This trend shows that there is a significant difference in lifespan when over-consuming amounts of red meat; alternatively, when consuming less than the average of 100 grams the difference in life expectancy is minimal. This shows that consumption of red meat in moderation has minimal effect on quality of life.

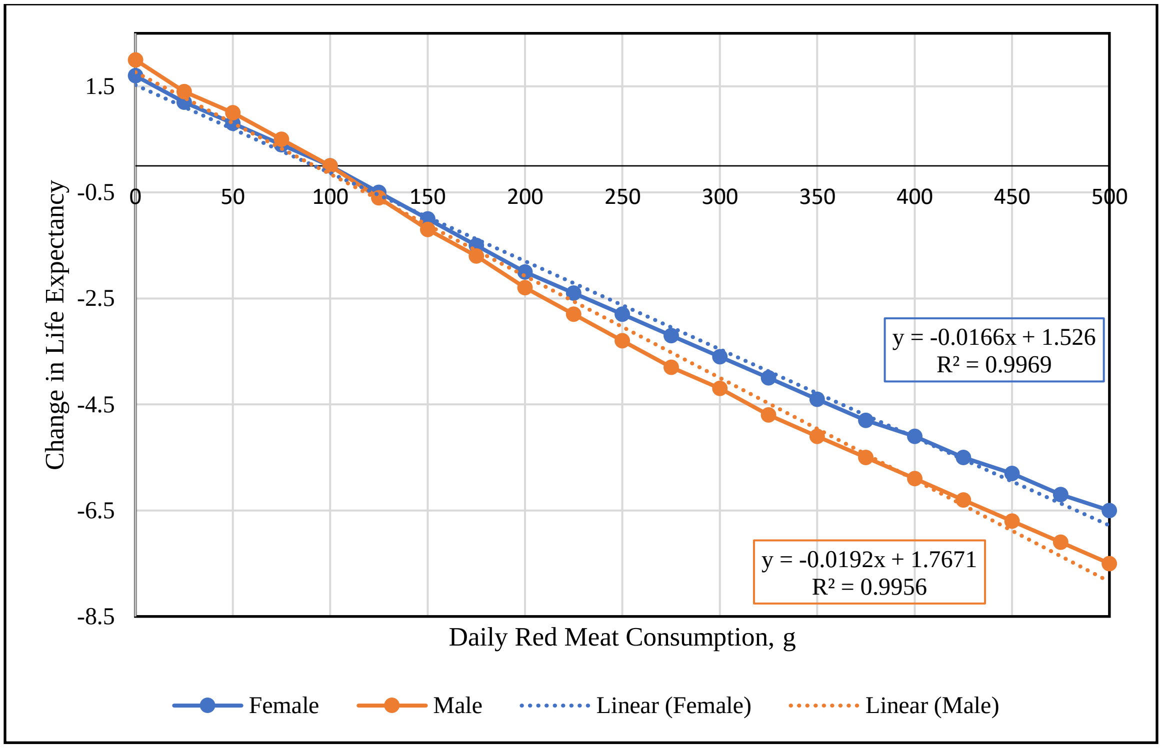

Figure 13. Red Meat Consumption vs. Change in Life Expectancy (Age 1)

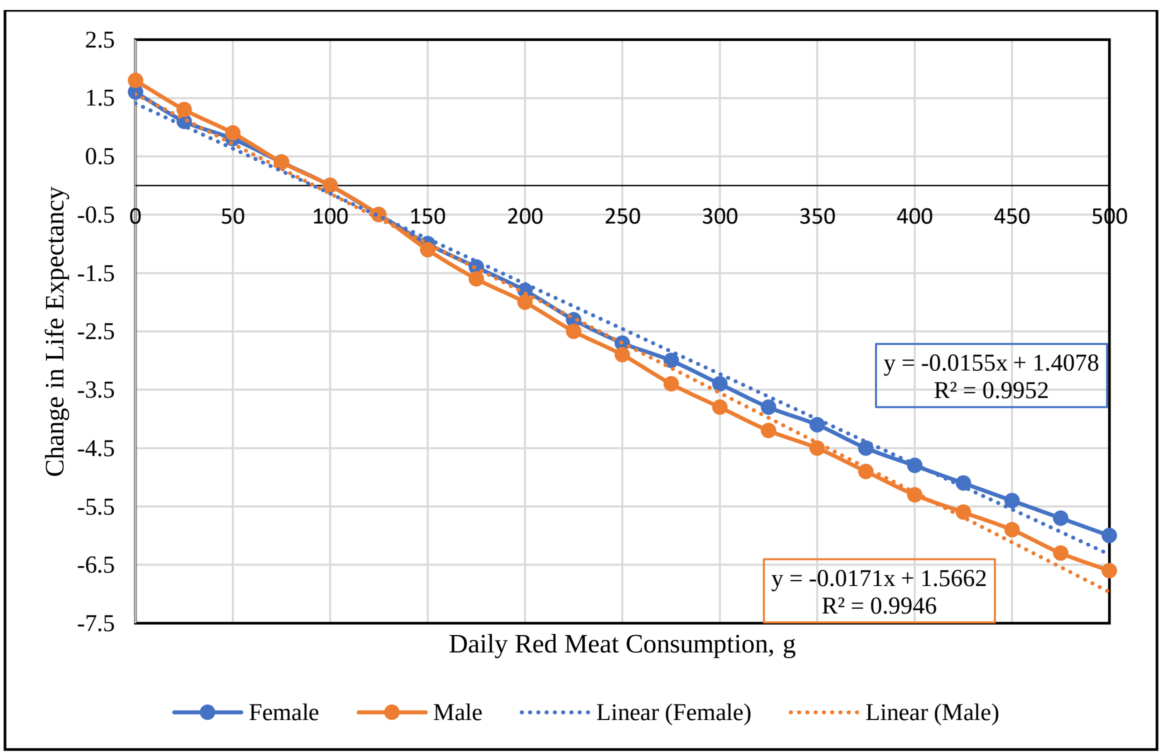

Figure 14. Red Meat Consumption vs. Change in Life Expectancy (Age 30)

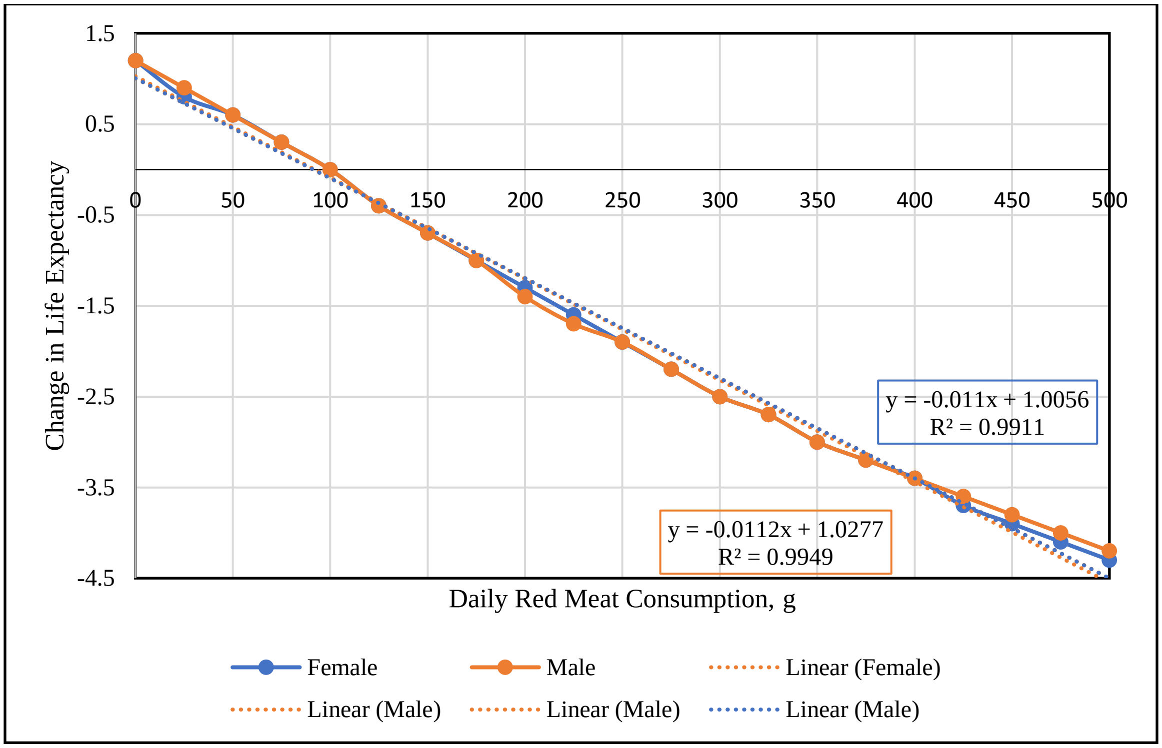

Figure 15. Red Meat Consumption vs. Change in Life Expectancy (Age 60)

5. Social and Cultural Effects on Beef Production and Consumption

5.1 Social Effects of Beef Production and Consumption

When one aspect of a system is altered, the direct and indirect effects that the change can have on the rest of the system must be analyzed. Many researchers have stated that removing livestock production from United States agriculture would decrease greenhouse gas emissions (GHGs), promote human health, and increase United States food system sustainability. However, most of these studies do not go into depth on the indirect social impact that removing animals from the food system would have.

While livestock is used for human consumption, livestock byproducts such as rendering products and fats are used to provide protein for pet foods to provide the required nutrients for approximately 69.9 million dogs, 74.1 million cats, 8.3 million birds, and 89.4 million other pets (White and Hall). Additionally, livestock agriculture greatly supports and impacts the United States economy by providing over 1.6 million Americans with jobs and more than $3.18 billion/year in animal products that are exported (Average Retail Food and Energy Prices, U.S. and Midwest Region, Foreign Agricultural Trade of the United States (Fatus)). Animal agriculture, crop agriculture, and industrial applications create an ecosystem with many transactions between the three components. When it comes to livestock production there are other uses aside from human consumption. Many fertilizers that are used to produce crop agriculture comes from livestock manure: Manure N (4.01 x 109 kg/yr), Manure P (1.69 x 109 kg/yr), Manure K (1.88 x

109 kg/yr), Manure S (2.84 x 108 kg/yr). Animal agriculture also provides byproducts, fiber, and biofuel, as well as 1.20 x 10^{11} kg of human food annually. (White and Hall) It is important to note that useful byproducts of livestock production for food includes non-food uses as well as vital amounts of manure for fertilizer for crop agriculture.

5.2 Cultural Effects of Beef Production and Consumption

Beef consumption has been a culturally significant lifestyle since around 8000 BC. Eating beef was seen as a sign of power, strength, and wealth among many cultures around the world, and even holds similar gravity now. Around the world beef production varies and can be a scarce resource in some nations, whereas in developed countries, it is a luxury that most middle-class citizens can indulge in daily. Beef production is one of the most environmentally taxing agricultural processes, using a surplus of water, energy, and resources to harvest. Currently, overall caloric intake has increased but beef consumption has remained relatively constant, meaning that people have started to incorporate more poultry into their diet. From a sustainability perspective, beef consumption should be an optimized process in order to preserve the atmosphere and resources; however, many people believe that beef production should be limited, hence the growing popularity in vegan diets, and beef alternatives. Within the next 50 years, beef consumption could be expected to be a less common commodity.

Commodity beef according to several beef forecasters, is projected to show a decline as early as the second half of 2022. Studies say feed prices are increasing while cattle availability is tightening, causing an increase in cost for producers and customers (Doran). As previously analyzed, organic derived beef is the best option nutritionally, however organically sourced beef is a scarce product that is only sold in specific store, environmentally taxing, and costly. When considering nutrition, purchasing organic beef would be the most beneficial option, but with the expected decline in commodity beef, organic beef will become more expensive due to the lack of resources. Beef is slowly being substituted with pork and poultry.

6. Conclusion

Red meat production raises a significant number of warnings, impacting the environment, human health, and the economy. Beef production has steadily increased from 1961 to 2018, but as of 2018 the per capita beef consumption has declined due to changes in population growth, decreases in resources, and increase in cost for producers and consumers. Cattle farming requires a large number of resources including protein, water, and energy, while also polluting ecosystems and the environment. Beef impacts human carcinogenic and non-carcinogenic toxicity, marine and freshwater ecotoxicity, and global warming on a large scale. The farming process used to raise cattle drastically changes the environmental impact of cattle. When considering sustainability, raising cattle on a combination of a pasture and feedlot impacted the environment the least in all significant categories. Alternatives to red meat have recently been encouraged among the United States and other developed countries, but the nutritional effects proved to be negatively consequential. Cutting out beef from a person’s diet could increase one’s lifespan by 1.7 and 2 years for a female and male respectively. Red meat contains a high amount of saturated fats that could lead to long term health problems, but vegan alternatives showed a greater level of saturated fats due to processing during production. While the depletion of beef production seems ideal for the environment, the social impact would affect workers in agriculture around the world. Culturally, it could be expected to see a shift in the consumption of beef; because of the decrease in resources and negative impacts of the beef production, beef may be seen as a delicacy for many around the world. While beef can be considered destructive to the environment, the positives of beef production is outstanding. Nutritionally beef offers unique vitamins and economically it molds a large portion of American agriculture; additionally, with beef consumption per capita decreasing, production should be expected to decrease significantly over time. Though beef should not be eaten in excess or produced at the level it is currently, the trends prove that the consumption and production rates will naturally reduce.

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Appendix

Table A.1. Global Beef Production Data, 1961 to 2018

Year	Argentina	Australia	Brazil	China	India	Us	World
1961	2145064	642924	1369078	79408	1056852	7425722	28755714
1962	2378826	803950	1355958	107441	1076380	7411207	30307673
1963	2605287	928606	1360928	134654	1088666	7885662	31976185
1964	2019240	1001315	1437185	152531	1116760	8830944	32437146
1965	1995096	1026287	1496849	167752	1142200	8957042	33040548
1966	2320931	946333	1452331	181123	1165820	9360283	34754098
1967	2521953	878683	1505502	185539	1199400	9530379	36497312
1968	2561320	904285	1694447	188982	1234196	9789000	38228120
1969	2882933	934766	1826440	196169	1257428	9888000	39212224
1970	2624011	1009954	1845182	197593	1289988	10102810	39662457
1971	2000893	1047200	1794200	215087	1322824	10182188	39414287
1972	2191102	1164393	2095200	229905	1338000	10374057	39899373
1973	2148578	1437944	2202000	250499	1376200	9812966	40260716
1974	2163033	1321817	2030000	258423	1419490	10715610	43311973
1975	2438552	1546965	2156979	270471	1459032	11271258	45198729
1976	2811410	1840415	2370000	270354	1500485	12166191	47582912
1977	2913776	1987800	2445520	284676	1536230	11844596	47986751
1978	3193244	2183800	2570000	282126	1569200	11281690	48514097
1979	3020199	2018000	2650000	315437	1620873	9925000	47357186
1980	2839248	1564400	2850000	342066	1673972	9998990	47172698
1981	2939205	1467200	3000000	352093	1710776	10353000	47634473
1982	2550542	1576195	3050000	363742	1877530	10425000	47727644
1983	2455270	1542890	3250000	401873	1893708	10746000	48999507
1984	2553720	1345276	3420000	453312	1912188	10927000	50395178
1985	2847838	1310020	3480000	511136	1953800	10996000	51304055
1986	3023413	1384923	3600000	634091	1980760	11292000	53086455
1987	2574359	1520723	3690000	838172	2038200	10884000	53048483
1988	2506467	1587724	4050000	997068	2063268	10879000	53542670
1989	2558857	1491478	4225000	1108537	2088339	10633000	53765572
1990	3007000	1676726	4115000	1279924	2114348	10465000	55296249
1991	2918000	1759569	4510800	1538585	2166802	10316064	55889747
1992	2784000	1790870	4715500	1780731	2178608	10394989	55095474
1993	2808000	1825813	4806900	2227504	2187641	10471646	54603532
1994	2783000	1824805	5136000	2420202	2196812	10454863	54571303
1995	2688000	1803417	5710200	2903233	2206259	11061317	55374837
1996	2694000	1744696	6186900	3253779	2216120	11441428	56259712
1997	2712000	1810300	5921500	3975263	2225602	11578866	57455189
1998	2469169	1955253	5794300	4376426	2230663	11562083	57018627
1999	2719784	2010530	6413300	5079177	2236138	11684553	58441366
2000	2718000	1987902	6578800	5155924	2242025	12016583	58850260
2001	2461000	2078900	6823600	5107845	2248361	12195753	58290302
2002	2493000	2089742	7139000	5239939	2255144	11890031	59444488
2003	2658000	1997563	7230000	5445101	2262720	12334552	60293480
2004	3024000	2112892	7774000	5624749	2304139	11947637	61991947
2005	3130800	2090272	8592000	5702119	2346316	11180612	62420785
2006	3033600	2188318	9020000	5924165	2389008	11242845	63881178
2007	3223700	2168946	9303000	6281250	2433418	11909626	65831135
2008	3131902	2138328	9024000	6191903	2450579	12030872	65940010
2009	3378460	2106385	8935000	6277317	2468973	12091245	66313389
2010	2630163	2128598	9115000	6306451	2543671	11818953	66553535
2011	2498954	2129021	9030000	6122697	2548922	11969954	66292175
2012	2595815	2152031	9307000	6162285	2553761	11916067	66888242
2013	2821608	2359064	9675000	6146303	2581291	11788608	67952557
2014	2674000	2595149	9723000	6173202	2576037	11698116	68473337
2015	2727000	2661640	9425000	6183515	2560374	10777601	67977549
2016	2644000	2315994	9284000	6183349	2594635	11470607	68653978
2017	2842000	2048517	9550000	6360647	2601639	11907239	69560423
2018	3066000	2219103	9900000	6455137	2610256	12219203	71609950

Table A.2. Data for Per Capita Meat Consumption by Type in the US, 1961 to 2017

Year	Mutton & Goat	Other Meats	Poultry	Pig meat	Beef
1961	2.11	1.2	16.44	27.69	41.22
1962	2.1	1.11	16.3	28.39	41.55
1963	1.98	1.1	16.61	29.24	43.68
1964	1.75	1.1	17.05	29.04	46.96
1965	1.58	1.12	18.08	25.98	47
1966	1.61	1.12	19.22	26.16	48.88
1967	1.58	1.11	19.95	28.61	49.62
1968	1.51	1.1	19.77	29.55	50.75
1969	1.4	1.11	20.61	28.98	50.94
1970	1.36	1.13	21.44	29.64	52.27
1971	1.34	1.12	21.64	32.56	51.88
1972	1.35	1.1	22.56	30.06	52.88
1973	1.16	1.11	21.6	27.48	49.64
1974	1.01	1.1	21.67	29.58	52.82
1975	0.9	1.08	21.16	24.13	54.93
1976	0.82	1.04	22.82	25.55	58.81
1977	0.75	1.01	23.15	26.97	56.85
1978	0.69	1.03	24.09	27	54.09
1979	0.67	1.04	25.92	30.83	48.13
1980	0.69	0.97	26.38	32.95	47.32
1981	0.71	0.98	27.57	31.41	47.81
1982	0.74	0.95	28.08	28.1	47.76
1983	0.75	0.94	28.76	29.62	48.41
1984	0.76	0.87	29.57	29.32	48.23
1985	0.72	0.86	30.61	29.44	48.71
1986	0.71	0.84	32.06	27.76	49.21
1987	0.65	0.81	34.55	27.95	47.34
1988	0.68	0.81	35.78	29.86	46.78
1989	0.69	0.76	37.49	29.64	44.17
1990	0.71	0.73	39.43	28.4	43.41
1991	0.7	0.75	41.03	28.67	43.13
1992	0.68	0.75	42.52	30.34	43.12
1993	0.65	0.73	43.1	30	42
1994	0.59	0.76	43.91	30.35	43.39
1995	0.59	0.78	43.54	30.03	43.19
1996	0.55	0.72	44.68	28.07	43.83
1997	0.53	0.64	45.04	27.82	42.85
1998	0.58	0.69	45.31	30.48	43.34
1999	0.57	0.75	47.81	30.84	43.85
2000	0.54	0.72	47.38	29.54	43.5
2001	0.56	0.69	47.57	29.16	42.8
2002	0.58	0.79	49.31	29.96	43.75
2003	0.54	0.77	49.65	30.12	42.09
2004	0.53	0.77	51.87	29.96	42.64
2005	0.48	0.77	52.62	29.18	42.25
2006	0.52	0.8	52.97	28.85	42.4
2007	0.53	0.82	52.67	29.56	41.89
2008	0.5	0.84	51.61	29.08	40.58
2009	0.46	0.82	48.75	29.07	39.61
2010	0.43	0.8	50.94	27.99	38.66
2011	0.4	0.8	51.44	26.81	36.84
2012	0.41	0.81	49.52	27.21	36.96
2013	0.43	0.81	50.01	27.64	36.24
2014	0.46	0.81	51.17	27.69	37.44
2015	0.48	0.81	54.67	29.72	35.18
2016	0.48	0.81	55.55	29.94	36.08
2017	0.51	0.81	55.68	30.02	37.08

Table A.3. Data for Daily Supply of Calories Per Person in the US, 1961 to 2018

Year	Daily Caloric Supply
1961	2880
1962	2858
1963	2860
1964	2926
1965	2922
1966	2954
1967	2978
1968	3001
1969	3033
1970	3029
1971	3052
1972	3062
1973	3040
1974	3031
1975	3033
1976	3163
1977	3135
1978	3155
1979	3214
1980	3178
1981	3218
1982	3191
1983	3230
1984	3275
1985	3380
1986	3352
1987	3450
1988	3458
1989	3433
1990	3493
1991	3522
1992	3559
1993	3605
1994	3665
1995	3580
1996	3587
1997	3648
1998	3658
1999	3673
2000	3755
2001	3707
2002	3783
2003	3777
2004	3809
2005	3828
2006	3783
2007	3757
2008	3700
2009	3645
2010	3650
2011	3649
2012	3687
2013	3682
2014	3717
2015	3735
2016	3760
2017	3778
2018	3782

Table A.4. Data for Price of Meat Per Pound in the US, 1980 to 2018

Year	Beef	Pork	Poultry
1980	2.724	1.962	0.699
1981	2.826	2.106	0.749
1982	2.877	2.195	0.712
1983	2.920	2.475	0.689
1984	2.928	2.409	0.839
1985	2.939	2.369	0.773
1986	2.909	2.473	0.766
1987	2.804	2.722	0.821
1988	2.883	2.663	0.740
1989	3.071	2.781	0.905
1990	3.303	3.025	0.882
1991	3.389	3.245	0.886
1992	3.404	3.081	0.878
1993	3.425	3.143	0.875
1994	3.319	3.256	0.899
1995	3.288	3.160	0.897
1996	3.225	3.347	0.941
1997	3.132	3.465	1.016
1998	3.100	3.342	1.022
1999	3.064	2.951	1.072
2000	3.177	3.211	1.059
2001	3.405	3.416	1.091
2002	3.524	3.554	1.091
2003	3.720	3.228	1.004
2004	4.038	3.008	1.062
2005	4.241	2.975	1.026
2006	4.089	3.150	1.062
2007	4.055	3.172	1.033
2008	3.984	3.314	1.163
2009	4.203	3.392	1.292
2010	4.084	3.228	1.265
2011	4.379	3.673	1.241
2012	4.843	3.850	1.334
2013	4.983	3.576	1.497
2014	5.033	3.831	1.529
2015	6.052	4.167	1.546
2016	5.856	3.714	1.429
2017	5.733	3.639	1.418
2018	5.608	3.814	1.509

Table A.5. Data for Population Growth in the US, 1961 to 2018

Year	Population	Growth Rate
2018	327,096,265	0.62%
2017	325,084,756	0.64%
2016	323,015,995	0.67%
2015	320,878,310	0.69%
2014	318,673,411	0.72%
2013	316,400,538	0.75%
2012	314,043,885	0.79%
2011	311,584,047	0.83%
2010	309,011,475	0.88%
2009	306,307,567	0.93%
2008	303,486,012	0.96%
2007	300,608,429	0.96%
2006	297,758,969	0.94%
2005	294,993,511	0.90%
2004	292,354,658	0.88%
2003	289,815,562	0.88%
2002	287,279,318	0.94%
2001	284,607,993	1.03%
2000	281,710,909	1.14%
1999	278,548,150	1.23%
1998	275,175,301	1.27%
1997	271,713,635	1.26%
1996	268,335,003	1.20%
1995	265,163,745	1.11%
1994	262,241,196	1.04%
1993	259,532,129	0.99%
1992	256,990,613	0.96%
1991	254,539,370	0.96%
1990	252,120,309	0.96%
1989	249,725,805	0.95%
1988	247,372,264	0.95%
1987	245,052,789	0.94%
1986	242,763,148	0.94%
1985	240,499,825	0.94%
1984	238,256,844	0.94%
1983	236,030,238	0.94%
1982	233,821,844	0.94%
1981	231,636,058	0.94%
1980	229,476,354	0.94%
1979	227,339,318	0.94%
1978	225,223,303	0.94%
1977	223,135,663	0.93%
1976	221,086,429	0.92%
1975	219,081,251	0.91%
1974	217,114,909	0.90%
1973	215,178,797	0.90%
1972	213,269,802	0.89%
1971	211,384,068	0.89%
1970	209,513,341	0.89%
1969	207,659,263	0.90%
1968	205,805,754	0.93%
1967	203,905,080	1.00%
1966	201,895,760	1.08%
1965	199,733,676	1.18%
1964	197,408,505	1.27%
1963	194,932,403	1.36%
1962	192,313,746	1.45%
1961	189,569,843	1.53%

Table A.6. Data for Energy Efficiency of Meat and Dairy Products in the US

Type of Meat	Energy Conversion Efficiency
Beef	1.9
Lamb/Mutton	4.4
Pork	8.6
Poultry	13
Eggs	19
Whole Milk	24

Table A.7. Data for Protein Efficiency of Meat and Dairy Products in the US

Type of Meat	Protein Conversion Efficiency
Beef	3.8
Lamb/Mutton	6.3
Pork	8.5
Poultry	19.6
Whole Milk	24
Eggs	25

Table A.8. Data for Human Non-Carcinogenic Toxicity

Human Non-Carcinogenic Toxicity		
Farming Method	**Internal Cost**	**Units**
Pasture	5326	kg 1,4-DCB
Pasture and Feedlot	1720	kg 1,4-DCB
Pasture and Proteic Supplement	3986	kg 1,4-DCB

Table A.9. Data for Marine Ecotoxicity

Marine Ecotoxicity		
Farming Method	**Internal Cost**	**Units**
Pasture	0.4815	kg 1,4-DCB
Pasture and Feedlot	0.2297	kg 1,4-DCB
Pasture and Proteic Supplement	0.3786	kg 1,4-DCB

Table A.10. Data for Freshwater Ecotoxicity

Freshwater Ecotoxicity		
Farming Method	**Internal Cost**	**Units**
Pasture	0.5537	kg 1,4-DCB
Pasture and Feedlot	0.2392	kg 1,4-DCB
Pasture and Proteic Supplement	0.4276	kg 1,4-DCB

Table A.11. Data for Human Carcinogenic Toxicity

Human Carcinogenic Toxicity		
Farming Method	**Internal Cost**	**Units**
Pasture	0.4347	kg 1,4-DCB
Pasture and Feedlot	0.2000	kg 1,4-DCB
Pasture and Proteic Supplement	0.3311	kg 1,4-DCB

Table A.12. Data for Global Warming

Global Warming		
Farming Method	**Internal Cost**	**Units**
Pasture	38.67	kg CO2 eq
Pasture and Feedlot	25.70	kg CO2 eq
Pasture and Proteic Supplement	33.56	kg CO2 eq

Table A.13. Data for Pasture Impact Category

Impact Category	Internal Cost	Units	External Cost	Normalization
1. Human Non-Carcinogenic Toxicity	0.000288653	CTUh	$44.50	35.73541
2. Marine Ecotoxicity	0.481536484	kg 1,4-DCB	$0.00	0.46661
3. Freshwater Ecotoxicity	0.553652248	kg 1,4-DCB	$0.02	0.45123
4. Human Carcinogenic Toxicity	7.82445E-08	CTUh	$0.06	0.15692
5. Global Warming	38.66533893	kg CO2 eq	$2.36	0.00484
		Total:	$46.94	

Table A.14. Data for Pasture and Feedlot Impact Category

Impact Category	Internal Cost	Unit	External Cost	Normalization
1. Human Non-Carcinogenic Toxicity	9.32348E-05	CTUh	$14.37	11.54254
2. Marine Ecotoxicity	0.229749271	kg 1,4-DCB	$0.00	0.22263
3. Freshwater Ecotoxicity	0.239199598	kg 1,4-DCB	$0.01	0.19495
4. Human Carcinogenic Toxicity	3.59913E-08	CTUh	$0.03	0.07218
5. Global Warming	25.70458265	kg CO2 eq	$1.57	0.00322
		Total:	$15.98	

Table A.15. Data for Pasture and Proteic Supplement Impact Category

Impact Category	Internal Cost	Unit	External Cost	Normalization
1. Human Non-Carcinogenic Toxicity	0.000216062	CTUh	$33.31	26.74866
2. Marine Ecotoxicity	0.378637503	kg 1,4-DCB	$0.00	0.3669
3. Freshwater Ecotoxicity	0.427639847	kg 1,4-DCB	$0.02	0.34853
4. Human Carcinogenic Toxicity	5.9931E-08	CTUh	$0.04	0.11953
5. Global Warming	33.55563932	kg CO2 eq	$2.05	0.0042
		Total:	$35.42	

Table A.16. Data for 1 Year Old Change in Diet

Red Meat Consumption (g)	Female	Male
0	1.7	2
25	1.2	1.4
50	0.8	1
75	0.4	0.5
100	0	0
125	-0.5	-0.6
150	-1	-1.2
175	-1.5	-1.7
200	-2	-2.3
225	-2.4	-2.8
250	-2.8	-3.3
275	-3.2	-3.8
300	-3.6	-4.2
325	-4	-4.7
350	-4.4	-5.1
375	-4.8	-5.5
400	-5.1	-5.9
425	-5.5	-6.3
450	-5.8	-6.7
475	-6.2	-7.1
500	-6.5	-7.5

Table A.17. Data for 30 Years Old Change in Diet

Red Meat Consumption (g)	Female	Male
0	1.6	1.8
25	1.1	1.3
50	0.8	0.9
75	0.4	0.4
100	0	0
125	-0.5	-0.5
150	-1	-1.1
175	-1.4	-1.6
200	-1.8	-2
225	-2.3	-2.5
250	-2.7	-2.9
275	-3	-3.4
300	-3.4	-3.8
325	-3.8	-4.2
350	-4.1	-4.5
375	-4.5	-4.9
400	-4.8	-5.3
425	-5.1	-5.6
450	-5.4	-5.9
475	-5.7	-6.3
500	-6	-6.6

Table A.18. Data for 60 Years Old Change in Diet

Red Meat Consumption (g)	**Female**	**Male**
0	1.2	1.2
25	0.8	0.9
50	0.6	0.6
75	0.3	0.3
100	0	0
125	-0.4	-0.4
150	-0.7	-0.7
175	-1	-1
200	-1.3	-1.4
225	-1.6	-1.7
250	-1.9	-1.9
275	-2.2	-2.2
300	-2.5	-2.5
325	-2.7	-2.7
350	-3	-3
375	-3.2	-3.2
400	-3.4	-3.4
425	-3.7	-3.6
450	-3.9	-3.8
475	-4.1	-4
500	-4.3	-4.2