Comparative Analysis of the Carbon Footprints of Mediterranean and Standard American Diet Models

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ABSTRACT

Objective: In this study, the carbon footprint of the Standard American Diet, which is mainly composed of, animal products, refined, heat-treated, high-fat, and fried foods, has been compared to the carbon footprint of the Mediterranean Diet. It is aimed to compare the effects of animal-based and plant-based dietary habits on environmental sustainability in terms of the carbon footprints each produce, in an evidence-based setting.

Methods: The Harris-Benedict formula was used, and the physical activity coefficient was determined as 1.4 for a 30-year-old male sample participant, who is 1.80 cm, and 75 kg and the energies of the diets, has been calculated as 2.500 kcal/day based on this data. The distribution of macronutrients of the Mediterranean Diet settled as, 20% for proteins, 40% for fats, and 40% for carbohydrates, one serving of wine included in the energy requirement. The distribution of the Standard American Diet consists of 40% protein, 55% fat, and 5% carbohydrates, and 1 liter of beer is added to the energy requirement.

Results: It has been displayed that Standard American Diet (23.20 kg CO_2 eq/day), causes 3.25 times more carbon footprints than the Mediterranean Diet (7.13 kg CO_2 eq/day).

Conclusion: It is thought that individuals should be encouraged to prioritize to increase the consumption of plant-based sources rather than animal products. The Mediterranean Diet can be said to be one of the healthiest diet models in terms of rich biodiversity, socioeconomic accessibility, and sustainability, as well as being adequate, balanced, and safe.

Keywords: Mediterranean diet, standard American diet, carbon footprints, sustainability

1. INTRODUCTION

Due to the increasing demand for food in latitude with population growth, the agricultural sector is expanding every day and constitutes one of the economic sectors with the greatest environmental impact. Nowadays, it takes approximately 18 months to replenish the natural resources consumed within a year by nature. Therefore, natural life is losing its ability to be sustainable, and biodiversity is decreasing every year. The agriculture sector is responsible for a quarter of global greenhouse gas emissions (Poore and Nemecek, 2018). However, plants grown on arable lands also provide emission reduction as carbon-absorbing agents.

Changes in land use such as agriculture [methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O)], and deforestation [CO_2], contribute to greenhouse gas emissions as anthropogenic, increases in atmospheric concentrations of these gases are leading to climate change. Even though, agriculture has an impact on climate change, is also one of the sectors that is most affected by climate change itself. Climate change is reducing water safety due to its effects such as temperature increase, rainfall regime changes, and drought, and decreasing agricultural production and food security. In these agricultural activities, the stages of production,

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storage, processing, packaging, shipping, preparation, and servicing lead to the release of greenhouse gases into the atmosphere. Especially in farming implementations, CH_4 is mainly produced and released by farm animals, as well as from stored fertilizers and organic waste in the soil. NO (nitrogen oxide) emissions are generated from organic and mineral nitrogen fertilizers. Agricultural activities account for 10% of the total amount of greenhouse gas emissions released in the European Union (EU) countries in 2012 (European Environment Agency, 2015). Due to the decline in the number of farm animals and the effective use of fertilizers, agricultural emissions in EU countries fell by 24% between 1990 and 2012. However, in contrast to this situation especially in developing countries, global imports from crop production and stockbreeding increased by 14% between 2001 and 2011 (European Environment Agency, 2015). In 2018, the share of agricultural activities in total emissions was 12.5 %, 0.3% in CO_2 emissions, 63.1% in CH_4 emissions, and 70.1% in N_2O emissions, according to a calculation by the Turkish Statistical Institute (TUIK, 2020). 35% of Turkey's ecological footprint is due to demand agricultural areas (approximately 0.96 kha per capita) (WWF, 2012). Meat and dairy are nutritional products with the highest global carbon footprint per kilogram compared to other food products. In terms of greenhouse gas emissions, livestock, and animal feed manufacture, cause more than 3 billion tons of CO_2 equivalent each (European Environment Agency, 2015). Although the most important recommendation for reducing the carbon footprints of nutrients is that local nutrients should be consumed, studies have shown that the greenhouse gas emissions caused by transport constitute a very small fraction of the emissions from nutrients. For most nutrients, a large proportion of the spread of their seagrasses is due to manufacturing procedures during land and farm use (Poore and Nemecek, 2018).

Studies examining the carbon footprints of food groups show that animal food consumption has more carbon footprints than plant-based food consumption. As a result of a study conducted by Hallström et al., in 2015, it has been shown that dietary change has an approximately 50% effect on reducing greenhouse gas emissions. The type of vegetable food counterparts added to replace meat products removed from the diet, can affect the amount of carbon footprint falling. Clune et al., (2016) examined greenhouse gas emissions of different food groups, and according to their research, cereals, fruits, and vegetables have the lowest impact in terms of emission release, while meat products have the highest impact.

In addition to the environmental consequences of dietary habits, the direct relationship of nutrients in the diet with human health is also quite essential. As a result of a meta-analysis study that examined the relation of the depression risk with the diet, western eating habits which are known to be pro-inflammatory were found to be associated with mental health problems and depression (Kiecolt-Glaser, et al., 2012). Besides, exposure to chronic inflammation has been associated with insulin resistance (IR), Type 2 Diabetes Mellitus (DM), atherosclerosis, obesity, and metabolic syndrome (Lopez et al., 2017).

According to the content of the diet, there is an increase or decrease in some biomarker's indicative of chronic disease. Consumption of red meat, refined foods and snacks were found to be associated with increased energy intake and higher BMI than required and increased inflammatory biomarkers, while consumption of vegetables, fruits, fish and whole grains was contraindicated with higher-than-normal BMI, high serum CRP levels and depression (Giudice et al., 2018). A diet rich in nutrients that reduces inflammation biomarkers plays an important role in maintaining health and preventing chronic diseases. In this context, the Mediterranean Diet is called the anti-inflammatory diet because of its anti-inflammatory biochemical components (García-Fernández et al., 2014). As shown in Table 1, anti-inflammatory foods are part of Mediterranean eating habits, but Standard American Diet mainly relies on pro-inflammatory nutrients (Schwingshackl et al., 2020). As part of the standard Mediterranean Diet, resveratrol in wine is considered to be one of the elements that positively affect general health and cognitive functions in a diet rich in unsaturated fats and insoluble fiber (Roberts et al., 2010). For this reason, Mediterranean eating habits have positive effects on the environment and public health.

Table 1. *The List of Anti-Inflammatory and Pro-Inflammatory Foods (McComber et al., 2016)*

Anti-inflammatory foods	Pro-inflammatory foods
Broccoli	Sugar
Cabbage	High-fructose corn syrup
Red cabbage	Starch-based sugars
Avocado	Sweeteners
Olive	Gluten
Strawberry	Grains
Blueberry	Alcohol
Cherry	Dairy products
Turmeric	Soy products
Ginger	Peanut
Hemp seed	Fries
Orange	Trans fats
Almonds, walnuts	Vegetable oils
Leek	Salami, sausage-like processed meat products
Tomato	Refined flour and sugar
Oily sea fish: Tons, salmon, mackerel, sardines	Carbonated sugar, added soft drinks
Pickles	Soda
Parsley, cress, arugula, spinach, chard, green leafy vegetables	Synthetic food dyes
Radish, carrot	Fats and margarines saturated with hydrogen
Onion, garlic	Industrial animal foods

Considering environmental sustainability, efforts to reduce carbon footprint are becoming increasingly critical. In order to reduce the carbon footprint, the consumption of foods with a high carbon footprint needs to be decreased, in this study, the carbon footprints of the widely preferred Standard American Diet and the Mediterranean Diet which is accepted as the gold standard by the authorities like World Health Organization (WHO), were compared.

2. METHODS

2.1. Sample Selection

Diets energies planned according to the anthropometric data of two hypothetical healthy male individuals with no acute or chronic diseases, at the same age, with the same body mass indexes (BMI), who have the same exercise routines, basal metabolic rates (BMR) and fat/muscle compositions. Thus Physical, biochemical, and anthropometric variants that could affect the study, such as BMR, thermogenic effect of the foods, digestive, excretory and respiratory activities which may differ in the presence of acute or chronic diseases and may affect the total energy consumption (TEE) value, eliminated. In this study, the basal metabolic rate of a healthy individual (Height: 180 cm, Weight: 75 kg, Age:30 yrs) was calculated with the Harris-Benedict formula given below.

BMR = 66.5 + (13.75*kg) + (5.003*cm) – (6.775*yr) (FAO/WHO/UNU, 1985)

Based on the consumer majority of the world population, calculations were made according to the adult male. The physical activity coefficient was taken as 1.4 (mildly active) and the physical activity coefficients were shown in Table 2 (FAO/WHO/UNU, 1985). Moreover, for the maintenance of the BMI in the current state the daily energy need was calculated according to basal metabolic rates with taking the physical activity coefficient into account. As a result, the BMI of the individual was determined as 23.14 kg/m^2 which is in the healthy BMI range of 18.5-24.5 kg/cm^2.

Table 2. *Classification of the Lifestyles According to Intensity of Habitual Physical Activity (Physical Activity Level, PAL) (FAO/WHO / UNU, 1985)*

Category	PAL
Sedentary or Mildly Active	1.40-1.69
Active or Moderately Active	1.70-1.99
High Intensity Active	2.00-2.40

In this context, the carbon footprints of macronutrients and dietary ingredients appropriate to the Mediterranean and Standard American Diets were determined. Both diets were evaluated according to approximately 2500 kcal/day. This value is reached by multiplying the basal metabolic rate by the activity coefficient.

Daily Calorie Need=BMR*PA (Academy of Nutrition and Dietetics, 2019)

Whilst determining daily energy requirements, the calculations were made based on the Academy of Nutrition and Dietetics (AND) and were performed in two repetitions. Considering the average healthy male, daily energy needs based on physical activity and age, are shown in the Table 3.

TEE (Male) = 864 – 9.72 × age (years) + PA × [(14.2 x weight (kg) + 503 × height (meters)] (Gerrior et al., 2006)

Table 3. *Estimated Calorie Requirements for Healthy Men by Age and Physical Activity (Academy of Nutrition and Dietetics, Eatright Organization, 2019)*

Age	Sedentary or Mildly Active (kcal)	Active or Moderately Active (kcal)	High Intensity Active (kcal)
19-30	2,400-2,600	2,600-2,800	3,000
31-50	2,200-2,600	2,400-2,600	2,800-3,000
51+	2,000-2,200	2,200-2,400	2,400-2,800

The carbon footprints of nutrients estimated according to the formula below:

Food: Consumption (kcal/day)*Emission Factor (kg CO_2eq/kcal)=Emissions (kg CO_2eq/day)

2.2. Meal Planning

The percentage distributions of the macronutrients of the Mediterranean Diet were made according to the current guidelines of the National Academies Institute of Medicine, and 40% of the energy was provided from fat, 20% from protein, and 40% from carbohydrates (Table, 2005). 1 glass of red wine in the Mediterranean Diet, (168 kcal, and 16.8 g carbohydrates) was deducted from the energy account and no carbohydrates from alcohol were taken into account, and percentages were determined according to the total energy. The traditional Mediterranean Diet consisted of 3 main courses and 3 snacks and distributions and the components of the diet were planned based on to the current guidelines of the National Academies Institute of Medicine (Institute of Medicine, 2005). According to the differentiation in the macronutrient percentages, (protein, carbohydrate, and fat) values were determined. The energy sum of the diet, (2500 kcal), provided from 125 grams of protein, 250 grams of carbohydrates, and about 111 grams of fat. By following the current guidelines of the National Academies Institute of Medicine, the components of the traditional Mediterranean Diet determined, which consisted of 3 main courses and 3 snacks (American Dietetic Association Exchange Lists, 2020).

The percentages of fat, protein, and carbohydrates in the Standard American Diet, account for 55%, 40%, and 5%, respectively, of energy from the diet. The current eating trends have been taken under considerations which suggest a spike on the consumption of the animal based low carb diets. Thus, alterations have been made around the ratios of the macro nutrients. 1 liter of beer in this diet was deducted from the energy calculation and the daily carbohydrate requirement was 62.5 g (36 grams of CHO came from beer and 26.5 CHO from the diet). The energy of the beer was determined to be 430 kcal and the energy of the diet to be 2.070 kcal/day. The diet consists of 3 main courses and 3 snacks and is considered to be low carb. A menu rich in animal foods but low in carbohydrate was planned based on the consumption averages of the American community (USDA, 2019). In this plan, unlike the Mediterranean Diet, in SAD mainly was composed of simple carbohydrates, processed, brine, fatty, smoked and fermented meat/fish/poultry, and modified vegetable saturated fats/saturated fat sources. The Mediterranean Diet included complex carbohydrates, wild fish and organic poultry, seasonal plants, legumes, beans, and whole grains rich in long-chain fatty acids. Low portions of red meat are available in the classic Mediterranean Diet, but red meat is not included in the menu planning. WHO's and the ADA's sample guidelines of the Mediterranean Diet, points out, plant-based protein sources and organic white meat consumption should be preauthorized while red meat consumption is being limited.

2.3. Calculation of Carbon Footprints of Each Diet

The menu planning of the Mediterranean Diet (Table 4) and Standard American Diet (Table 5) calculated, furthermore the carbon footprint counts for each of the food items according to their portions made, however, the food preparation and cooking procedures were excluded.

Table 4. *Mediterranean Diet*

Meals	Portions/Unit	Nutritional Values (Macros)
Breakfast:		
Eggs Olives Walnuts Green leafy vegetables Dairy Whole grain bread	2 (boiled) 5 4 halves 100 grams (raw) 200 mL 50 grams	29 grams of Proteins 41 grams of CHO 16 grams of Fats
Snack:		
Nuts/seeds	10 raw hazelnuts	24 grams of CHO 5 grams of Fats
Lunch:		
Lentil soup Vegetable dish with olive oil (Leeks, peas, artichokes etc.) Yoghurt Poultry	2 Soup ladles (240 grams) 4 Soup spoons (cooked) + with 10 grams of olive oil 180 grams 120 grams	38 grams of Proteins 66 grams of CHO 46 grams of Fats
Snack:		
Roasted chickpeas Dairy Seasonal fruits	25 grams 200 mL 2 portions	11 grams of Proteins 48.6 grams of CHO 6 grams of Fats
Dinner:		
Grilled fish (wild) Salad (no dressing) Whole grain bread Red wine	180 grams 100 grams (raw) 50 grams 200 mL	41 grams of Proteins 35.6 grams of CHO 30 grams of Fats
Snack:		
Seasonal fruits	2 portions	24 grams of CHO

Table 5. *Standard American Diet*

Meals	Portions/Unit	Nutritional Values (Macros)
Breakfast:		
Eggs Egg whites Cheese	4 (scrambled) 5 grams 30 grams	30 grams of Proteins 9 grams of Fats
Snack:		
Avocado	½ large	1,5 grams of Proteins 6 grams of CHO 12 grams of Fats
Lunch:		
Rice Lamb Salad with parmesan	3 soup spoons 240 grams 60 grams	62 grams of Proteins 15 grams of CHO 50 grams of Fats
Snack:		
Eggs Cheese	3 egg whites 30 grams	24 grams of Proteins 9 grams of Fats
Dinner:		
Beef Salad with low fat cheese Beer	300 grams 30 grams	78 grams of Proteins 50 grams of Fats
Snack:		
Skimmed milk (2%)	200 mL	9 grams of Proteins 2 grams of Fats

Figure 1 shows where the emissions in the supply chains of food products are due. These stages range from land-use changes to shipping and packaging.

Figure 1. *Greenhouse Gas Emission throughout the Food Supply Chain*

Each food leads to different carbon emission values; beef emits 25 kg of CO_2eq greenhouse gas, while green peas emit 0.36 kg of CO_2eq greenhouse gas. Animal products, in general, have more carbon footprints than plant-based foods. Furthermore, these emission rates are mainly due to processes in land-use fluctuations (yellow circle) and the divergences in farming techniques (green circle). Stages of the Food Supply Chain accounts for more than 80% of the carbon footprint for most foods (Poore and Nemecek, 2018). Carbon footprints of certain nutrients used in diets per kilogram are shown in Table 6

Table 6. Carbon Footprints of the Nutrients

Foods	Reference Unit GHG Emissions (kg CO_2eq)	Source
Egg	2.12	Hamerschlag et al., 2011
Feta cheese	9.82	Hamerschlag et al., 2011
Whole milk	1.06	Hamerschlag et al., 2011
Poultry	2.33	LCA Food Data Base, 2007
Wild Fish	0.00	North Sea Foundation, 2008
Farmed Fish	3.50	Poore and Nemecek, 2018
Beef	25.00	Poore and Nemecek, 2018
Lamb	20.00	Poore and Nemecek, 2018
Pork	6.50	Poore and Nemecek, 2018
Legumes	0.65	Poore and Nemecek, 2018
Peas	0.36	Poore and Nemecek, 2018
Nuts and seeds	0.80	Poore and Nemecek, 2018
Sugar cane	3.00	Poore and Nemecek, 2018
Grains	1.40	Poore and Nemecek, 2018
Tomatoes	1.40	Poore and Nemecek, 2018
Corn	1.00	Poore and Nemecek, 2018
Apple	0.40	Poore and Nemecek, 2018
Tangerine	0.30	Poore and Nemecek, 2018
Banana	0.70	Poore and Nemecek, 2018
Olive oil	6.00	Pattara et al., 2016
Rice	1.00	Liu et al., 2015

3. RESULTS AND DISCUSSION

On the ground of these evaluations, it was observed that the carbon footprint of the Standard American Diet was 3.25 times greater than that of the Mediterranean Diet. It has been stated that altering eating habits, may lead to a significant reduction of an individual's carbon footprint. Therefore, it is contemplated that reducing the consumption of animal products in the diet or prioritizing seafood consumption as a counterpart to red meat products which possesses a greater carbon footprint, may help to downscale the carbon footprint. It is projected that halving global population meat consumption will reduce the world's total greenhouse gas emissions by 10% and reduce CO_2 density in the atmosphere by 330 ppm by now in 2050 to less than 420 ppm (Stehfest et al., 2009). The 10% drop in greenhouse gas emissions has the same effect as the withdrawal of about 8 million cars from traffic (Hoolohan et al., 2013). Since off-season plant-based food intake requires higher energy utilization in terms of manufacturing, the quality of the food consumed is as important as the period in which it is consumed. Therefore, alterations in nutritional behaviours, such as favouring commodities in season, promote to a retrenchment of the carbon footprint. Carbon footprint rates increase parallel to the multiplicity of operation steps of the industrialization.

The industrial food chain structure provides nutrients to less than 30% of the world's population using more than 75% of agricultural resources, while peasant agriculture supplies more than 70% of the world's population using less than 25% of resources. Because of the distortion of the industrialized mass food yielding systems, billions of people are suffering from hunger or malnourishment. Thus, small-scale producers should be encouraged for the environment and human health. The repercussions of nutritional habits on health and the environment should be reconsidered. Industrial farming systems are significant contributors to the global warming by increasing the carbon footprints, via the usage of the synthetic fertilizers, fossil fuels, agricultural chemicals, and industrial machinery to transport, storage, manufacturing, operation, and packaging. 44% of the agricultural crop acclimatized by the industrial food chain to accommodate meat production, 15%of the total yield lost in transportation and storage, 9% utilized as biofuels and secondary variants, 8% wasted, and only 24% is directly offered to human consumption. Due to excessive supply, the industrial food chain produces more food than is necessary to compensate the demand, increasing its carbon footprint, and causing obesity and correlated chronic diseases.

Mediterranean and Atlantic Diets were found to possess a superior nutritional value and lower carbon footprints when compared to the Standard American Diet. As SAD is rich in dairy products as the main source of protein, it is stated that this might be the essential factor that increases the carbon footprint. (González-García et al., 2018.) However, it is declared that following the Mediterranean Diet may have a significant impact on reducing greenhouse gas emissions (72%), land usage (58%), energy consumption (52%), and water consumption.

On the other hand, it has been reported that following a western diet will result in an enhancement in all these rates from 12% to up to 72% (Sáez-Almendros et al., 2013). An adaption to the Mediterranean Diet may benefit to save more than 152.749 million cubic meters of water over six years (Lacirignola et al., 2014). Agriculture is responsible for 44-57% of greenhouse emissions from the field to fork throughout the food supply chain and further. One-quarter of its due is led by stockbreeding (Hristov et al., 2013).

Although there is a decline targeted to greenhouse gas emissions globally, agriculture shares, expected to increase (FAO, 2017). The industrial food chain is responsible for 85-90% of emissions from agriculture. Furthermore, ocean trawlers cause 1 billion tons of CO_2 emissions per year, while small fishing boats use one-fifth of that amount to fish for the same volume (Driscoll and Tyemers, 2010). Today, industrial activities have seen to not consider the long-term environmental consequences and public health on the contrary leading companies provoke the environmental damage thus adversely affect public health.

According to FAO data, 83% of agricultural land is used for livestock and lowering meat consumption will contribute to efforts to combat famine. The goods need of 4 billion people could be met with agricultural products grown for livestock.

Since in order to obtain 500 g of red meat, 10 times the amount of water needs to be used for wheat and rice (7000 l), it has been indicated that meat production is also associated with water wastage.

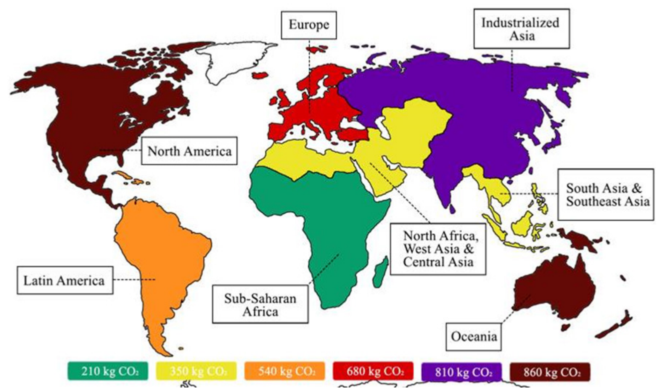

***Figure 2.** Distribution of Carbon Footprints by Region (FAO, 2011)*

Due to the variability of habitual dietary behaviours among various segments of society, the carbon footprints of the distinctive socioeconomic groups are different from each other. As the number of units consumed increases in line with the income level, the carbon footprints of high-income countries turn out to be greater. When carbon footprints are examined globally in Figure 2, the per capita carbon footprint in high-income countries is more than twice that of low-income countries. Socioeconomic status and dietary habits are shaping industrial production products, and the effects of the American diet on consumer culture and in-demand products are thought to increase the carbon footprint.

4. CONCLUSIONS

Dietary habits significantly influence the amount of carbon footprint on a global scale. In this study, the carbon footprint variations of the Mediterranean Diet and the Standard American Diet were calculated. Based on the dietary preparations, GHG emission of the Standard American Diet was found to be 3.25 times higher than that of the Mediterranean Diet. Thus, it has been determined that dietary habits played a key role in altering the number of carbon footprints. Therefore, moving away from the industrial food production systems within processed products, and supporting local agriculture will promote a decline in carbon footprint.

It is also known that frequent exhaustion of the red meat and refined foods have negative short term and long-term influences on general wellbeing. Conversely, it has been established that Mediterranean Diet has a positive effect both on the prevention of inflammation and nutritional treatment of chronic inflammation-related diseases. Small-scale producers offer a plant-based Healthy Diet, preserving soil, water, practices, and culture that support biodiversity. Therefore, support should be given to the production of local small-scale farmers to reduce the carbon footprint. Moreover, assuming a downscale on global meat consumption, the world's total greenhouse gas emissions e and CO_2 density in the atmosphere would decrease.

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