

LIFE CYCLE ANALYSIS OF DIFFERENT CUISINES

by

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ABSTRACT

LIFE CYCLE ANALYSIS OF DIFFERENT CUISINES

The extensive global food system is responsible for approximately 30% of greenhouse gas emissions. While the steps of the global food system such as production, packaging, transportation, distribution, storage, and disposal are followed, environmental effects remain intangible. With the life cycle assessment (LCA), environmental impacts are seen in concrete form at every stage of the system. In this study, the environmental impacts of different cuisines were investigated through life cycle assessment. Three menus have been created, consisting of Turkish, Far East, and Mediterranean cuisines, which are known and have a wide variety of food. Each menu has been chosen in accordance with the culture of the cuisine it has. The menus consist of soup, main course, side course and dessert. As a result of the life cycle assessment made on the menus selected for 3 cuisines, it has been determined that the environmental impact of the Mediterranean cuisine is quite low. The reason why the environmental impact is very low compared to the Turkish and Far Eastern cuisines, mainly agricultural foods are included in the Mediterranean cuisine and animal-based meals are not preferred much. On a food basis, the environmental impact of animal-based foods is greater than that of plant foods. As a result of the study, Turkish cuisine, in which animal-based meals are predominant, is the cuisine with the most environmental impact.

ÖZET

FARKLI MUTFAKLARIN YAŞAM DÖNGÜSÜ ANALİZİ

Geniş bir ağına sahip olan küresel gıda sistemi sera gazı emisyonlarının yaklaşık %30'undan sorumludur. Küresel gıda sistemi üretim, paketlenme, ulaştırma, dağıtım, depolama, bertaraf etme gibi adımları izlerken çevresel etkiler soyut kalmaktadır. Yaşam döngüsü değerlendirmesi (LCA) ile sistemin her aşamasında çevresel etkiler somut halde görülmektedir. Bu çalışmada; farklı mutfakların yaşam döngüsü değerlendirmesi aracılığı ile çevresel etkileri incelenmiştir. Bilinen ve gıda çeşitliliğinin fazla olduğu Türk, Uzakdoğu ve Akdeniz mutfaklarından oluşan 3 tane menü oluşturulmuştur. Her bir menüye sahip olduğu mutfağın kültürüne uygun seçilmiştir. Menüler çorba, ana yemek, yan ürün ve tatlıdan oluşmaktadır. 3 mutfak için seçilen menüler nezdinde yapılan yaşam döngüsü değerlendirmesi sonucunda Akdeniz mutfağının çevresel etkisinin oldukça düşük olduğu saptanmıştır. Akdeniz mutfağında ağırlıklı olarak sebze bazlı gıdalara yer verilmesi, hayvansal bazlı gıdaların çok tercih edilmemesi çevresel etkinin Türk ve Uzakdoğu mutfağına göre çok düşük çıkmasının nedenidir. Gıda bazında bakıldığında hayvan bazlı gıdaların çevresel etkileri bitki bazlı gıdalara göre daha fazladır. Çalışma sonucunda da hayvansal bazlı yemeklerin ağırlıklı bulunduğu Türk mutfağı en çok çevresel etkiye sahip mutfaktır.

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LIST OF ACRONYMS / ABBREVIATIONS

GWP	Global Warming Potential
GHG	Greenhouse Gas
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Analysis
NMVOC	Non-methane, volatile organic compound
REPA	Resource and Environmental Pacific Analysis
SOP	Surplus Ore Potential
TEP	Terrestrial Ecotoxicity Potential

1. INTRODUCTION

One of the most serious issues in nowadays is climate change that is an environmental and global problem. It is difficult to prevent that due to increasing greenhouse gases. In addition to reasons such as industry and transportation, the global food system is responsible for approximately 30% of greenhouse gas (GHG) emissions (Crippa et al., 2021; Poore and Nemecek, 2018; Takacs et al., 2022). For instance, according to Crippa et al. (2021), China, Indonesia, the United States of America, the European Union and India accounted for the 51% of GHG emissions from the food system in 2015 (Crippa et al., 2021). If GHG emissions originating from the whole systems excluded food systems are stopped, the existing food system may not be enough to come back the global temperature rise back to preindustrial levels (Clark et al., 2020; Poore and Nemecek, 2018). Therefore, the sustainability of the all stages of food system becomes more important. GHG emissions from the supply chain, livestock and fisheries, crop production and land use are taken into account for global food system. Livestock and fisheries have the highest environmental impact on global food system instead of other components of the food system (Cucurachi et al., 2019; Poore and Nemecek, 2018). According to the data in 2019, 77% of agricultural land is used for animal feed production and grazing land, while 23% is used for crop production for human consumption (Ritchie and Rosser, 2019; FAO, 2019) In addition, livestock is associated with biodiversity loss and deforestation (Coimbra et al., 2020; IPBES, 2019; Pereira et al., 2010; Takacs et al., 2022). Food production is responsible for 78% of eutrophication and 32% of global terrestrial acidification (Poore and Nemecek, 2018). As exemplified, environmental impacts, which are the responsibility of the food system, are obtained through life cycle assessments (LCA). A lot of different kinds of foodstuffs have different environmental effects.

Life cycle assessment emerged as “Resource and Environmental Pacific Analysis (REPA)” at the US Midwest Research Institute in the beginnings of 1970s (Klöpffer, 1997). LCA studies in this period were based on examining product systems, energy and resource

use (Simonen, 2014). On the other hand, LCA focuses on the comparison of product systems. The first comparative LCA study was conducted on beverage packaging (Klöpffer, 1997). LCA methods have become official by the standardization studies carried out with ISO 14040 and ISO 14044. LCA is defined in many studies as taking into account all the processes of products from cradle to grave and tracking inputs and outputs that affect the environment (Curran, 2016; Klöpffer, 1997; Simonen, 2014). Simonen (2014) made a different explanation and refer to life cycle assessment as an environmental accounting method (Simonen, 2014). ISO is explained that LCA is the “compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO, 2006a).

LCA consists of 4 stages; i. Goal and scope definition, ii. Inventory analysis, iii. Impact assessment, and iv. Interpretation (Curran, 2000; ISO, 2006a; Simonen, 2014). While determining the goal of the LCA study to be done, its scope should be formed. According to ISO (2006b), the identification of processes included and excluded from the system, formation of data sources, impact assessments and interpretations determine the scope of LCA (ISO, 2006b). Goal and scope should be in harmony with each other. According to Simonen's (2014) example, when reduce water use is aimed in production, LCA coverage can ignore emissions to air and follow water data (Simonen, 2014). For this reason, the goal, scope, and data obtained must be clearly explained for the inventory analysis to be carried out correctly. According to the recommendation of ISO 14044; inventory data can be classified 4 stages; i. Inputs, ii. Products, iii. Emissions, iv. Other environmental aspects (ISO, 2006b).

In the life cycle impact assessment (LCIA) stage, which is the third stage of LCA, there are indicators of how the natural environment and human health are affected as a result of the resource use and emissions of the products in the cradle-to-grave process (Curran, 2000; ISO, 2006a; ISO, 2006b; Simonen, 2014). Impact assessments are reported on the overall impacts such as toxicity, global warming, stratospheric ozone depletion, acidification, photochemical ozone, and smog formation, eutrophication and oxygen depletion (Finnveden et al. 2009; ISO, 2006a). Impact categories are divided in two as midpoint and endpoint. For instance; the midpoint impact is climate change, while the

endpoint impact is impacts on the natural environment, such as global average temperatures (Espadas-Aldana et al.,2019; Wu and Su, 2020). In calculations, the uncertainties of endpoint impacts are higher than mid-point impacts (Wu and Su, 2020). For instance; In the ReCiPe 2016 method which used for impact assessment, the midpoint impact categories are global warming, fossil resources, particulate matter formation, tropospheric ozone (human) formation, ionizing radiation, stratospheric ozone depletion, human toxicity (cancer), human toxicity (non-cancer), water use, freshwater ecotoxicity, freshwater eutrophication, tropospheric ozone (eco), terrestrial ecotoxicity, terrestrial acidification, land use, marine ecotoxicity, mineral resources, while the endpoint impact categories are human health, ecosystem and resource availability (Huijbregts et al., 2017). For example; The characterization factor for global warming which is midpoint impact category is the global warming potential (GWP). The indicator of GWP is the increase in infrared radiative forcing and its unit is kg CO₂ eq (Huijbregts et al, 2017; IPCC, 2013; Joos et al., 2013).

LCA studies focus on the comparison of product systems, not only the product system. There are food and cuisine-based comparisons in the literature. From the cradle-to-farm life cycle evaluation study of beef conducted by Asem-Hiablie et al. (2018), it was concluded that feed production and cattle production had the highest environmental impact values. In calf and cow breeding, their acidification potential was found to be quite high due to NH₃ release from cattle feces and urine. Ammonia was released during the fertilization phase for feed crops. The global warming potential impact category is caused by CH₄ emissions from feed processes and cattle farming processes. In an LCA study conducted by Abdelkader et al. (2022) on potatoes, tomatoes and onions, cradle-to-agricultural field study was carried out via openLCA. In the study, it was found that the impact of potato on the environment is less than that of onions and tomatoes. In addition, as a result of the studies, it has been observed that the use of machinery in agricultural activities and the use of diesel fuel increase environmental impact. In a study, beef and pea production were compared to take into account climate change and land use impact assessments. While the impact value of 100 g of beef on climate change is 50 kg CO₂ eq, it is 100 times higher than that of peas. The land use impact value for 100g of beef is 164 m² per year, while the land use of peas is 50 times less (Cucurachi et al., 2019). When the GHG emissions of wheat and rice from cereal products are measured, it was found that rice has 5 times more GHG emissions than wheat

(Cucurachi et al., 2019). In the comparative LCA study conducted by Schmidt (2015), the impact categories of global warming, land use and water consumption of vegetable-based oils such as palm oil, soybean oil, rapeseed oil, sunflower oil and peanut oil were examined. The potential impact of global warming of rapeseed (262 kg CO₂ eq) and sunflower oil (760 kg CO₂ eq) have the lowest, while peanut oil (4717 kg CO₂ eq) has the highest. Peanut oil (18,750 m²) and sunflower oil (11,150 m²) have the greatest impact on land use, while palm oil (1712 m²) and soybean oil (1712 m²) have a low impact. Peanut oil (2477 m³) has the most effect on water use, and sunflower oil (-431 m³) has the least effect (Schmidt, 2015). Looking at the potential effects of 5 vegetable oils, peanut oil has the highest environmental impact. Espadas-Aldana et al (2019) calculated 460 kg CO₂ eq for 1 ton of olives and 16 kg CO₂ eq for 1 liter olive oil in the climate change effect category (Espadas-Aldana et al., 2019). In a study on milk and dairy products, it was observed that the environmental impact of butter is higher than yogurt, cheddar and milk, and the biggest reason for the effect is due to raw milk production (Üçtuğ, 2019).

When viewed from a broader point of view, not product-based, cuisine culture is one of the reasons that determine the ecosystem deterioration, human health and resource efficiency caused by the city, country or countries. Among the known cuisines, Mediterranean cuisine, Turkish cuisine and Far East cuisine focus on different types of food. Mediterranean cuisine is a cuisine where herbal foods predominate. While cereals, fruits, legumes and olive oil are mainly used, seafood is consumed at a moderate level and red meat is consumed at a limited level as protein (Davis et al., 2015; Lacatusu et al., 2019). It has been proven that the Mediterranean diet, which consists mainly of plant-based foods, has less environmental impact than protein-based eating habits (Saez-Almendros et al., 2013). It has minimal impact on the natural environment and benefits human health. For example; It has been observed that if the Spanish people adopt the Mediterranean diet instead of the Spanish diet containing animal products, GHG emissions will decrease by 72%, land use by 58%, energy consumption by 52% and water consumption by 33% (Sáez-Almendros et al., 2013). According to studies, it is beneficial in the prevention of cardiovascular diseases, obesity, type 2 diabetes, metabolic syndromes and cancer diseases in people with Mediterranean diet habits (Gotsis et al., 2015; Lacatusu et al., 2019; Sofi et al., 2013; Wright, 2011)

Turkish cuisine is a cuisine based on agricultural and animal based foods (Aktaş and Özdemir, 2007; Çakmak and Sarıışık, 2019; Girgin et al., 2017; Güler, 2007; Yüksel, 2011). In addition to the frequent use of butter, tail, and tallow in meals, olive oil is widely used in regions with olive trees (Aktaş and Özdemir, 2007; Çakmak and Sarıışık, 2019; Doğdubay, 2000). Kebabs, casseroles ve meat dishes are mainly preferred (Doğdubay, 2000; Solmaz and Altıner, 2018; Sürücüoğlu and Özçelik, 2007). Grains such as bulgur, noodles, rice, legumes such as dry beans and lentils are widely used (Güler, 2007, p. 22; Nenes, 2009, p. 460; Çakmak and Sarıışık, 2019; Solmaz and Altıner, 2018). Baklava, molasses, kadayif and ashura are among the most well-known and consumed desserts (Çakmak and Sarıışık; Nenes, 2009; Yuksel, 2011).

The most known and common food in Far East cuisine is rice. Paddy fields are very common in Far East countries such as China, Thailand, and Korea (Berno et al., 2019; Dedeoğlu et al., 2019;). In Far East cuisine, agricultural-based foods are consumed a lot, while fish is the second most common food item. They have also mainly included meat and meat products in their cuisine (Brittin, 2011; Dedeoğlu et al, 2019; Seubsman et al., 2009).

In a study by Rivera and Azapagic (2019), ready meals selected from British, Italian, Indian and Chinese cuisines were compared and a life cycle impact assessment was made. Lasagna and lamb masala curry are responsible for 70% of the global warming impact value. 90% of the contribution of these two meals to the impact value is due to containing beef. While lasagna has the highest acidification potential impact value, roast pork and fishermen's pie are lower. (Rivera and Azapagic, 2019). However, the impact values of lasagna and lamb masala curry meals are high in the eutrophication potential. Lamb masala curry (0.58 kg DCB eq) and pork and prawns fried rice (0.59 kg DCB eq) have the highest effect on freshwater aquatic ecotoxicity originatin from foodstuff in ingredients (Rivera and Azapagic, 2019). In a recent study, looking at the life-cycle impact assessments of vegan, vegetarian and meat-based meals, meat-based meals have 14 times more impact than vegan meals, and vegetarian food has 3 times more impact than vegan meals (Takacs et al., 2022). When the life cycle impact categories are evaluated, meat-based meals have the highest impact on global warming potential, freshwater eutrophication potential, terrestrial acidification

potential and freshwater depletion potential, followed by vegetarian meals and the lowest vegan meals (Takacs et al., 2022).

2. METHODS AND METHODOLOGY

2.1. Life Cycle Assessment

Life cycle assessment provides us to obtain environmental impacts with concrete data by addressing all processes of products from cradle to grave. OpenLCA was used to compare the environmental impacts of the menus created from each of the Turkish, Far East and Mediterranean cuisines (OpenLCA, n.d.).

2.2. Goal and Scope

The goal of the study is to evaluate and compare the environmental impacts of Turkish, Far East, and Mediterranean cuisines with different proportions of food raw materials used throughout their life cycle. LCA was used for environmental analysis. For each cuisine, the soup, main course, by-product which is served alongside the main course and dessert were selected. Animal based products, cereals and pastries are generally consumed in Turkish cuisine. Mediterranean Cuisine mostly uses vegetables and fresh spices, seafood, and a small amount of meat products. In Far Eastern cuisine, mainly rice, noodles, vegetables, fish, and meat products are preferred.

2.3. System Boundaries

The system limits are the same for all meals, and all processes from raw food production to packaging, transportation, distribution, storage, taking its place on the market shelf, and the food preparation stage are in the system. Life cycle analysis from cradle to supermarket was performed in OpenLCA. Meals were prepared by choosing foods and then menus were created. Since there is no food product with a Turkey location in the database, the supermarket stage of the products has been chosen, but different locations are taken as a basis. Therefore, this deficiency was not included in the study because there were datasets taken from several locations in the study. Cooking methods are limited to a single energy source. Natural gas has been selected and its 10 minutes are calculated as 1.2 kWh.

2.3.1. Menus of Three Cuisines

Soup, main course, by-product which is served alongside the main course and dessert were selected from Turkish cuisine, Far East cuisine, and Mediterranean cuisine. For Turkish cuisine (menu A), a menu is suitable for Turkish food culture has been created with lentil soup, Adana kebab, bulgur pilaf and baklava. Chinese vegetarian soup, beef noodles, sushi and soboro bread from Far Eastern cuisine (menu B) were evaluated. Vegetable minestrone soup, chops with hummus and roasted tomatoes, Greek lemon rice and maamul were chosen for Mediterranean cuisine (menu C) (Table 2.1).

Table 2.1. The portions of menu A, menu B and menu C.

MENUS	FOODS	QUANTITIES	TOTAL
MENU A	Lentil Soup	150 g	600 g
	Adana Kebab	150 g	
	Bulgur Pilaf	150 g	
	Baklava	150 g	
MENU B	Chinese Vegetable Soup	150 g	600 g
	Beef Noodle	150 g	
	Sushi	150 g	
	Soboro Bread	150 g	
MENU C	Vegetarian Minestrone Soup	150 g	600 g
	Chops with Hummus and Roasted Tomatoes	150 g	
	Greek Lemon Rice	150 g	
	Maamul	150 g	

2.3.2. Ingredients of the Menus

A total of 12 dishes with 3 soups, 3 main courses, 3 side meals and 3 desserts and their contents are shown in the Table 2.2, 2.3 and 2.4. The ingredients and content ratios of the meals were taken from home cooking recipes. Each of the 12 cooked meals is calculated at 1000 g. While creating the menus, 150 gr portions were taken from each cooked meal. The total portion of each of Menu A, Menu B, and Menu C is 600 gr. The menu content

ratios are divided into 3: i. animal-based food, ii. vegetable-based food and iii. water. Menu A consists of 32% animal-based food, 60.5% vegetable-based food, and 7.5% water. About 78% of menu A's animal-based meals consist of minced from beef steak (Figure 2.1). Menu B consists of 11.5% animal-based food, 68.6% vegetable-based food, and 19.9% water. About 36% of menu B's animal-based meals consist of sirloin steak (Figure 2.2). Menu C consists of 11.5% animal-based food, 51.5% vegetable-based food, and 37% water. About 87% of menu B's animal-based meals consist of lamb chop fillet (Figure 2.3).

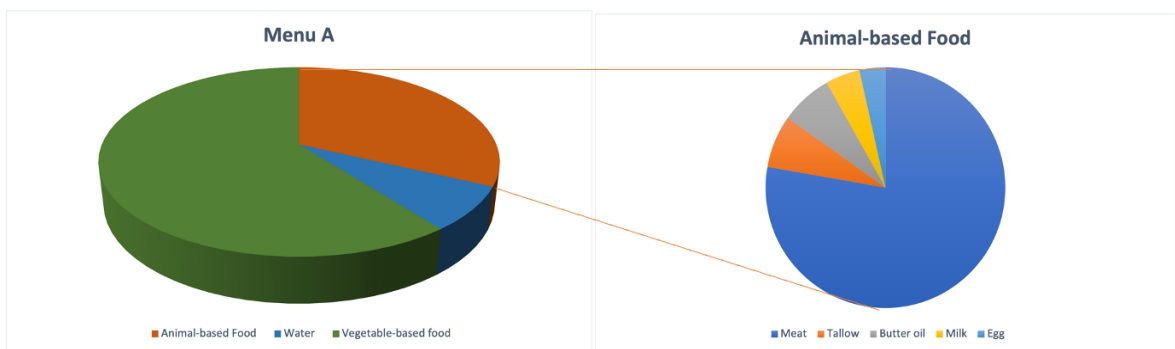


Figure 2.1. The proportion of the ingredients of Menu A and its animal-based meals.

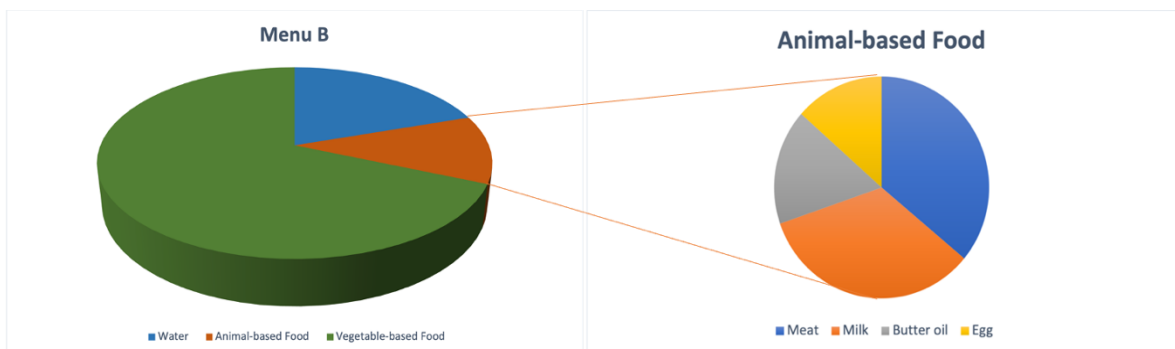


Figure 2.2. The proportion of the ingredients of Menu B and its animal-based meals.

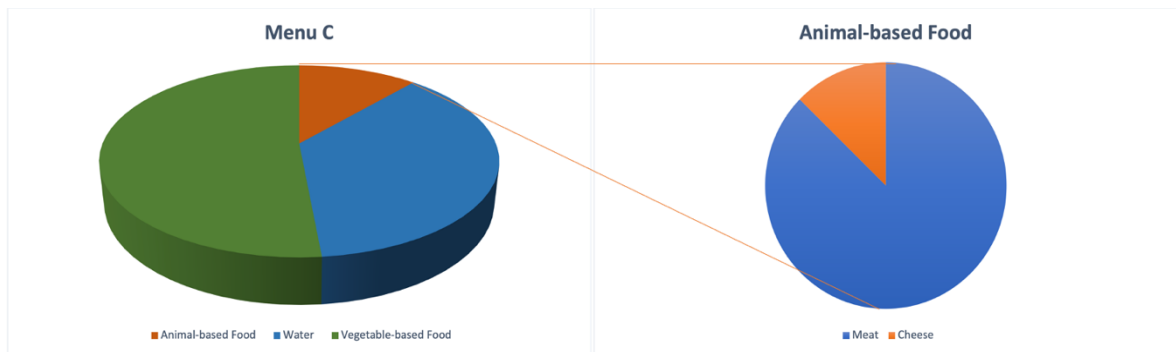


Figure 2.3. The proportion of the ingredients of Menu C and its animal-based meals.

Table 2.2. The ingredients of menu A.

Ingredients (gram)	MENU A			
	Lentil Soup	Adana Kebab	Bulgur Pilaf	Baklava
Baking powder	-	-	-	3
Beef	-	1000	-	-
Black pepper	0.8	-	-	-
Butter oil	-	-	-	90
Carrot	40	-	-	-
Egg	-	-	-	45
Lemon	-	-	-	1.2
Lentil	136	-	-	-
Milk	-	-	-	60
Mineral water (dm ³)	0.8	-	0.9	0.3
Natural gas (kWh)	3.6	12.2	2.4	6
Onions	40	-	100	-
Salt	6.4	10.9	11	1.2
Sugar, white	-	-	-	204
Sunflower oil	28	-	50	54
Sweet pepper	-	9.09	-	-
Tallow	-	90.9	-	-
Tomato coulis	3.2	-	200	-
Vinegar, cider	-	-	-	4.5

Table 2.2. The ingredients of menu A (cont.).

Ingredients (gram)	MENU A			
	Lentil Soup	Adana Kebab	Bulgur Pilaf	Baklava
Walnut	-	-	-	120
Wheat bulgur	-	-	300	-
Wheat flour, type 55 (pastry)	6.4	-	-	180
TOTAL (cooked)	1000 g	1000 g	1000 g	1000 g

Table 2.3. The ingredients of menu B.

Ingredients (gram)	MENU B			
	Chinese Vegetable Soup	Beef Noodle	Sushi	Soboro Bread
Asian noodles	2	137.5	-	-
Avocado	-	-	153	-
Beef, sirloin steak	-	165	-	-
Bakers's yeast	-	-	-	19.25
Baking powder	-	-	-	3.08
Black pepper	-	2.75	-	-
Broccoli	-	165	-	-
Broth	800	-	-	-
Butter oil	-	-	-	77
Carrot	100	-	-	-
Chinese cabbage	150	-	-	-
Chive	-	-	-	-
Coriander	5	-	-	-
Corn flour	-	8.8	-	-
Cucumber	-	-	170	-
Egg	-	-	-	61.6
Garlic	5	-	-	-

Table 2.3. The ingredients of menu B (cont.).

Ingredients (gram)	MENU B			
	Chinese Vegetable Soup	Beef Noodle	Sushi	Soboro Bread
Ginger	2	5.5	-	-
Honey	-	-	-	15.4
Lemon	-	99	-	-
Milk	-	-	-	154
Mineral water (dm ³)	-	0.412	0.382	-
Mushroom	75	-	-	-
Natural gas (kWh)	1.2	4.8	2.4	2.4
Peanut butter	-	-	-	12.3
Rice	-	-	255	-
Salt	6	2.75	8.5	-
Seaweed	-	-	212.5	-
Sesame oil	1.4	2.2	-	-
Soy sauce	18	49.5	2.5	-
Spring onion	100	44	-	-
Sugar, brown	-	-	-	88.5
Sugar, white	-	17.6	12.75	-
Sunflower oil	-	11	-	-
Vinegar, balsamic	-	-	85	-
Wheat flour, type 55 (bread)	-	-	-	462
Wheat flour, type 55 (pastry)	-	-	-	154
TOTAL (cooked)	1000 g	1000 g	1000 g	1000 g

Table 2.4. The ingredients of menu C.

Ingredients (gram)	MENU C			
	Vegetarian Minestrone Soup	Chops with Hummus and Roasted Tomatoes	Greek Lemon Rice	Maamul
Baker's yeast	-	-	-	18.2
Basil	22.5	-	-	-
Black pepper	0.9	-	-	-
Carrot	90	-	-	-
Celery stalk	45	-	-	-
Chickpea	-	288	-	-
Cinnamon	-	-	-	36.4
Courgette	67.5	-	-	-
Dill	-	-	27	-
Dried pasta	153	-	-	-
Durum, wheat semolina	-	-	-	455
Feta cheese	-	36	-	-
Garlic	9	14.4	5.5	-
Lamb, chop	-	403.2	-	-
Lemon	-	21.6	132	-
Lemon zest	-	-	4.4	-
Mineral water (dm ³)	0.54	0.5	0.44	-
Mint	-	2.88	-	-
Natural gas (kWh)	4.2	2.4	2.4	2.4
Olive oil	25.65	28.8	50.6	-
Olives	-	34.56	-	-
Onion	45	-	110	-
Orange juice	-	-	-	13.65
Parmesan cheese	22.5	-	-	-
Parsley	22.5	-	55	-
Pine nuts	-	28.8	-	-

Table 2.4. The ingredients of menu C (cont.).

Ingredients (gram)	MENU C			
	Vegetarian Minestrone Soup	Chops with Hummus and Roasted Tomatoes	Greek Lemon Rice	Maamul
Rice	-	-	330	-
Rosemary	0.9	-	-	-
Salt	2.7	-	-	1.8
Sugar, white	-	-	6.6	95.5
Sunflower oil	-	-	-	227.5
Tahini	-	10.8	-	-
Thyme	2.7	-	-	-
Tomato	180	144	-	-
Walnut	-	-	-	182
Wheat flour, type 55 (pastry)	-	-	-	136.5
TOTAL (cooked)	1000 g	1000 g	1000 g	1000 g

2.4. LCA Impact Categories

ReCiPe 2016 method was selected for impact assessment, which is the third phase of LCA. The midpoint effect was selected to calculate and interpret the environmental impacts of the products. There are 18 categories of the ReCiPe 2016 Midpoint (H) method: i. fine particulate matter formation, ii. fossil resource scarcity, iii. Freshwater ecotoxicity, iv. Freshwater eutrophication, v. global warming, vi. Human carcinogenic toxicity, vii. Human non-carcinogenic toxicity, viii. Ionizing radiation, ix. Land use, x. Marine ecotoxicity, xi. Marine eutrophication, xii. Mineral resource scarcity, xiii. Ozone formation-human health, xiv. Ozone formation-terrestrial ecosystems, xv. Stratospheric ozone depletion, xvi. Terrestrial acidification, xvii. Terrestrial ecotoxicity, xviii. Water consumption.

3. RESULT

3.1. Life Cycle Impact Assessment

3.1.1. Fine Particulate Matter Formation

Fine particulate matter formation in the impact category is an indicator of air quality. The $PM_{2.5}$ value, which is defined for 2.5 micron and smaller substances in the atmosphere, such as nitrogen oxides (NO_x) and ammonia (NH_3), determines the air quality. In the impact category, the nitrogen oxides and ammonia values scattered to the atmosphere during the formation of the products are taken as a basis (Van Zelm et al., 2016). The end-point of fine particulate matter formation, which is the mid-point category, is the damage which causes to human health with respiratory diseases (Huijbregts et al., 2017). Menu A has the highest effect on fine particulate matter formation while Menu C has the lowest (Figure 3.1 and 3.2). Looking at the menu contents, it is seen that Adana kebab and beef steak in the Adana kebab have increased the value of air $PM_{2.5}$ considerably (Figure 3.3). The main reasons of this are ammonia and nitrogen oxides. In the suckler cow system, ammonia is produced during the production of animal food sources. For example; One of the biggest effects is baled hay (permenent meadow), one of the reasons is mowing with a rotary mower during the formation process of these bales. Nitrogen oxides are released by the rotary mower and round baler used in mowing and baling processes to form baled straw used as animal feed. The reasons why baklava is in the second place are ammonia, nitrogen oxides, particulates smaller than $2.5 \mu m$, and sulfur dioxide released during the production of agricultural machinery. Butter, which is an animal food in the content of baklava, is the main reason. Diesel engine irrigation systems used during rice and wheat production for animal nutrition cause the release of particulates smaller than $2.5 \mu m$, while agricultural residues cause volatilization of ammonia. The 3rd place soboro bread shows similar impacts to baklava as it contains butter. The lowest impact was bulgur pilaf and lentil soup, respectively.

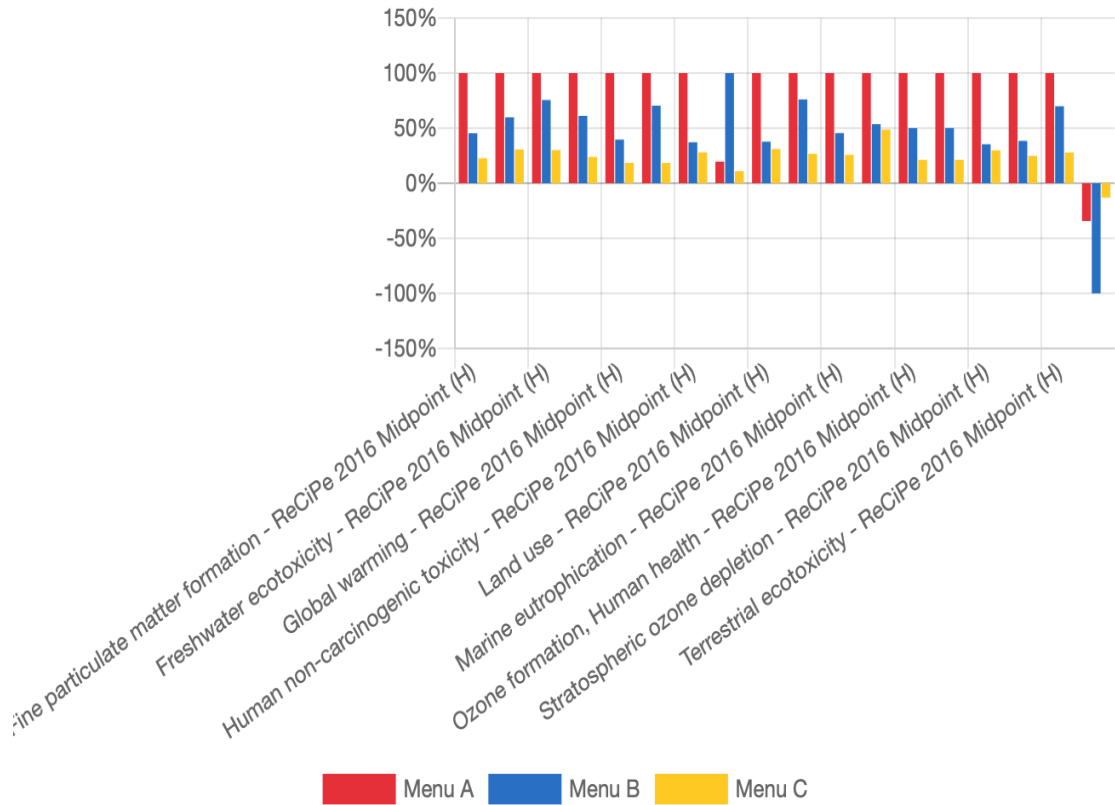


Figure 3.1. LCA impact categories of menus (It is set the maximum effect value to 100).

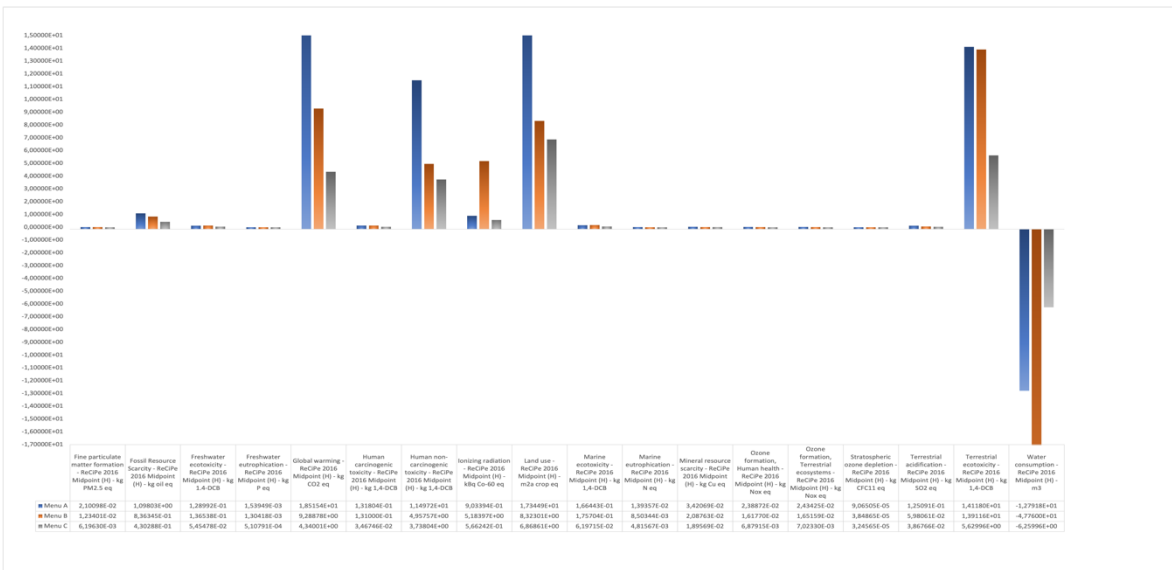


Figure 3.2. LCA impact values of menu A, menu B and menu C.

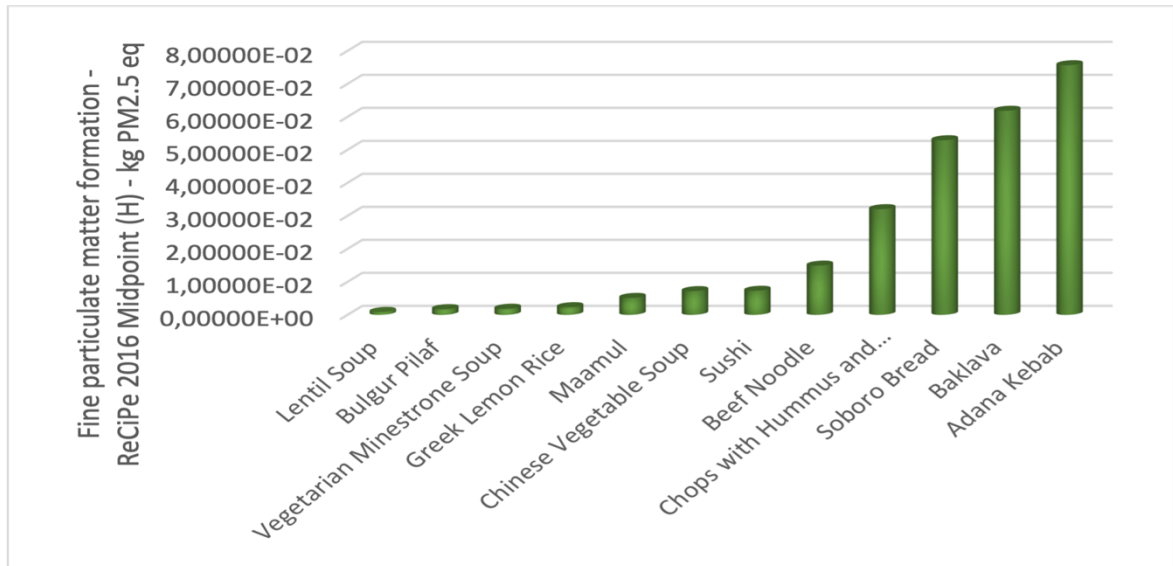


Figure 3.3. Fine particulate matter formation impact for 12 meals – ReCiPe 2016 Midpoint (H) – kg PM_{2.5} eq.

3.1.2. Fossil Resource Scarcity

Fossil resource scarcity is the ratio of the heating value of the fossil resource to the energy content of the crude oil. (Huijbregts et al., 2017; Jungbluth and Frischnecht, 2010). Menu A is the one most impacting on fossil resource scarcity (Figure 3.2). Considering at Menu A, baklava has the biggest impact, followed by Adana kebab. Butter in baklava and beef steak in Adana kebab causes an increase fossil resource scarcity. Some of the reasons behind the high impact of baklava are the use of brown coal, natural gas and crude oil in the production of agricultural machinery. Natural gas is used as a result of the heat production in conventional suckler cow system for the beef steak using in Adana kebab. Lentil soup and bulgur pilaf have the lowest effect (Figure 3.4).

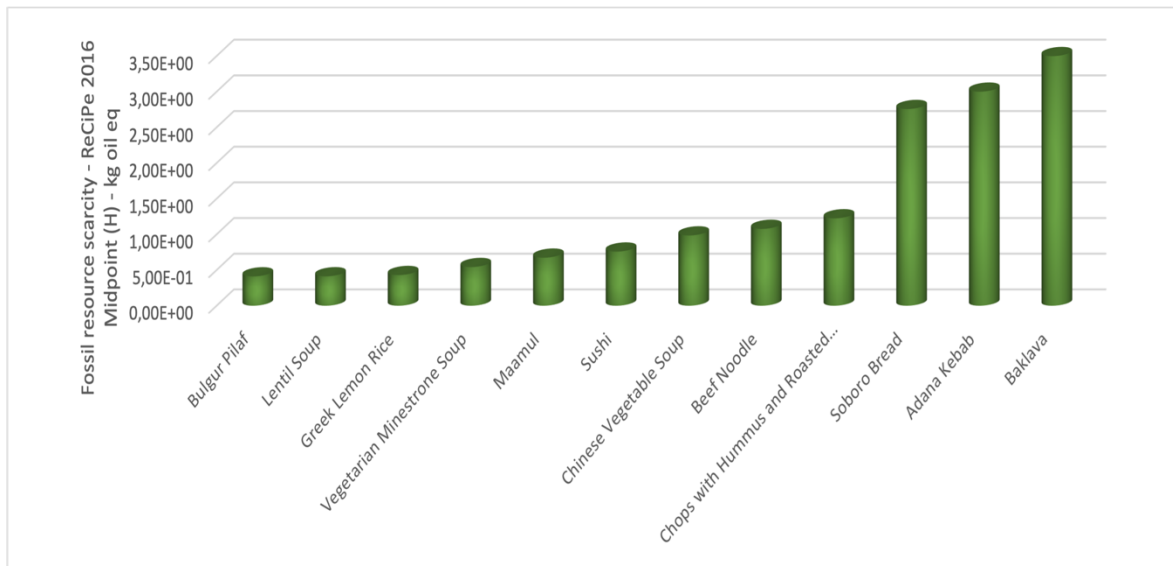


Figure 3.4. Fossil resource scarcity for 12 meals – ReCiPe 2016 Midpoint (H) – kg oil eq.

3.1.3. Freshwater Ecotoxicity

Among the emissions released by products throughout their life cycle are chemicals (Verones et al., 2020). Substances such as zinc, copper, nickel, vanadium, pronamide, chlorothalanil etc. mixed with fresh waters increase the freshwater ecotoxicity value in the mid-point impact category. As a result, the ecosystem as an end-point impact category suffers. Specifically, reductions can be seen in the species living in fresh waters (Huijbregts et al., 2017 ; Van Zelm et al., 2009). When considering at menus in general, Menu B has the most impact, while Menu C has the least impact (Figure 3.2). The impact of Menu B is high due to the bouillon used in the Chinese vegetable soup. The impact value of freshwater ecotoxicity of Chinese vegetable soup is 0.27492 kg 1,4-DCB. 0.21614 kg 1,4-DCB of this value is market for electricity (medium voltage). When it comes to the most basic, copper (0.14943 kg 1,4-DCB), zinc (0.05226 kg 1,4-DCB), vanadium (0.00621 kg 1,4-DCB) and nickel (0.00436 kg 1,4-DCB) substances increase the impact value. Copper, nickel and vanadium are involved in the use of medium voltage electricity used for the water evaporated stage, which is one of the bouillon production stages. Zinc, on the other hand, is involved in the use of industrial ovens in the baking stage applied for bouillon production. The negative contribution of baklava, which ranks second, to freshwater ecotoxicity is 0.51679 kg 1,4-DCB and it is the most effective cause of agricultural machinery production (0.02341 kg

1,4-DCB). The main reason for this effect is butter, one of the milk and dairy products in baklava. In the butter production processes, diesel-powered vehicles used to irrigate the rice grown for animal feed were used. Therefore, agricultural machinery production is the cause of the impact. As a result of this, Copper (0.00340 kg 1,4-DCB), zinc (0.01551 kg 1,4-DCB), nickel (0.00250 kg 1,4-DCB), vanadium (0.00050 kg 1,4-DCB) and chromium VI (0.00072 kg 1,4-DCB) substances increase the baklava's impact value. Lentil soup in menu A is the product that provides the least impact (Figure 3.5).

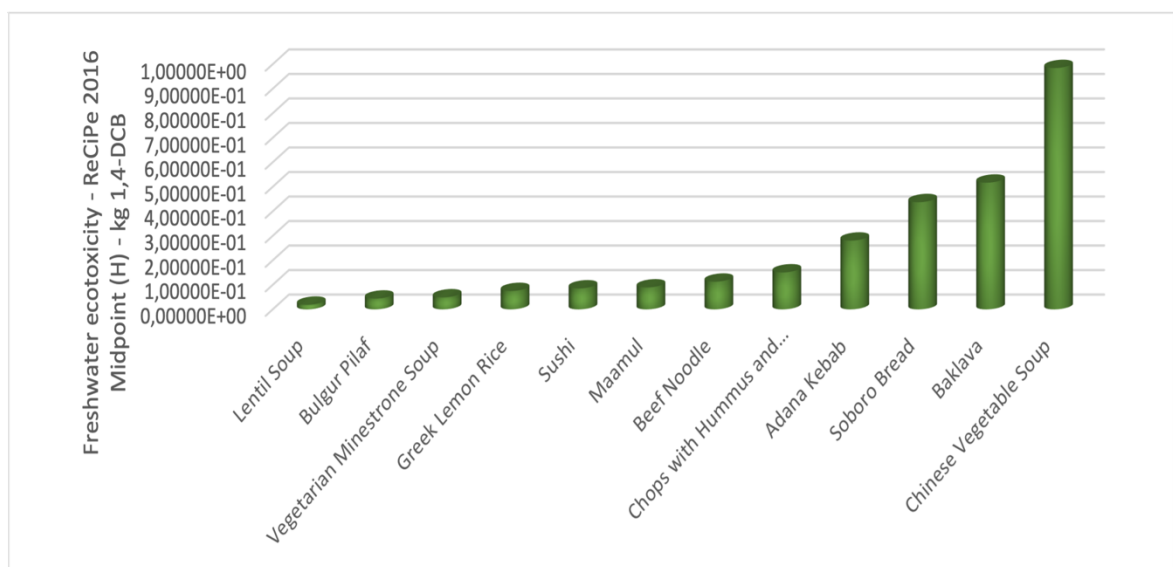


Figure 3.5. Freshwater ecotoxicity impact for 12 meals - ReCiPe 2016 Midpoint (H) - kg 1,4-DCB.

3.1.4. Freshwater Eutrophication

Freshwater eutrophication in mid-point impact category is measured by the amount of phosphorus and phosphate in freshwater. Any factor that increases the amount of phosphorus increases the freshwater eutrophication impact value. At the end-point impact point, living species in the freshwater ecosystem are damaged (Huijbregts et al., 2017). The freshwater eutrophication impact value of menu A (1.53949×10^{-3} kg P eq) is the highest due to baklava (1st) and Adana kebab (3rd) (Figure 3.2). The second highest impact value belongs to menu B (1.30418×10^{-3} kg P eq), and soboro bread ranks second among the meals. (Figure 3.6). menu C (5.10791×10^{-4} kg P eq) which contains chops with hummus and roasted tomatoes

in 4th place has the 3rd impact value. The butter used in the baklava increases the impact. Phosphorus and phosphate are mixed into rivers and groundwaters because of cultivation of agricultural food for animals such as winter wheat grain. Soboro bread shows the same results as baklava. Butter and milk in its content increase the impact. Beef minced steak used in Adana kebab (3rd) is the main reason for the increase in freshwater eutrophication impact value. Silage maize is responsible for the mixing of phosphorus and phosphate into rivers and ground waters in animal feed production, which is included in the conventional suckler cow system for obtaining beef steak. Greek lemon rice, vegetarian minestrone soup and lentil soup have little impact on freshwater eutrophication. The absence of animal-based foods in its content provides an environmental advantage.

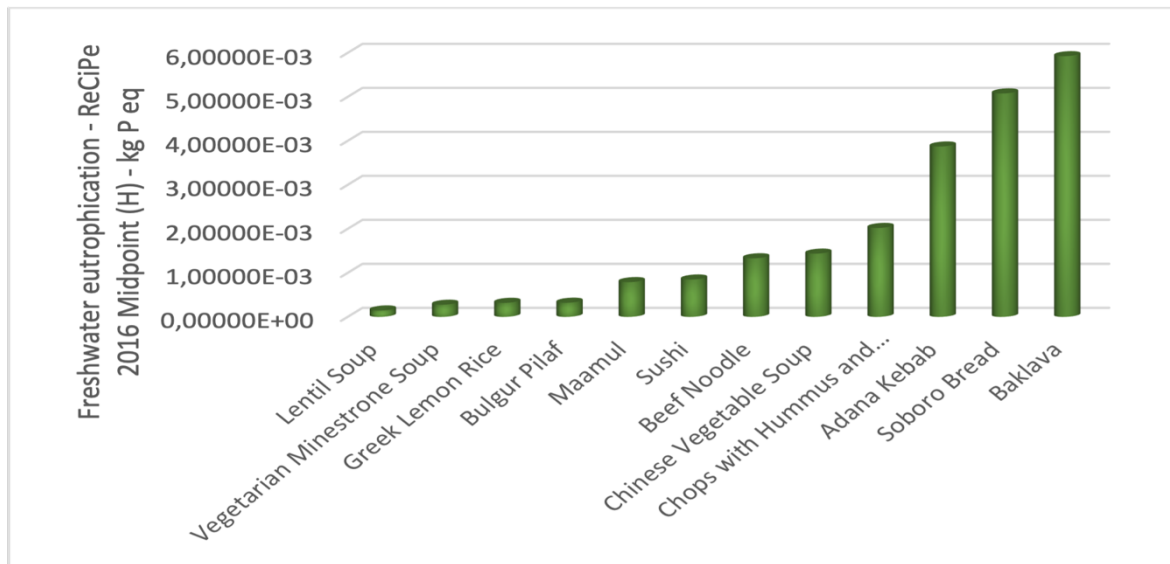


Figure 3.6. Freshwater eutrophication impact for 12 meals - ReCiPe 2016 Midpoint (H) - kg P eq.

3.1.5. Global Warming

Carbon dioxide conjugate gases such as carbon dioxide, methane, dinitrogen monoxide, sulfur hexafluoride and ethane etc. released into the atmosphere due to production activities cause an increase in the greenhouse effect. There is the effect on the increase or decrease in global temperatures as a result of the change in the energy flows in the atmosphere. Menus containing animal-based foods have increased the global warming

impact value. Menu A ($1.85154e+1$ kg CO₂ eq) has the most effect, menu B ($9.28782e+0$ kg CO₂ eq) is the 2nd rank and menu C ($4.34001e+0$ kg CO₂ eq) is the 3rd rank (Figure 3.2). The global warming effect value of Adana kebab in menu A is 69.89333 kg CO₂ eq. Beef minced steak product, which constitutes approximately 90% of Adana kebab, is the main cause of the impact. When the beef steak production process is examined, the biogenic methane and dinitrogen monoxide emitted into the atmosphere as a result of 0-day calf rearing in the suckling cow system increase the global warming potential.

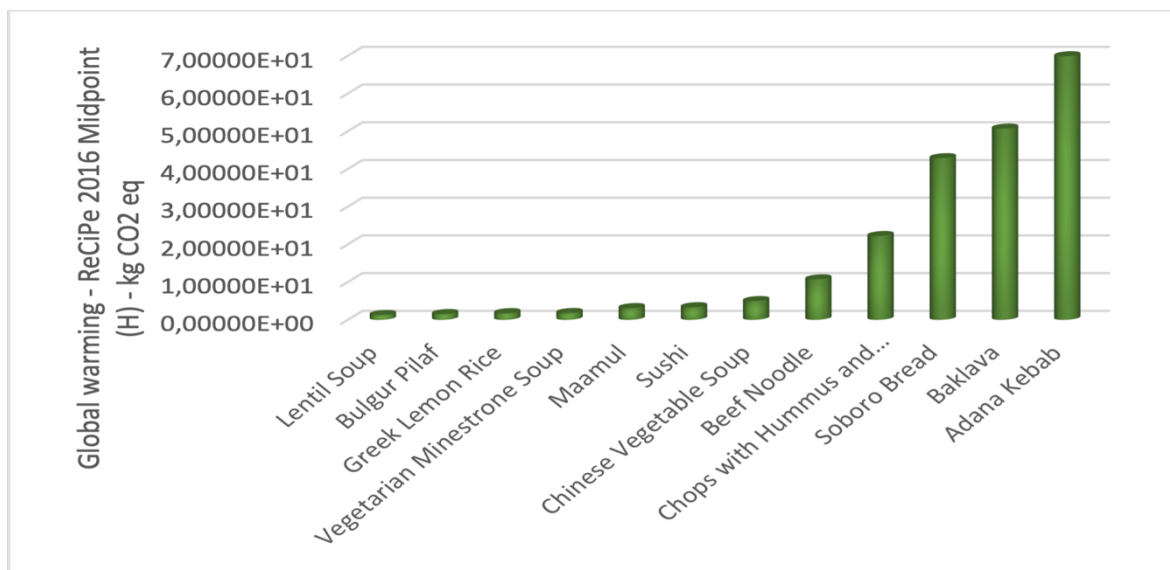


Figure 3.7. Global warming impact for 12 meals - ReCiPe 2016 Midpoint (H) - kg CO₂ eq.

After Adana kebab, the 5 meals with the highest impact are baklava, soboro bread, chops with hummus and roasted tomatoes, and beef noodles, respectively (Figure 3.7). These meals contain meat, milk and dairy products. The butter used for baklava and soboro bread is the reason for the increased global warming potential. As a result of growing winter wheat grain, which is one of the animal feeds originating from butter used in baklava, dinitrogen monoxide and carbon dioxide are released into the atmosphere. In soboro bread, on the other hand, biogenic methane gas from the animals is released into the atmosphere during the production of raw milk on the farm. Biogenic methane and dinitrogen monoxide are released into the atmosphere due to lamb chop fillet in chops with hummus and roasted tomatoes and beef steak in beef noodle.

3.1.6. Human Carcinogenic Toxicity

Carcinogenic toxicity that harms human health occurs when substances such as chromium VI and nickel etc. mix with water, soil and air, and this increases the value of human carcinogenic toxicity (Huijbregts et al., 2017). As a result, an increase in cancer types occurs. Menu A (1.31804e-1 kg 1,4-DCB) and Menu B (1.31000e-1 kg 1,4-DCB) are the cuisines that most affects human carcinogenic toxicity (Figure 3.8). Vegetable-based menu C (3.46746e-2 kg 1,4-DCB) has the lowest impact (Figure 3.2). Chromium VI and nickel are mixed into the atmosphere, groundwaters and rivers due to the butter contained in baklava (0.54107 kg 1,4-DCB) and soboro bread (0.45800 kg 1,4-DCB). Carcinogenic impacts may occur as a result of inhalation of aerosols containing chromium VI (World Health Organization, 2000). The biggest reason why the impact value of baklava is high is due to urea production in the animal feed production process in butter production system. Soboro bread has a high impact value due to agricultural machinery production for irrigation in rice production system for animal feed. Adana kebab (0.28218 kg 1,4-DCB), which ranks 3rd, causes carcinogenic toxicities as a result of beef steak use. To obtain beef steak, animal feed production is also included in the system. At this point, monocalcium phosphate, which is important for animal development, is included in bovine feeds. This substance is produced industrially and as a result chromium VI enters ground waters and rivers. Chinese vegetable soup (0.19801 kg 1,4-DCB) ranks 4th because of the bouillon content. Sushi (0.11719 kg 1,4-DCB) ranks 5th due to its seaweed content.

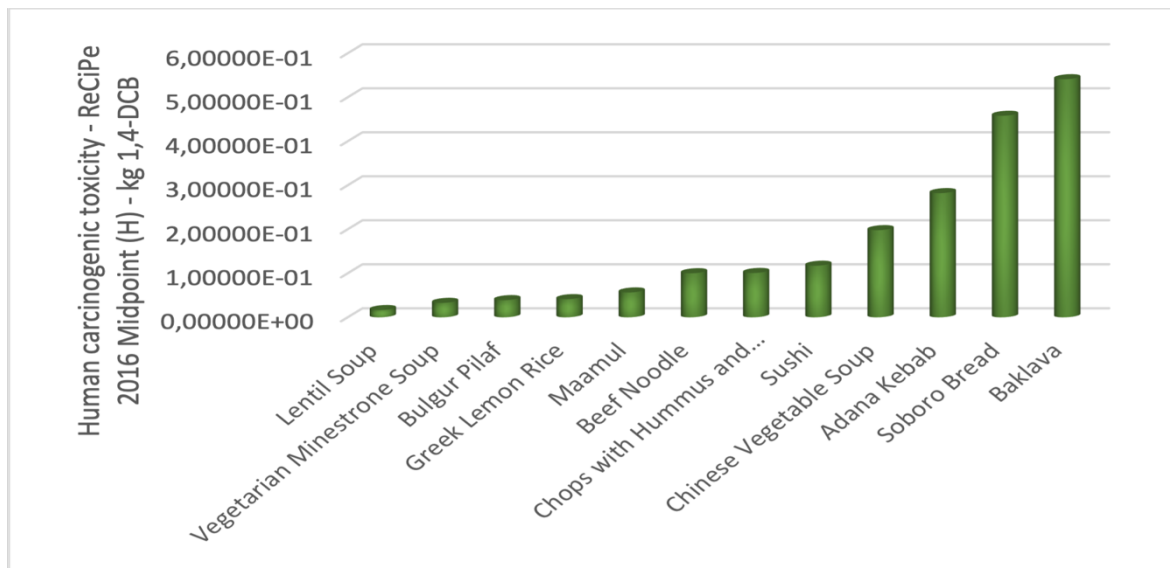


Figure 3.8. Human carcinogenic toxicity impact for 12 meals - ReCiPe 2016 Midpoint (H) - kg 1,4-DCB.

3.1.7. Human Non-carcinogenic Toxicity

As a result of the mixing of substances such as zinc, lead, beryllium, mercury and cadmium etc. into water and soil throughout the life cycle of the products, non-carcinogenic toxicity that harms human health arises and this increases the human non-carcinogenic toxicity value (Huijbregts et al., 2017). Menu A with the highest human non-carcinogenic toxicity impact value (1.14972 kg 1,4-DCB), Adana kebab (57.11028 kg 1,4-DCB) with the 1st impact value and baklava with the 3rd impact value (18.21876 kg 1,4-DCB). In Menu C with the least impact (3.73804 kg 1,4-DCB), chops with hummus and roasted tomatoes (19.72585 kg 1,4-DCB) take the 2nd place, and the impact value of the remaining 3 meals is quite low. The 2nd place Menu B (4.95757 kg 1,4-DCB) meals are soboro bread (4th), beef noodles (5th), Chinese vegetable soup (6th) and maamul (8th) (Figure 3.2 and 3.9). When the meals are examined in detail, it is observed that the human non-carcinogenic toxicity value increases with the mixing of zinc and cadmium substances into water and soil. The use of beef steak in Adana kebab, lamb chop fillet in chops with hummus and roasted tomatoes originate from the grazed grass (permenant meadow clover) areas created for grazing. Baklava and soboro bread cause zinc and cadmium to mix with soil and groundwater due to the butter.

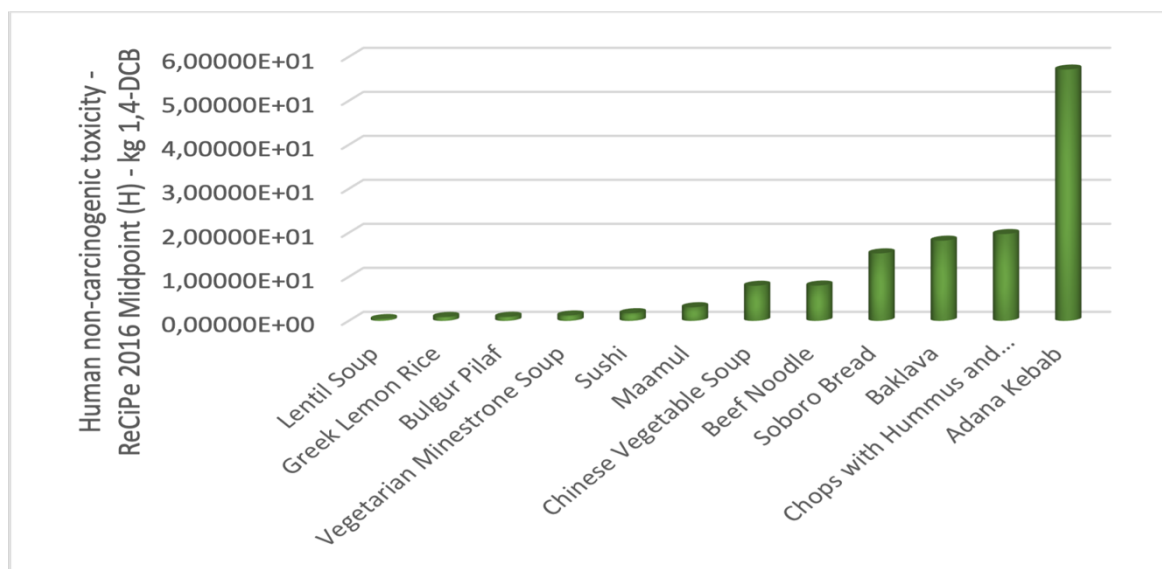


Figure 3.9. Human non-carcinogenic impact for 12 meals – ReCiPe 2016 Midpoint (H) – kg 1,4-DCB.

3.1.8. Ionizing Radiation

Radionuclides such as radon-222 and carbon-14 are released into the atmosphere during activities such as burning coal. These types of substances eventually mix with ionizing radiations in people's food and water, and as a result, an increase in cancer types occurs and harms human health (Frischknecht et al., 2000 ; Huijbregts et al., 2017 ; Verones et al., 2020). Chinese vegetable soup (25.57085 kBq Co-60 eq), beef noodle (5.14709 kBq Co-60 eq) and sushi (2.78630 kBq Co-60 eq) are formed menu B (5.18397e+0 kBq Co-60 eq) with the highest impact values, respectively (Figure 3.2 and 3.10.). When 12 meals are examined, radon-222 is released into the atmosphere and carbon-14 is formed. Bouillon for Chinese vegetable soup (25.57085 kBq Co-60 eq) , Asian noodles for beef noodles (5.14709 kBq Co-60 eq), seaweed for sushi (2.786630 kBq Co-60 eq), beef steak for Adana kebab (2.68856 kBq Co-60 eq), dried onion for bulgur pilaf (1.66043 kBq Co-60 eq) and Greek lemon rice (1.59288 kBq Co-60 eq), butter for soboro bread (1.05560 kBq Co-60 eq), dried onion for vegetarian minestrone soup (0.78225 kBq Co-60 eq) and lentil soup (0.51398 kBq Co-60 eq) was used and radon-222 and carbon-14 emerged due to the medium voltage applied during the water evaporation process. Radon-22 and carbon-14 are formed due to

urea production during the rice cultivation stage, which is produced as animal feed during the butter production process used for baklava (0.51398 kBq Co-60 eq). Animal feeds used in livestock are produced to obtain lamb chop fillet, which is used for chops with hummus and roasted tomatoes (0.95545 kBq Co-60 eq). Radon-222 and carbon-14 are formed due to the energy (medium voltage) spent in the process of grinding the wheat grain. Condition wheat semolina used for maamul (0.44437 kBq Co-60 eq) is the reason for the formation of these two substances.

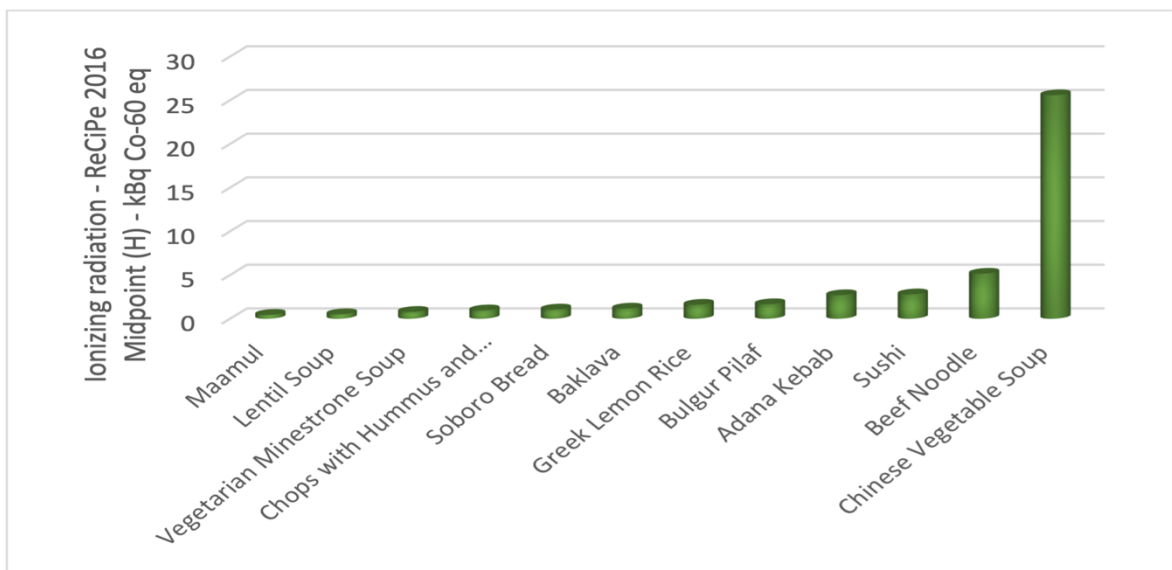


Figure 3.10. Ionizing radiation impact for 12 meals - ReCiPe 2016 Midpoint (H) - kBq Co-60 eq.

3.1.9. Land Use

Land use or transformation is one of the main causes of global biodiversity loss (Millennium Ecosystem Assessment, 2005 ; Verones et al., 2020). Land use has been increasing due to reasons such as agriculture, forestry, livestock and construction (Verones et al., 2020). In the life cycle analysis of food, land use impact values increase due to industrial areas, annual crops and pasture. As a result, terrestrial species are lost and the ecosystem is damaged (Huijbregts et al., 2017). The impact value of the meals, which are dominated by agricultural food in land use, has increased more. Menu A (1.73449 m²a crop eq) has a much higher impact value than menu B (8.32301e+0 m²a crop eq) and menu C

(6.86861 m²a crop eq) (Figure 3.2). When the meals are examined in detail, baklava and soboro bread have 47.11436 m²a crop eq and 40.52088 m²a crop eq effect values, respectively, due to the butter contained (Figure 3.11). Milk is required for the manufacture of butter. Livestock is done for milk production. In livestock, a large agricultural land is used with the cultivation of winter wheat as animal feed. Beef noodle (11.92495 m²a crop eq), ranked 4th, has similar processes. Agricultural land is used for the cultivation of soft wheat due to the Asian noodle it contains. It ranks 3rd because of the lamb chop fillet used in the content of chops with hummus and roasted tomatoes (36.97408 m²a crop eq). At this point, grazed grass areas are used for animals.

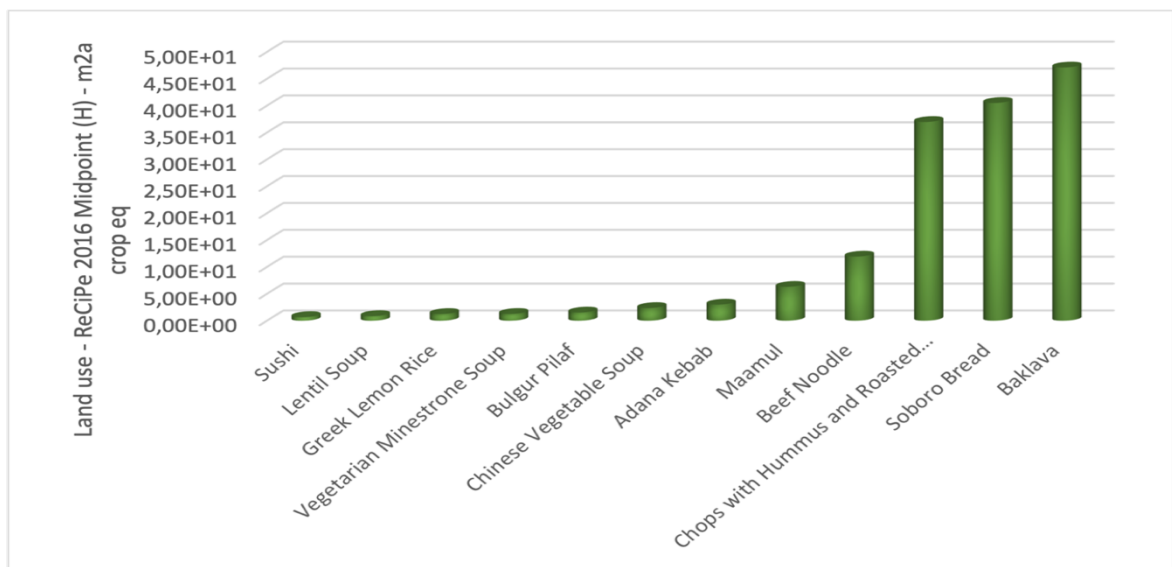


Figure 3.11. Land use impact for 12 meals - ReCiPe 2016 Midpoint (H) - m²a crop eq.

3.1.10. Marine Ecotoxicity

As a result of the mixing of substances such as zinc, copper, antimony, vanadium and chromium VI etc. into the water and air, the amount of chemical substances in sea waters increases. Increasing toxicity in the marine harms marine life and causes loss of marine species (Huijbregts et al., 2017 ; Verones et al., 2020). The impacts of the menus on marine ecotoxicity are menu B (1,75704e-1 kg 1,4-DCB), Menu A (1,66443e-1 kg 1,4-DCB) and Menu C (6,19715e-2 kg 1,4- DCB) respectively (Figure 3.2). The use of butter in cooking baklava in Menu A and Soboro bread in menu B is an effective reason. Examining

specifically at baklava, animal feeds such as winter wheat are grown under livestock activities in order to provide the milk required for butter production. During this winter wheat cultivation, zinc, nickel and copper are mixed into the rivers and groundwater. The great impact of Soboro bread on marine ecotoxicity comes from the construction of dried roughage stores. At this stage, zinc, copper, antimony and vanadium are mixed with groundwater. Adana kebab, which is in the 3rd place, is mixed with copper and zinc groundwater as a result of low-voltage electricity used in the stages of obtaining beef steak. Lentil soup and vegetarian minestrone soup have the least effect on marine ecotoxicity and contain more plant-based foodstuffs (Figure 3.12).

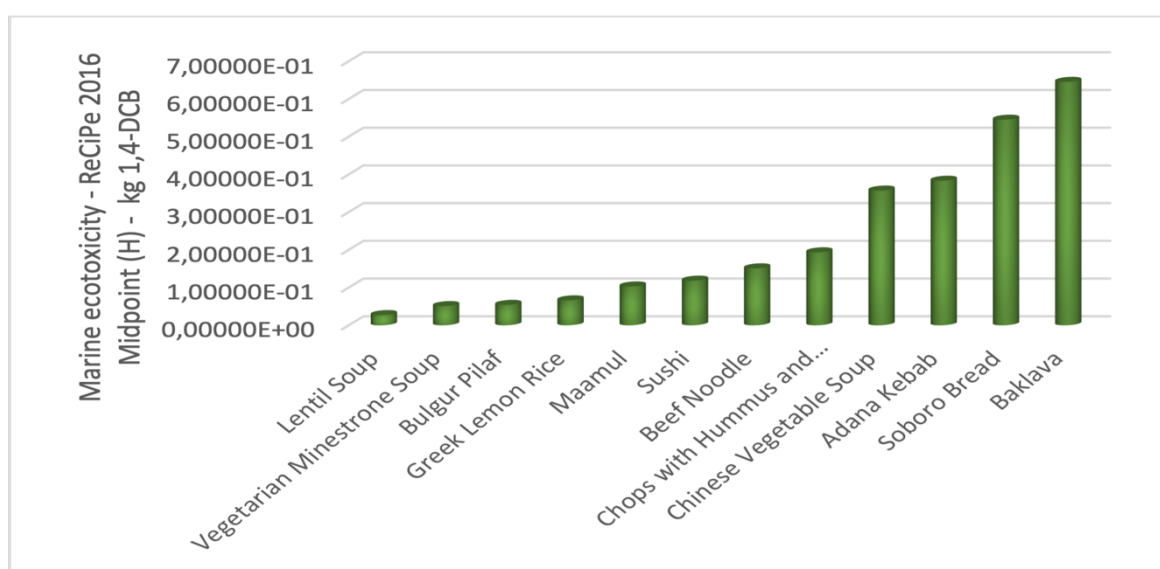


Figure 3.12. Marine ecotoxicity for 12 meals - ReCiPe 2016 Midpoint (H) - kg 1,4-DCB.

3.1.11. Marine Eutrophication

The leading causes of marine eutrophication are the inorganic nutrients nitrogen and phosphorus. Nitrogen and nitrogen conjugates are transferred from land to seawater by streams, rivers and runoff of rainwater and by the degradation of organic matter in the water. Nitrogen conjugate substances are generally formed due to activities in agricultural areas. Ammonium from fertilization and nitrogen oxides from ships are released into the atmosphere and are mixed with the oceans due to precipitation (European Commission, n.d.). The increase in nitrate ion in marine determines the marine eutrophication impact value.

Among the created menus, menu A has the highest impact with 1.39357×10^{-2} kg N eq, while menu B has 8.50344×10^{-3} kg N eq and menu C is 4.81567×10^{-3} kg N eq (Figure 3.2). Baklava (0.04742 kg N eq) and Adana kebab (0.01058 kg N eq) belonging to the menu A in the first two place in ranking (Figure 3.13). In the life cycle assessment of butter used for baklava, the mixing of nitrate into the seas during the cultivation of winter wheat under agricultural residues caused an increase in the value of marine eutrophication. Since Adana kebab contains mostly beef minced steak, it is observed that the biggest reason for the mixing of nitrate to groundwater is grazed grass (permanent meadow without clover). Soboro bread (0.04071 kg N eq) has similar properties with baklava. At the very beginning of the production phase of the butter in its ingredient, nitrate is mixed into the groundwater because of the rice cultivation as animal feed.

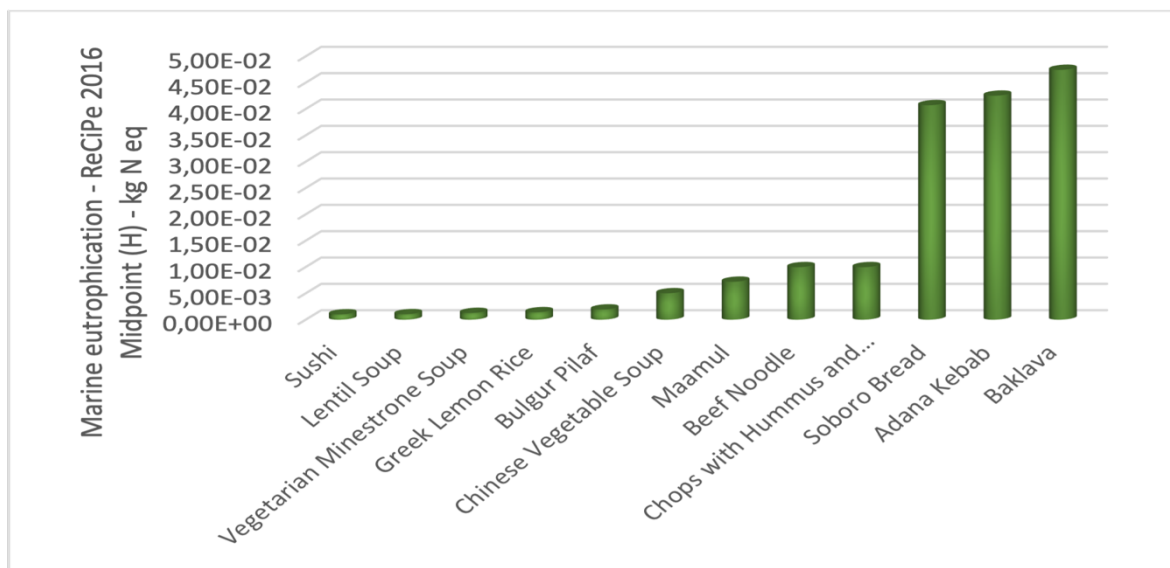


Figure 3.13. Marine eutrophication impact for 12 meals - ReCiPe 2016 Midpoint (H) - kg N eq.

3.1.12. Mineral Resource Scarcity

Metals and minerals such as potash salt, uranium, nickel, copper, clay, silver, gold and molybdenum are mined from sources for use as raw materials in industrial sectors such as construction, energy and transportation (Verones et al., 2020). Surplus Ore Potential

(SOP) value which is characterization factor is taken into account for mineral resource scarcity. SOP is the average amount of extra ore produced when a mineral resource is mined, considering all future production of that mineral resource (Huijbregts et al., 2017; Vieira et al. 2016). Menu A (3.42069×10^{-2} kg Cu eq) has the largest share in the SOP increase, while menu C (1.89569×10^{-2} kg Cu eq) has the least share (Figure 3.2). Adana kebab (0.16675 kg Cu eq) in menu A has the highest SOP. Continuing the sequence, chops with hummus and roasted tomatoes and beef noodle are 0.08997 kg Cu eq and 0.04992 kg Cu eq, respectively. The meals with the lowest share are lentil soup (0.00459 kg Cu eq) and vegetarian minestrone soup (0.00565 kg Cu eq) (Figure 3.14). The reason why all meals have a mineral resource scarcity impact value is that they contain agricultural activities. Mineral scarcity value increases due to potash chloride used during fertilization processes. When Adana kebab and chops with hummus and roasted tomatoes are examined, beef minced steak and lamb chop fillet are animal products and mineral fertilizer containing potash chloride is used as animal feed during the production of baled hay. Potash salt occurs because beef noodle contains both beef steak and egg. The use of eggs is due to the fertilization process used in the maize breeding stage produced for laying hens.

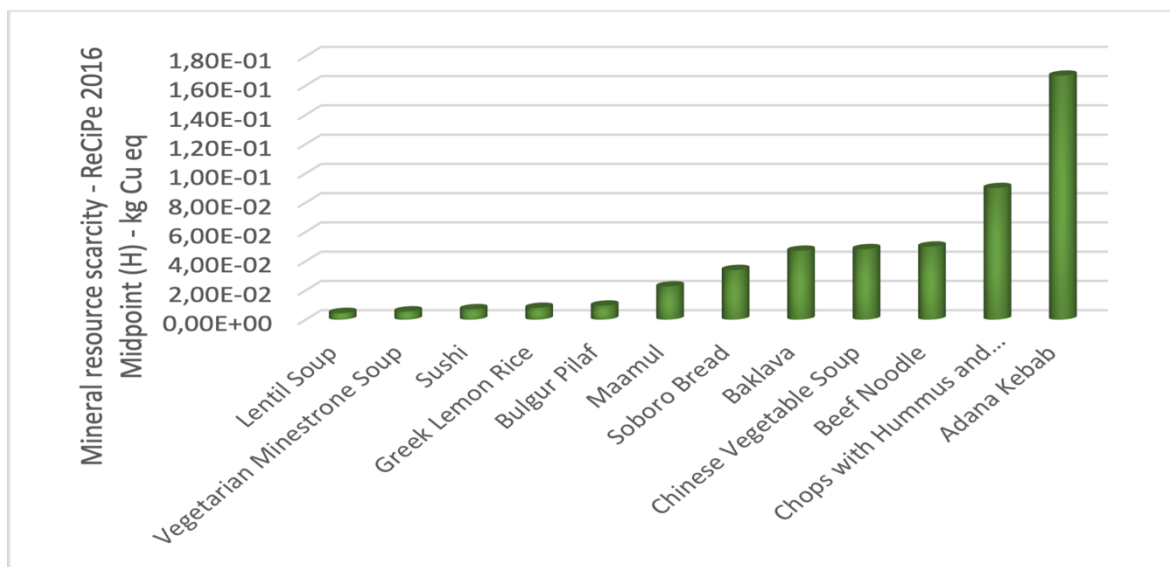


Figure 3.14. Mineral resource scarcity impact for 12 meals - ReCiPe 2016 Midpoint (H) - kg Cu eq.

3.1.13. Ozone Formation-Human Health

Emission of NO_x conjugate substances such as nitrogen oxides and non-methane volatile organic compounds (NMVOCs) released into the atmosphere turns into tropospheric ozone and harms human health. Respiratory diseases occur in humans (Huijbregts et al., 2017 ; Verones et al., 2020). NO_x emission released into the atmosphere turns into tropospheric ozone and harms human health. Menu A (2.38872e-2 kg NO_x eq) emits the most NO_x eq to the atmosphere, followed by menu B (1.6177e-2 kg NO_x eq) and menu C (6.87915e-3 kg NO_x eq), which has the least share (Figure 3.2 and 3.15). Baklava (0.08475 kg NO_x eq) causes the most emissions of NO_x and No_x eq in the atmosphere. The impact value was high due to the butter in the baklava and soboro bread (0.07184 kg No_x eq) which is second one. Milk is needed to make butter and livestock is needed for milk. At the livestock stage, rice is grown as for animals feed and irrigation is done with burned water pumps working with diesel. Nitrogen oxide and NMVOC were released into the air because of diesel burned powered water pumps. The third one is Adana kebab (0.06905 kg NO_x eq). In order to obtain beef steak, which forms approximately 90% of the meal, livestock is similarly carried out and baled hay is prepared as animal feed. While baling this hay with a round baler, diesel combustion tractors are used and they release nitrogen oxides into the atmosphere. NMVOC, on the other hand, is due to the diesel combustion of the silage machines used to harvest the grown grasses. In summary, nitrogen oxide and NMVOC are released into the atmosphere due to agricultural vehicles such as diesel-combustion harvesters and tractors, transportation vehicles (ships) used in the formation processes of 10 meals. It causes the release of two substances to the atmosphere caused by the use of natural gas in the cooking process of lentil soup and vegetarian minestrone soup, which has the least impact.

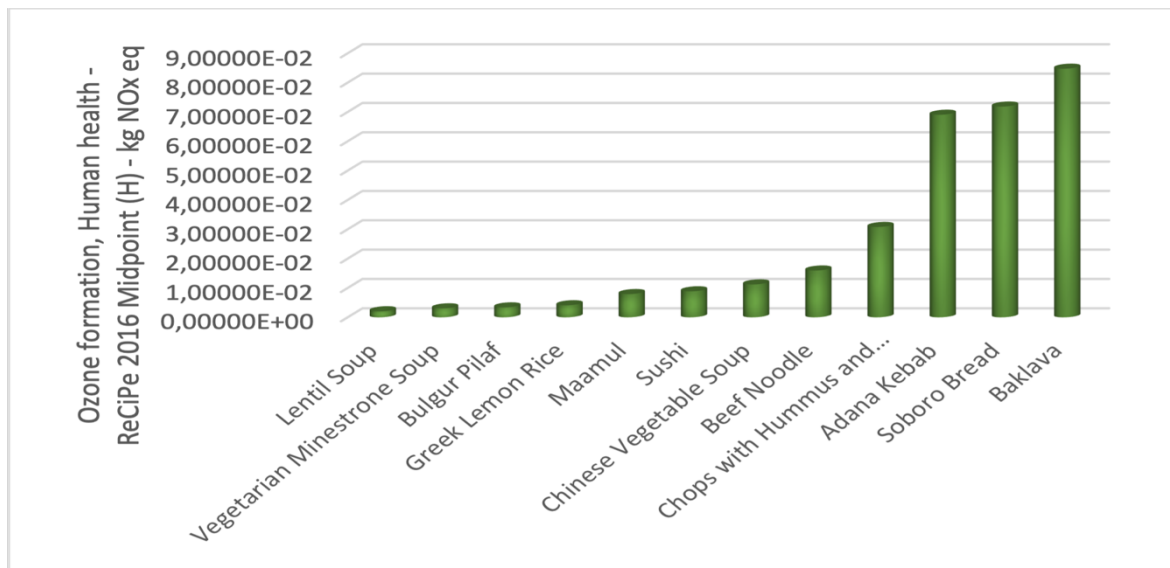


Table 3.15. Ozone formation impact (human health) for 12 meals- ReCiPe 2016 Midpoint (H) - kg NO_x eq.

3.1.14. Ozone Formation-Terrestrial Ecosystems

Emission of NO_x conjugate substances such as nitrogen oxides and non-methane volatile organic compounds (NMVOCs) released into the atmosphere turns into tropospheric ozone and damages terrestrial ecosystem. Decreases can be observed in plant biomass (Huijbregts et al., 2017 ; Verones et al., 2020). Menu A (2.43425e-2 kg NO_x eq) emits the most NO_x eq to the atmosphere, followed by menu B (1.65159e-2 kg NO_x eq) and menu C (7.0233e-3 kg NO_x eq), which has the least emitting NO_x eq (Figure 3.10 and 3.16). It seems that there are similarities between ozone formation-human health and ozone formation-terrestrial ecosystems. The similarities are the menu order, the order of the meals and the values obtained. For example, baklava with the first effect value is 0.08649 kg NO_x eq, while the ozone formation-human health effect value is 0.08475 kg NO_x eq. In both impact categories, the emission of nitrogen oxide and NMVOC into the atmosphere is due to the diesel-powered motor pump irrigation system.

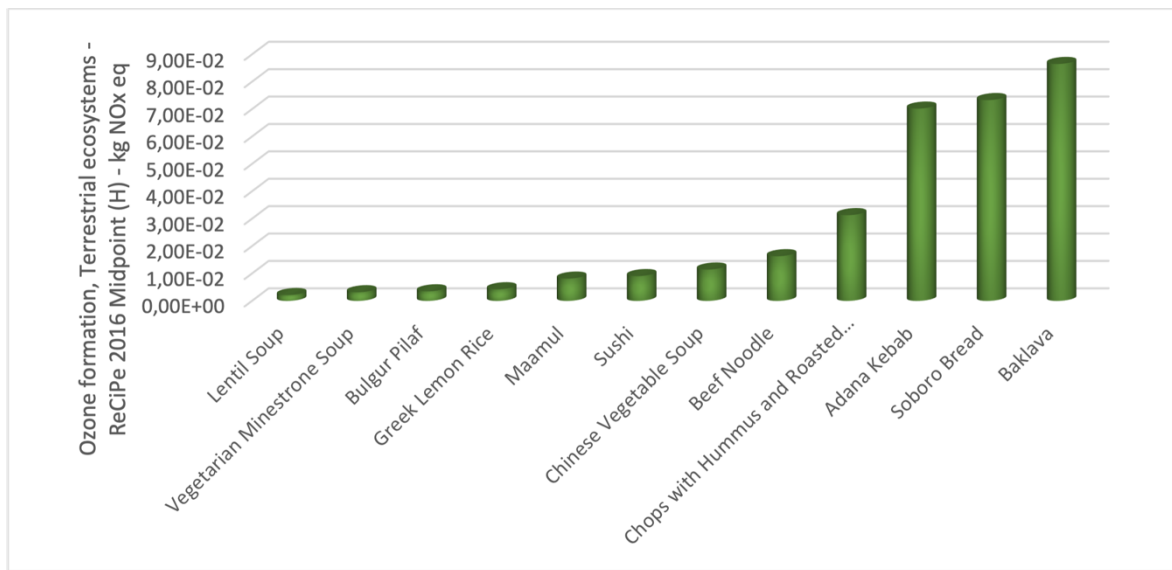


Figure 3.16. Ozone formation impact (terrestrial ecosystems) for 12 meals - ReCiPe 2016 Midpoint (H) - kg NO_x eq.

3.1.15. Stratospheric Ozone Depletion

Stratospheric ozone depletion occurs because of the increase of chlorofluorocarbon gases that thin the ozone layer in the stratosphere and causes an increase in UV-B rays coming from the sun to the earth (Huijbregts et al., 2017; Hayashi. et al., 2004). In this case, it is quite harmful to human health. Exposure to UV-B rays causes an increase in diseases such as skin cancer and cataracts (Huijbregts et al., 2017). In the life cycle assessment of menus, the stratospheric ozone depletion impact value increases with the release of gases such as dinitrogen monoxide, ethane, and methane into the atmosphere. Menu A (9.06505e-5 kg CFC11 eq) has a huge impact in the emission of ozone-depleting gases than Menu B (3.84865e-05 kg CFC11 eq) and Menu C (3.24565e-05 kg CFC11 eq) (Figure 3.2). The difference between Adana kebab(0.00041 kg CFC11 eq), which has the first impact value, and chops with hummus and roasted tomatoes (0.00019 kg CFC11 eq), which has the second effect value, is almost 2 times. However, approximately 90% of one portion of Adana kebab contains beef steak, which is an animal-based food, while approximately 33% of chops with hummus and roasted tomatoes contain lamp chop fillet. CFC 11 eq gases released to the atmosphere proportionally are higher in Adana kebab. Similar stages increase the effect value in the production stages of beef steak and lamb chop fillet. Adana kebab and chops

with hummus and roasted tomatoes in grazed grass without clover, baled hay making and soft wheat cultivation stages cause stratospheric ozone depletion. The meals with the lowest share are plant-based meals such as lentil soup and sushi (Figure 3.17).

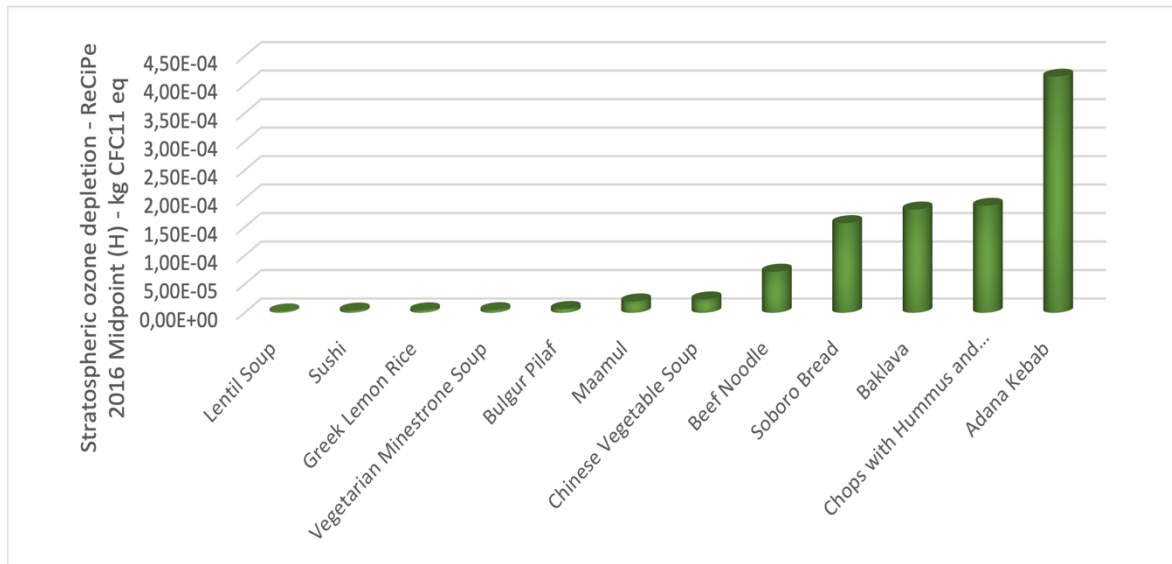


Figure 3.17. Stratospheric ozone depletion impact for 12 meals - ReCiPe 2016 Midpoint (H) - kg CFC11 eq.

3.1.16. Terrestrial Acidification

The biggest factors in changing the chemical properties of the soil are nitrogen oxide (NO_x), sulfur dioxide (SO_2) and ammonia (NH_3) which are the conjugates of sulfur dioxide (Huijbregts et al., 2017; Roy et al., 2014). Generally, ammonia is released into the atmosphere as a result of food processes. Ammonia is caused by livestock and fertilizer applications containing ammonia (Behere et al., 2013). Menu A ($1.25091e-1$ kg SO_2 eq) has a huge impact on terrestrial acidification than menu B ($5.98061e-2$ kg SO_2 eq) and menu C ($3.86766e-2$ kg SO_2 eq) (Figure 3.2). Adana kebab (0.52152 kg SO_2 eq) causes terrestrial acidification due to the beef steak it contains. Ammonia is released due to livestock and agricultural activities such as hay production at the stage of obtaining beef steak. Due to the butter used in making baklava (0.30384 kg SO_2 eq) and soboro bread (0.26141 kg SO_2 eq), both ammonia and nitrogen oxide are released. The main reason is rice at farm and these gasses originate from agricultural residues. Vegetable-based meals such as vegetarian

minestrone soup, bulgur pilaf and lentil soup have very little impacts on terrestrial acidification.

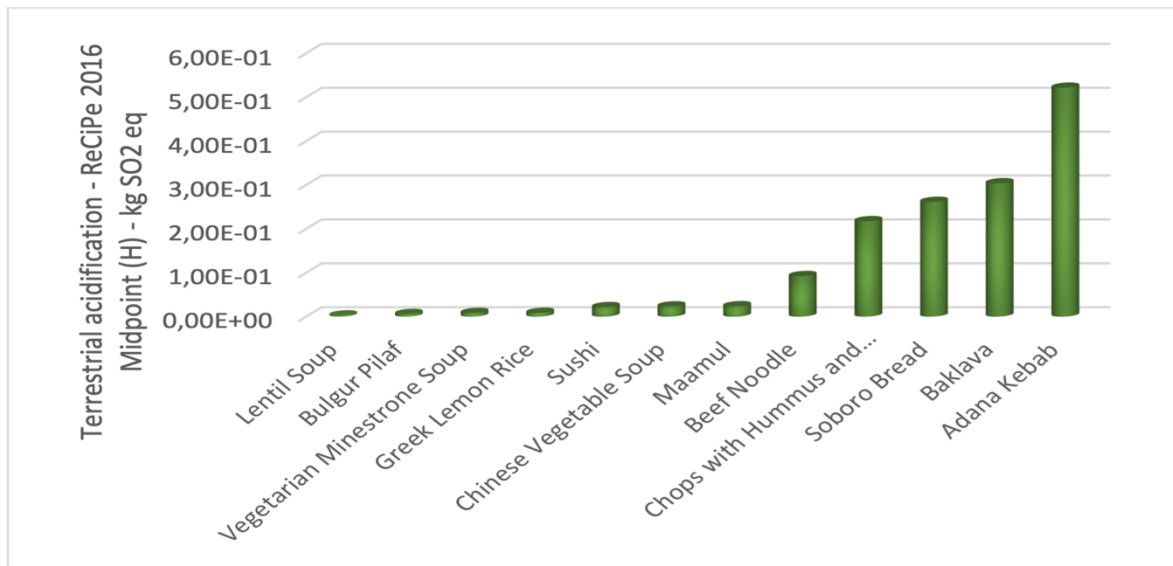


Figure 3.18. Terrestrial acidification impact for 12 meals- ReCiPe 2016 Midpoint (H) - kg SO₂ eq.

3.1.17. Terrestrial Ecotoxicity

Terrestrial ecotoxicity increases as a result of the release of the substances such as copper, vanadium, nickel, zinc, lead, antimony and cadmium into the atmosphere and mixing with the soil due to reasons such as precipitation. Terrestrial ecotoxicity occurs when chemicals contaminate the soil. It is calculated with the the indicator of terrestrial ecotoxicity potential (TEP) Huijbregts et al., 2017 ; Verones et al., 2020). Menu A (1.41180e+1 kg 1,4-DCB) is approximately 3 times menu C (5.62958e+0 kg 1,4-DCB), and menu B (1.39116e+1 kg 1,4-DCB) is approximately 2 times menu C (Figure 3.2). When examined in detail, the highest pollutants are baklava (1st) and Adana kebab (3rd) from menu A, soboro bread (2nd) and Chinese vegetable soup (4th) from menu B (Figure 3.19). Transportation (lorry) and dried roughage store construction due to the butter used in the production of baklava and soboro are the biggest reasons for the release of copper, antimony and zinc. In Adana kebab, copper, antimony, and zinc are released due to transportation (lorry) and copper oxide production in the steps taken to obtain beef steak used.

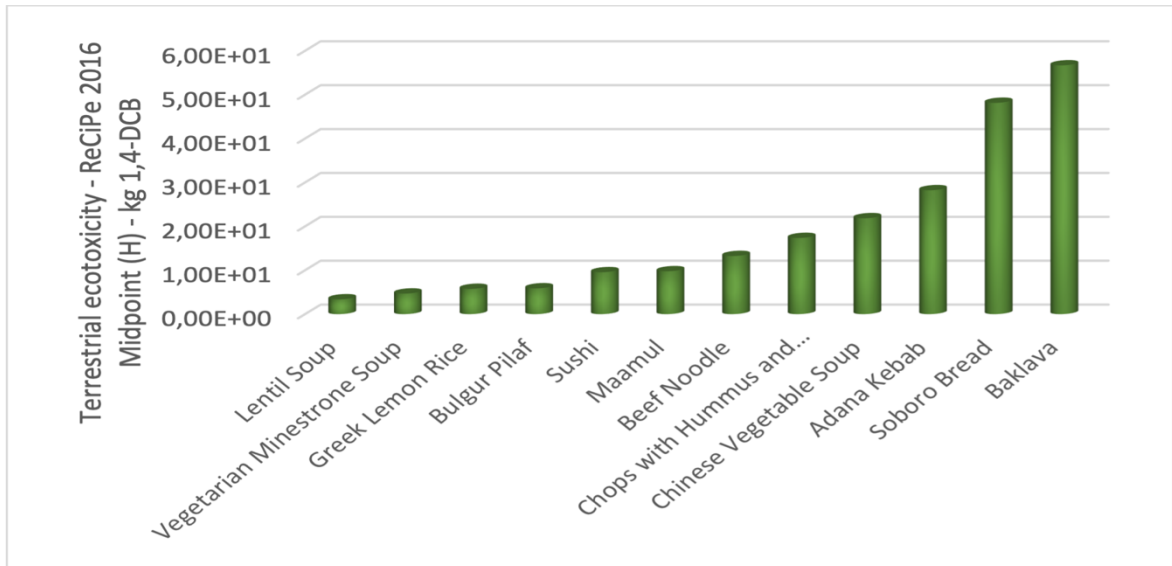


Figure 3.19. Terrestrial ecotoxicity impact for 12 meals- ReCiPe 2016 Midpoint (H) - kg 1,4-DCB.

3.1.18. Water Consumption

Similar examples such as evaporation of water, adding water to products and foods, transferring it to other basins and mixing with the sea are collected under the name of water consumption (Falkenmark et al., 2004 ; National Institute for Public Health and the Environment, 2017). Water scarcity, which is expected to be experienced with increased water consumption, can damage natural aquatic and terrestrial ecosystems (Verones et al., 2020). During the preparation of the meals belonging to menu B ($-4.76000e+1 \text{ m}^3$) and in all stages of the food products contained in these meals from the cradle to the grave, the use of water is quite high compared to menu A ($-1.27918e+1 \text{ m}^3$) and menu C ($-6.25996e+0 \text{ m}^3$). If the values are negative, it indicates that there is consumption. It has no mathematical value. When 12 meals are examined in detail, especially the water consumption effect value of Chinese vegetable soup is -214.00206 m^3 , which is approximately 4.5 times the effect value of beef noodles (-45.28859 m^3), which is in the second place. There is water consumption from water evaporated in all meals. For bouillon used for Chinese vegetable soup, water consumption is quite high due to processes such as low-voltage and medium-voltage

electricity use during the dehydration of vegetables. Beef noodles also have similar results with Chinese vegetable soup due to Asian noodles in its content.

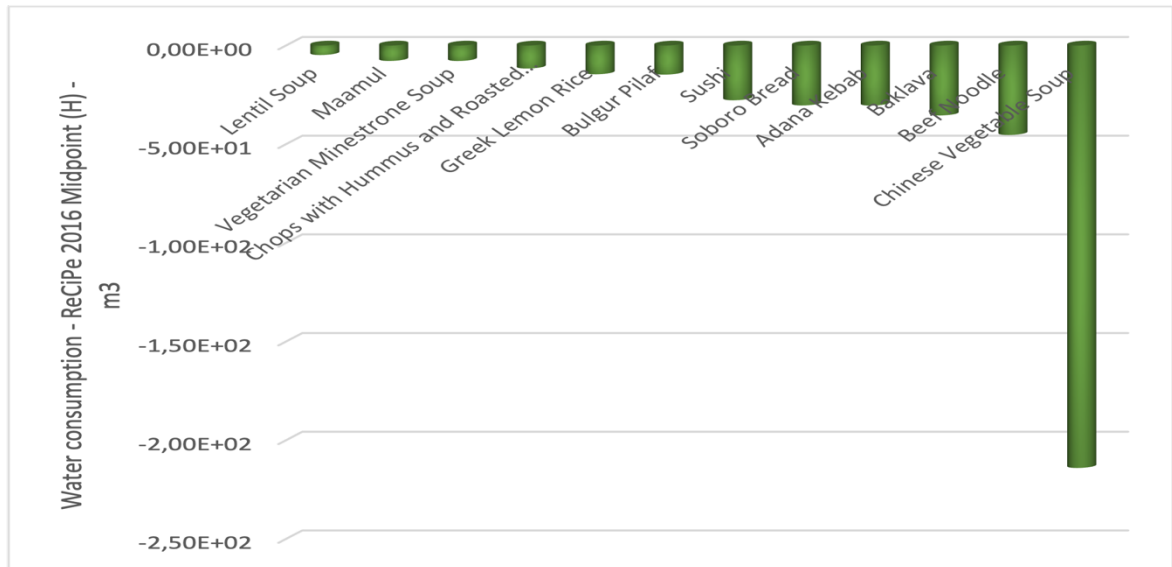


Figure 3.20. Water consumption impact for 12 meals - ReCiPe 2016 Midpoint (H) - m³.

4. CONCLUSION

Every cuisine has indispensable foodstuffs. Grain and meat of Turkish cuisine, rice and noodles of Far East cuisine, greens and olive oil of Mediterranean cuisine are the most commonly used foodstuffs. 18 impact categories of ReCiPe 2016 Midpoint (H) were examined in the OpenLCA program for menu A, menu B and menu C, which were prepared with these foodstuffs by taking into consideration. All foods used in meals were analyzed from the cradle to the supermarket in the system. When the foods used in the meals belonging to the menus are considered, results consistent with the literature were obtained.

Menu A and Menu B have much more environmental impact than Menu C in all 18 impact categories. The reason for this is the diversity in the ratios of animal-based food, vegetable-based food and water in the menus. Looking at the 18 impact categories, baklava and Soboro bread have similar properties in terms of impact due to the butter they contain. In the life cycle analysis for butter from the cradle to the supermarket, the most prominent steps responsible for the increase in the value of impact categories are as follows: Raw milk is required for butter making. Livestock is done for milk. Animal feed is required to maintain livestock activities. For this reason, feed crops are planted. During the cultivation of feed plants, processes such as fertilization and irrigation are carried out. Agricultural residues remain after the harvest of forage crops. The same processes were examined in the system for the butter used in both meals. Although the process steps are the same, baklava has a slightly more environmental impact. Baklava has a greater impact value than soboro bread in 18 impact categories because while baklava contains 8.47% butter, soboro bread contains 7.35% butter.

The biggest contribution of Adana kebab, beef noodles and chops with hummus and roasted tomatoes to the impact categories is beef steak, beef sirloin steak, and lamb chop filet, respectively. The contribution process of meat products to the impact categories is livestock activities and feed crop cultivation. For example, in addition to agricultural activities for baled hay production, the production and use of diesel-burned baling machines are responsible for the increase in the value of impact categories. Apart from the impact

categories of land use, ionizing radiation, and water consumption, the order from the most effective to the least effective among these three meals containing meat is Adana kebab, chops with hummus, and roasted tomatoes and beef noodles. The reason is that the meat proportion in their ingredients is 25% in Adana kebab, 4% in chops with hummus and roasted tomatoes, and 10% in beef noodles.

In conclusion, when the life cycle of animal-based foods from cradle-to-supermarket is examined, agricultural activities for livestock and animal feed play a major role in increasing environmental impacts. In plant-based foods, agricultural activities (such as harvesting, use of machinery, land use and fertilization) play a major role in increasing environmental impacts. When food-based and cuisine-based assessments were combined, outputs compatible with the literature were obtained (Abdelkader et al., 2022 ; Asem-Hiable et al., 2018 ; Cucurachi et al., 2019 ; Rivera and Azapagic, 2019 ; Saez-Almendros et al., 2013 ; Takacs et al., 2022). Considering at the overall, the life cycle analysis of the Mediterranean cuisine, which includes vegetable-based foods, provided positive results compared to the other two cuisines. In other words, the environmental impact of Mediterranean cuisine is quite small. Far East cuisine includes both vegetable-based foods and animal-based foods, and the ratio of vegetable-based foods is high. Therefore, considering its environmental impact, Far East cuisine comes after Mediterranean cuisine. Turkish cuisine, on the other hand, has a very high ratio of animal-based food. Among the three cuisines, Turkish cuisine has the highest environmental impact value.

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APPENDIX A

Project Variants

This table shows the name and description of the variants as defined in the project setup. The variant names of the project setup are used for all charts and tables of the other report components.

Variant	Description
Menu A	Menu A includes lentil soup, Adana kebab, bulgur pilaf and baklava which belong to Turkish cuisine.
Menu B	Menu B includes Chinese vegetable soup, beef noodle, sushi and soboro bread which belong to Far East cuisine.
Menu C	Menu C includes vegetarian minestrone soup, chops with hummus and roasted tomatoes, Greek lemon rice and maamul which belong to Mediterranean cuisine.

Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines.

Selected LCIA Categories

The table below shows the LCIA categories of the selected LCIA method of the project. Only the LCIA categories that are selected to be displayed are shown in the report. Additionally, a user friendly name and a description for the report can be provided.

Indicator	Unit	Description
Fine particulate matter formation - ReCiPe 2016 Midpoint (H)	kg PM2.5 eq	The formation of fine particulate matter is an indicator of air quality with the PM2.5 value defined for 2.5 micron and smaller substances in the atmosphere.
Fossil resource scarcity - ReCiPe 2016 Midpoint (H)	kg oil eq	Fossil resource scarcity is the ratio of the heating value of the fossil resource to the energy content of the crude oil. (Huijbregt et al., 2017; Jungbluth and Frischnecht, 2010).
Freshwater ecotoxicity - ReCiPe 2016 Midpoint (H)	kg 1,4-DCB	Substances such as zinc, copper, nickel, vanadium, pronamide, chlorothalanil mixed with fresh water cause freshwater ecotoxicity.
Freshwater eutrophication - ReCiPe 2016 Midpoint (H)	kg P eq	It is measured by the amount of phosphorus and phosphate in freshwater.
Global warming - ReCiPe 2016 Midpoint (H)	kg CO2 eq	Carbon dioxide conjugate gases such as carbon dioxide, methane, dinitrogen monoxide, sulfur hexafluoride and ethane etc. released into the atmosphere due to production activities cause an increase in the global warming impact value.

Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Human carcinogenic toxicity - ReCiPe 2016 Midpoint (H)	kg 1,4- DCB	It is measured by the amount of substances chromium VI and nickel etc. in water, soil and air.
Human non-carcinogenic toxicity - ReCiPe 2016 Midpoint (H)	kg 1,4- DCB	It is measured by the amount of substances zinc, lead, beryllium, mercury and cadmium etc. in water, soil and air.
Ionizing radiation - ReCiPe 2016 Midpoint (H)	kBq Co-60 eq	It is measured that the amount of radionuclides releasing to atmosphere. Radionuclides mix into water and nutrients as ionizing radiations.
Land use - ReCiPe 2016 Midpoint (H)	m2a crop eq	It is measured by the amount of land used for reasons such as agriculture, forestry, livestock and construction.
Marine ecotoxicity - ReCiPe 2016 Midpoint (H)	kg 1,4- DCB	It is measured by the amount of chemical substance such as zinc, copper, antimony, vanadium and chromium VI etc. in the seas.
Marine eutrophication - ReCiPe 2016 Midpoint (H)	kg N eq	It is measured by the amount of nitrogen and nitrogen conjugates in the oceans. For reasons such as agricultural activities, inorganic substances such as nitrogen and phosphorus mix with fresh and salt water.
Mineral resource scarcity - ReCiPe 2016 Midpoint (H)	kg Cu eq	It is measured that the average amount of extra ore produced when a mineral resource is mined, taking into account all future production of that mineral resource (Huijbregts et al., 2017; Vieira et al. 2016).

Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Ozone formation, Human health - ReCiPe 2016 Midpoint (H)	kg NO _x eq	It is measured by the amount of NO _x conjugate which is nitrogen oxides and non-methane volatile organic compounds. The substances in the atmosphere turn into the tropospheric ozone which harms human health (Huijbregts et al., 2017 ; Verones et al., 2020).
Ozone formation, Terrestrial ecosystems - ReCiPe 2016 Midpoint (H)	kg NO _x eq	It is measured by the amount of NO _x conjugate which is nitrogen oxides and non-methane volatile organic compounds. The substances in the atmosphere turn into the tropospheric ozone which harms terrestrial ecosystem (Huijbregts et al., 2017 ; Verones et al., 2020).
Stratospheric ozone depletion - ReCiPe 2016 Midpoint (H)	kg CFC11 eq	It is measured by the amount of chlorofluorocarbon gases in the atmosphere.
Terrestrial acidification - ReCiPe 2016 Midpoint (H)	kg SO ₂ eq	It is measured by the amount of sulfur dioxide conjugates such as nitrogen oxide (NO _x), sulfur dioxide (SO ₂) and ammonia (NH ₃) which change the structure of the soils (Huijbregts et al., 2017 ; Roy et al., 2014).
Terrestrial ecotoxicity - ReCiPe 2016 Midpoint (H)	kg 1,4-DCB	It is calculated with the the indicator of terrestrial ecotoxicity potential (TEP) Huijbregts et al., 2017 ; Verones et al., 2020). Terrestrial ecotoxicity potential increases as a result of the release of substances such as copper, vanadium, nickel, zinc, lead, antimony and cadmium into the atmosphere due to precipitation and mixing with the soil.
Water consumption - ReCiPe 2016 Midpoint (H)	m ³	It is measured by water consumption in cases such as evaporation of water, addition of water to products and foods, transfer to other basins and mixing with the sea (Falkenmark et al., 2004; National Institute for Public Health and the Environment, 2017).

Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

LCIA Results

This table shows the LCIA results of the project variants. Each selected LCIA category is displayed in the rows and the project variants in the columns. The unit is the unit of the LCIA category as defined in the LCIA method.

Indicator	Menu A	Menu B	Menu C	Unit
Fine particulate matter formation - ReCiPe 2016 Midpoint (H)	2.10098e-2	1.23401e-2	6.19630e-3	kg PM2.5 eq
Fossil resource scarcity - ReCiPe 2016 Midpoint (H)	1.09803e+0	8.36345e-1	4.30288e-1	kg oil eq
Freshwater ecotoxicity - ReCiPe 2016 Midpoint (H)	1.28992e-1	1.36538e-1	5.45478e-2	kg 1,4-DCB
Freshwater eutrophication - ReCiPe 2016 Midpoint (H)	1.53949e-3	1.30418e-3	5.10791e-4	kg P eq
Global warming - ReCiPe 2016 Midpoint (H)	1.85154e+1	9.28782e+0	4.34001e+0	kg CO2 eq
Human carcinogenic toxicity - ReCiPe 2016 Midpoint (H)	1.31804e-1	1.31000e-1	3.46746e-2	kg 1,4-DCB
Human non-carcinogenic toxicity - ReCiPe 2016 Midpoint (H)	1.14972e+1	4.95757e+0	3.73804e+0	kg 1,4-DCB

Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Ionizing radiation - ReCiPe 2016 Midpoint (H)	9.03394e-1	5.18397e+0	5.66242e-1	kBq Co-60 eq
Land use - ReCiPe 2016 Midpoint (H)	1.73449e+1	8.32301e+0	6.86861e+0	m2a crop eq
Marine ecotoxicity - ReCiPe 2016 Midpoint (H)	1.66443e-1	1.75704e-1	6.19715e-2	kg 1,4- DCB
Marine eutrophication - ReCiPe 2016 Midpoint (H)	1.39357e-2	8.50344e-3	4.81567e-3	kg N eq
Mineral resource scarcity - ReCiPe 2016 Midpoint (H)	3.42069e-2	2.08763e-2	1.89569e-2	kg Cu eq
Ozone formation, Human health - ReCiPe 2016 Midpoint (H)	2.38872e-2	1.61770e-2	6.87915e-3	kg NOx eq
Ozone formation, Terrestrial ecosystems - ReCiPe 2016 Midpoint (H)	2.43425e-2	1.65159e-2	7.02330e-3	kg NOx eq
Stratospheric ozone depletion - ReCiPe 2016 Midpoint (H)	9.06505e-5	3.84865e-5	3.24565e-5	kg CFC11 eq
Terrestrial acidification - ReCiPe 2016 Midpoint (H)	1.25091e-1	5.98061e-2	3.86766e-2	kg SO2 eq
Terrestrial ecotoxicity - ReCiPe 2016 Midpoint (H)	1.41180e+1	1.39116e+1	5.62958e+0	kg 1,4- DCB
Water consumption - ReCiPe 2016 Midpoint (H)	-1.27918e+1	-4.76000e+1	-6.25996e+0	m3

Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Single Indicator Results

The following chart shows the single results of each project variant for the selected indicator. You can change the selection and the chart is dynamically updated.



Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

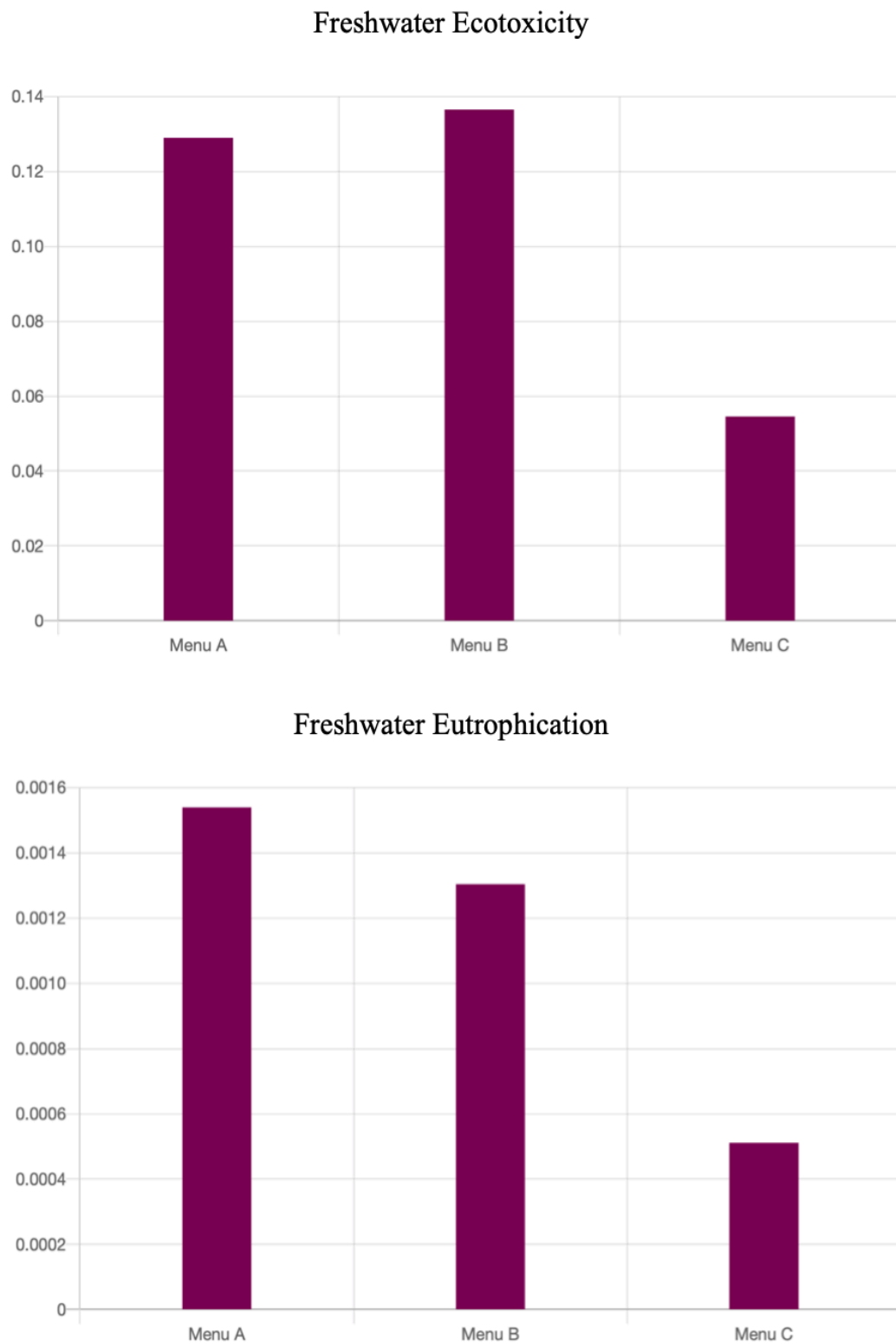


Figure A1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.)

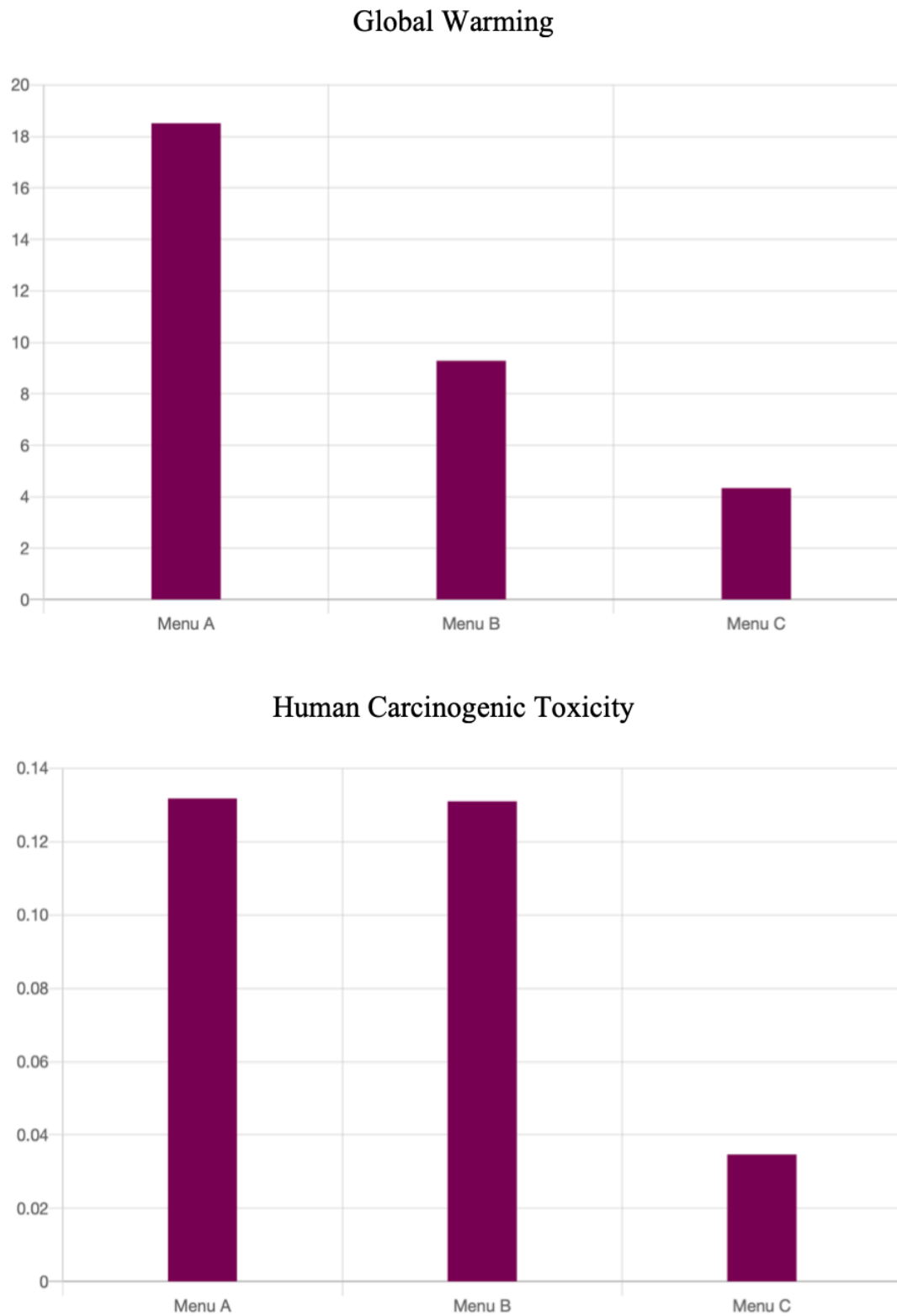
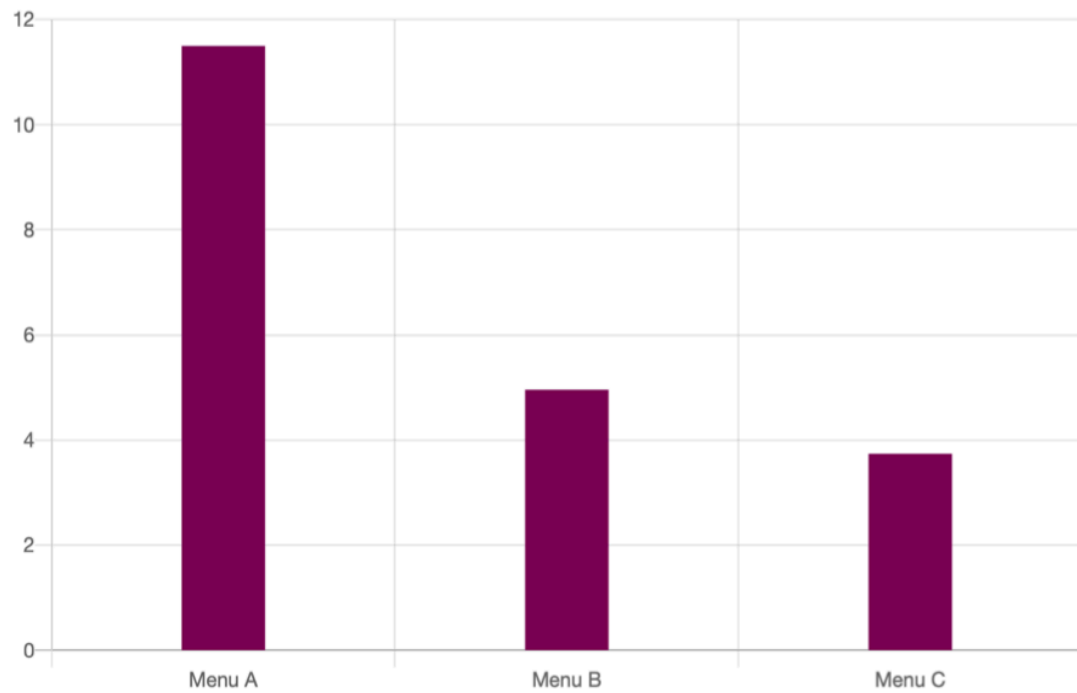


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Human Non-carcinogenic Toxicity



Ionizing Radiation

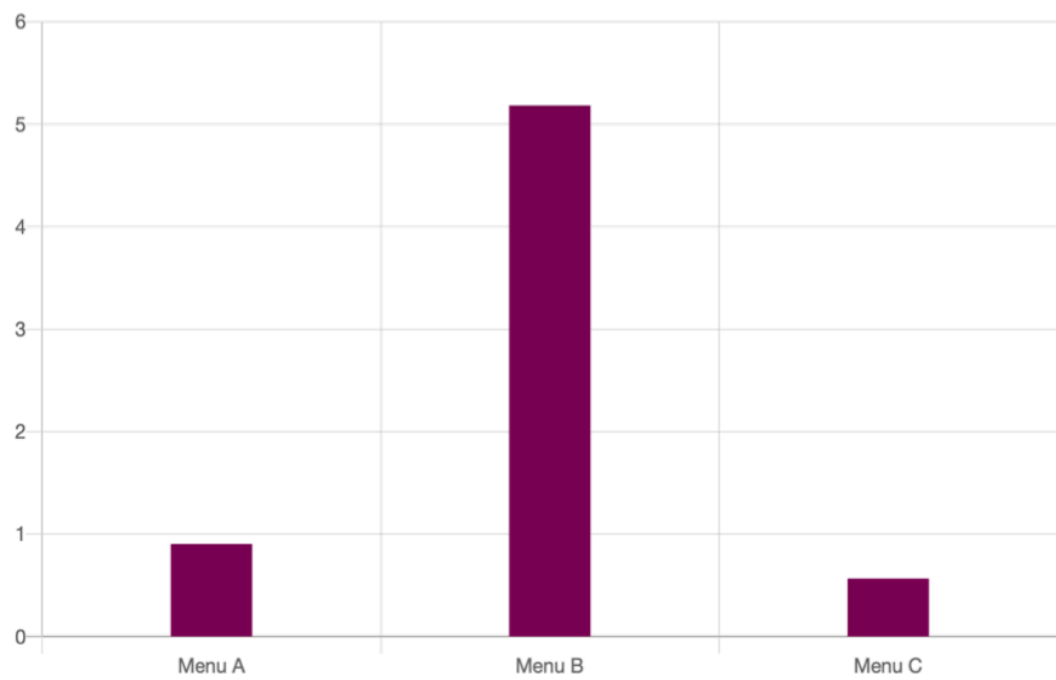


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

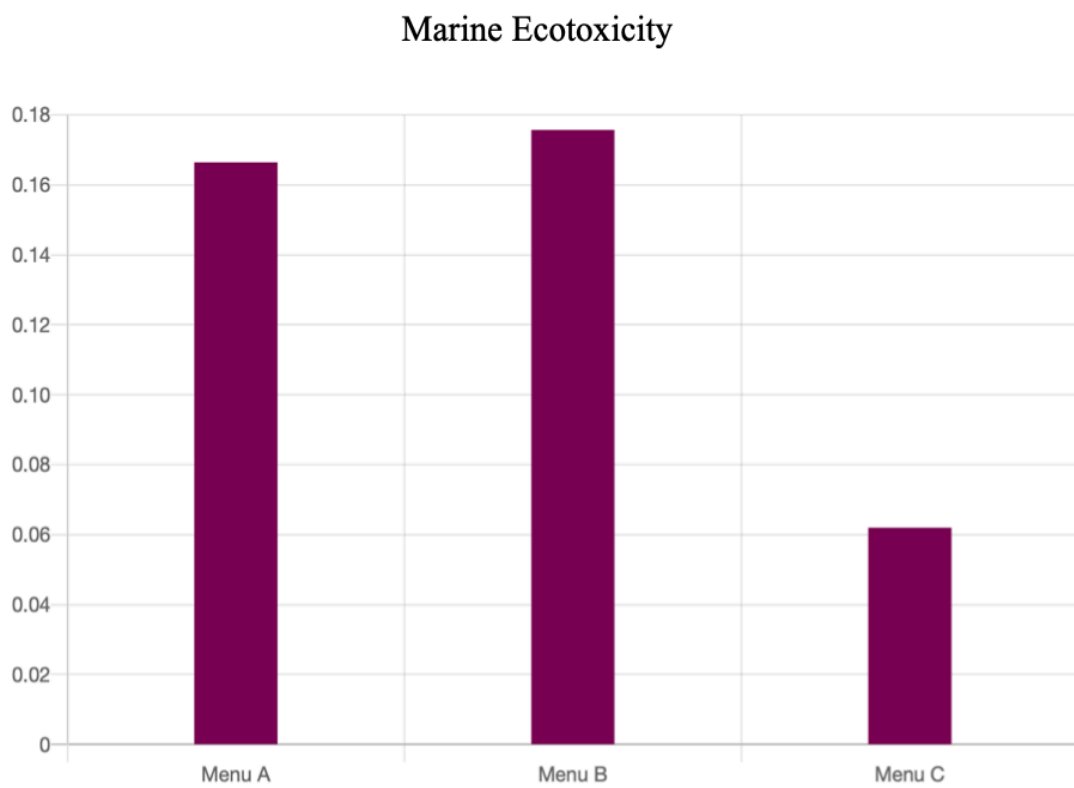
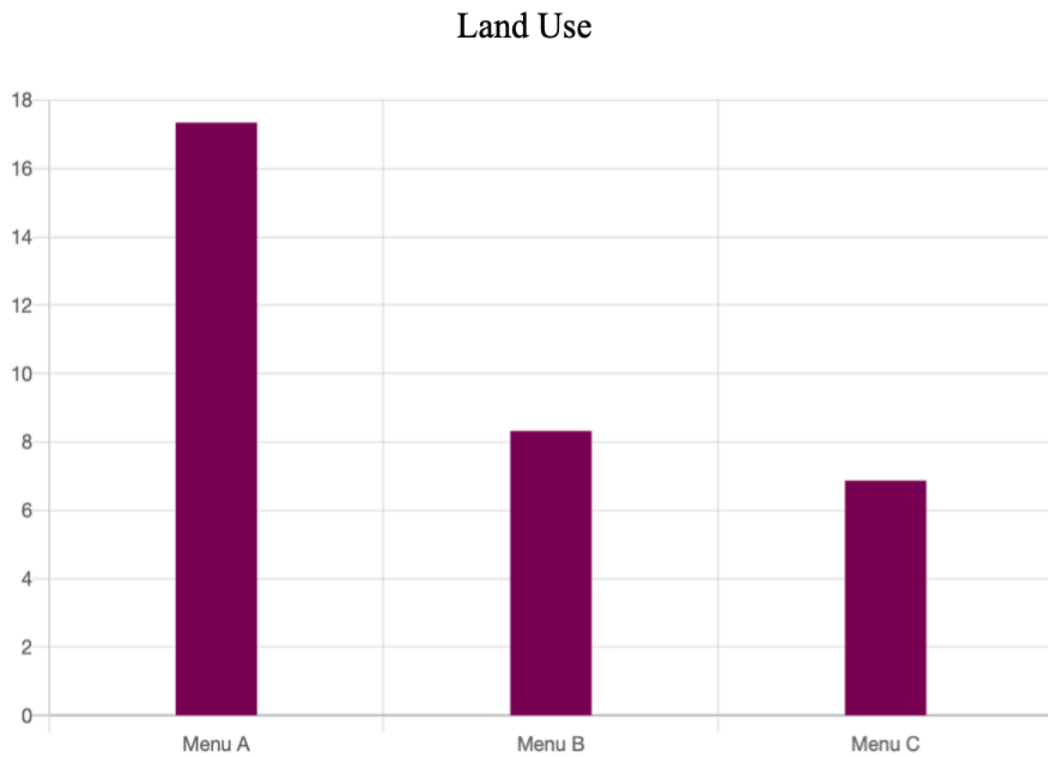


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

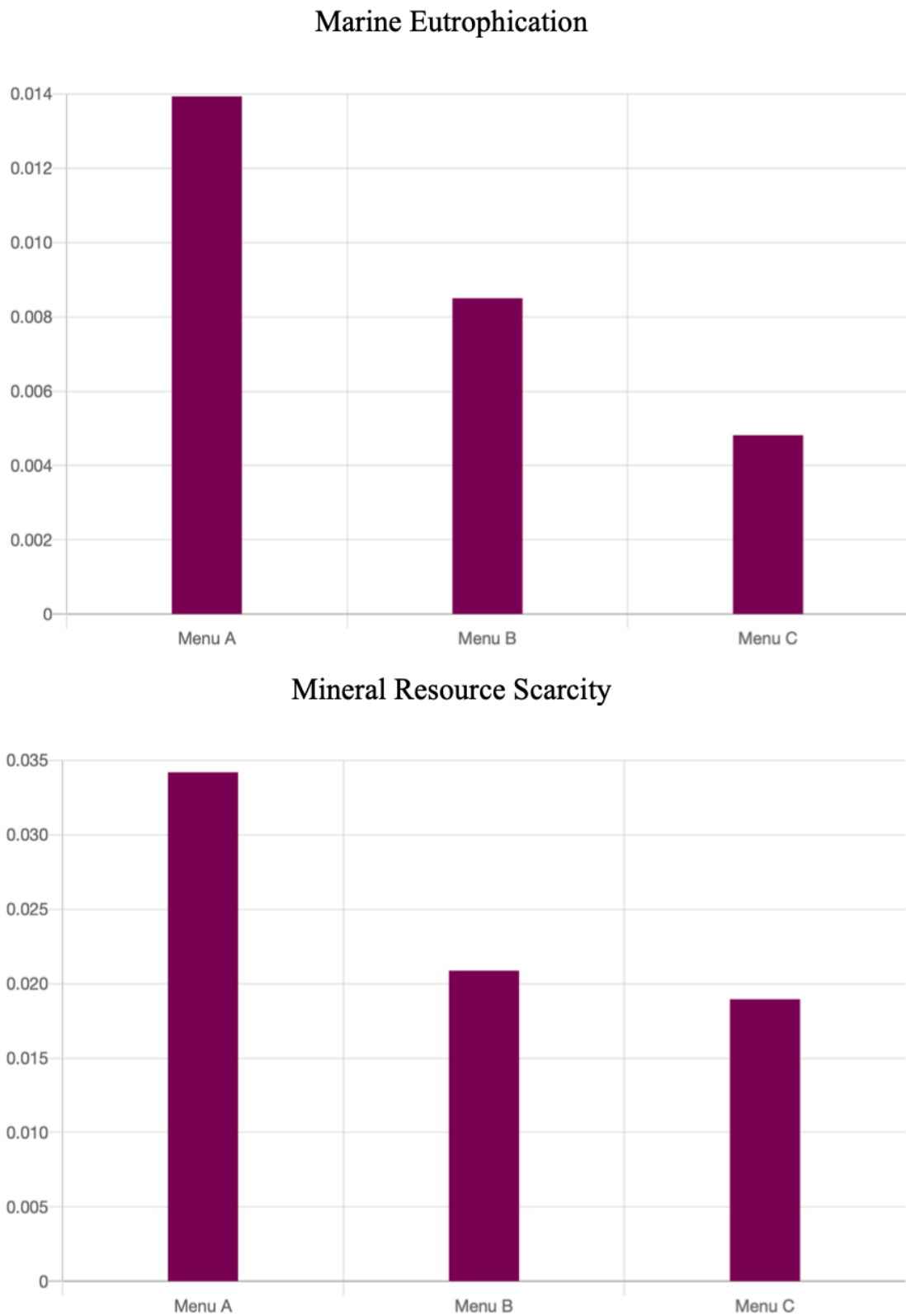
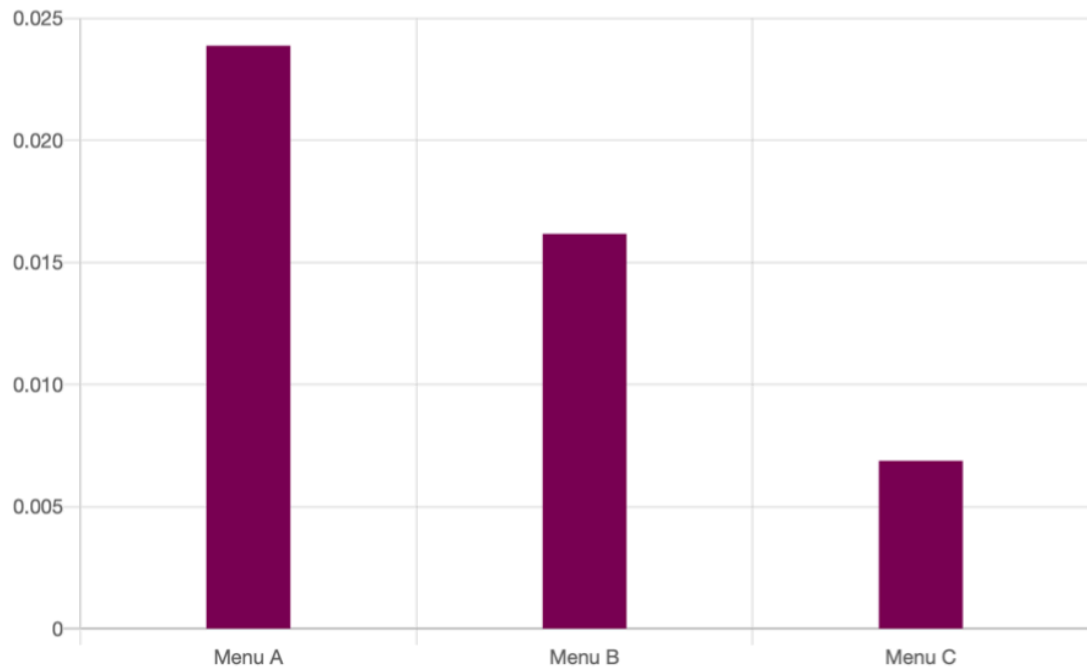


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Ozone Formation, Human Health



Ozone Formation, Terrestrial Ecosystem

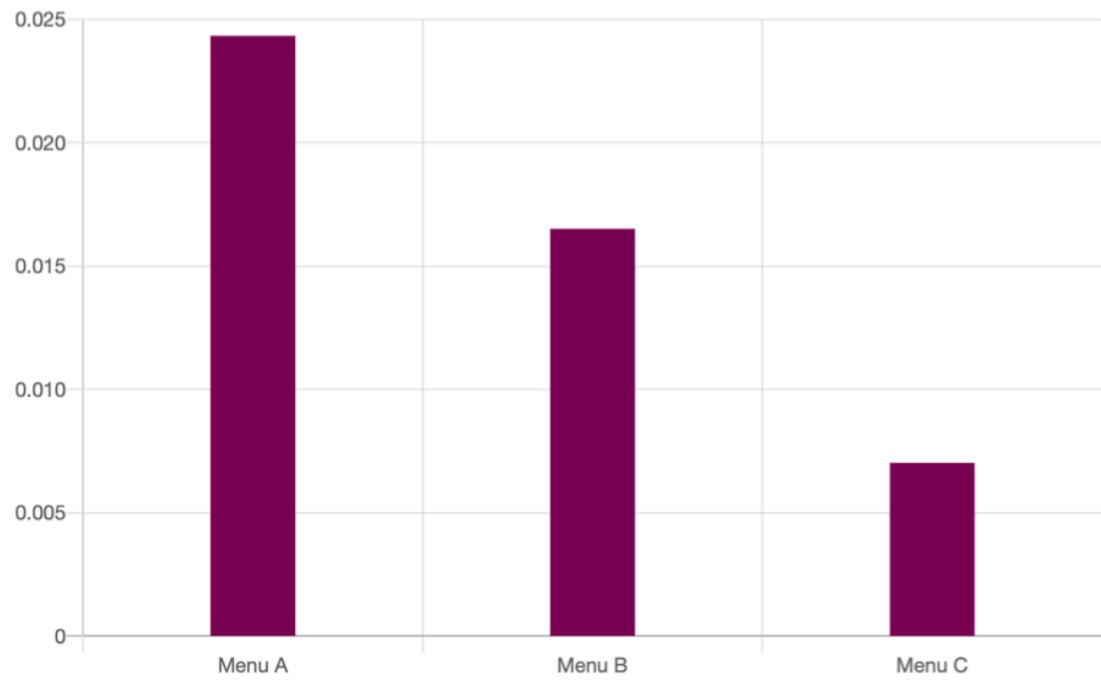


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

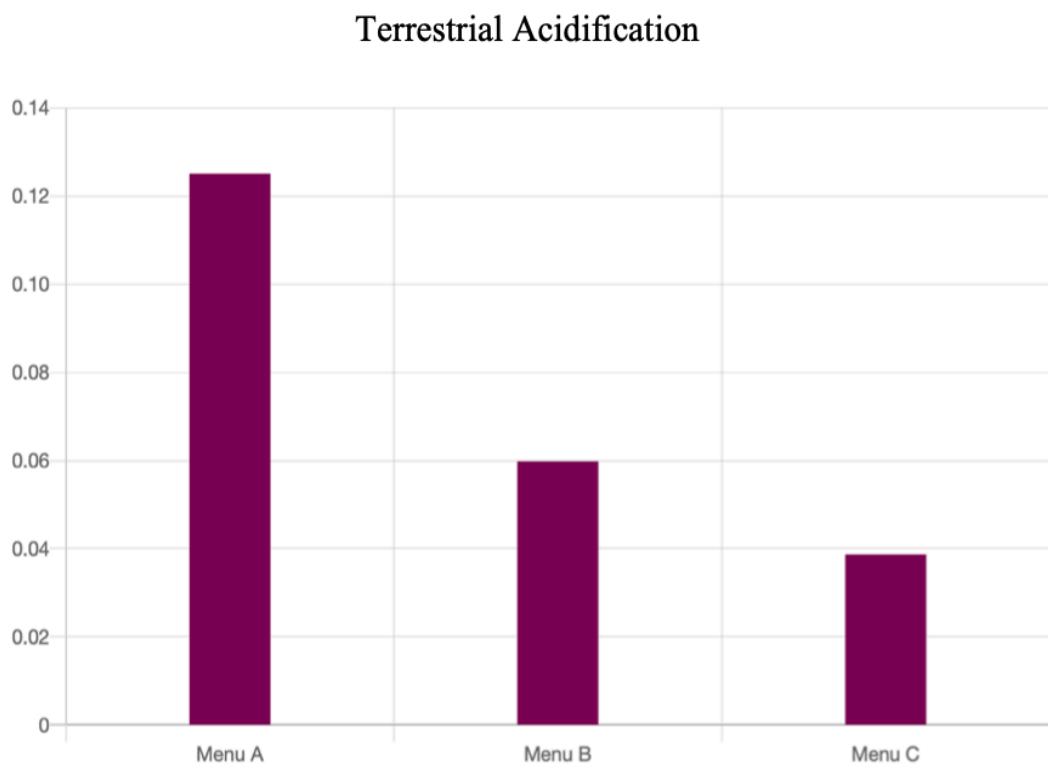
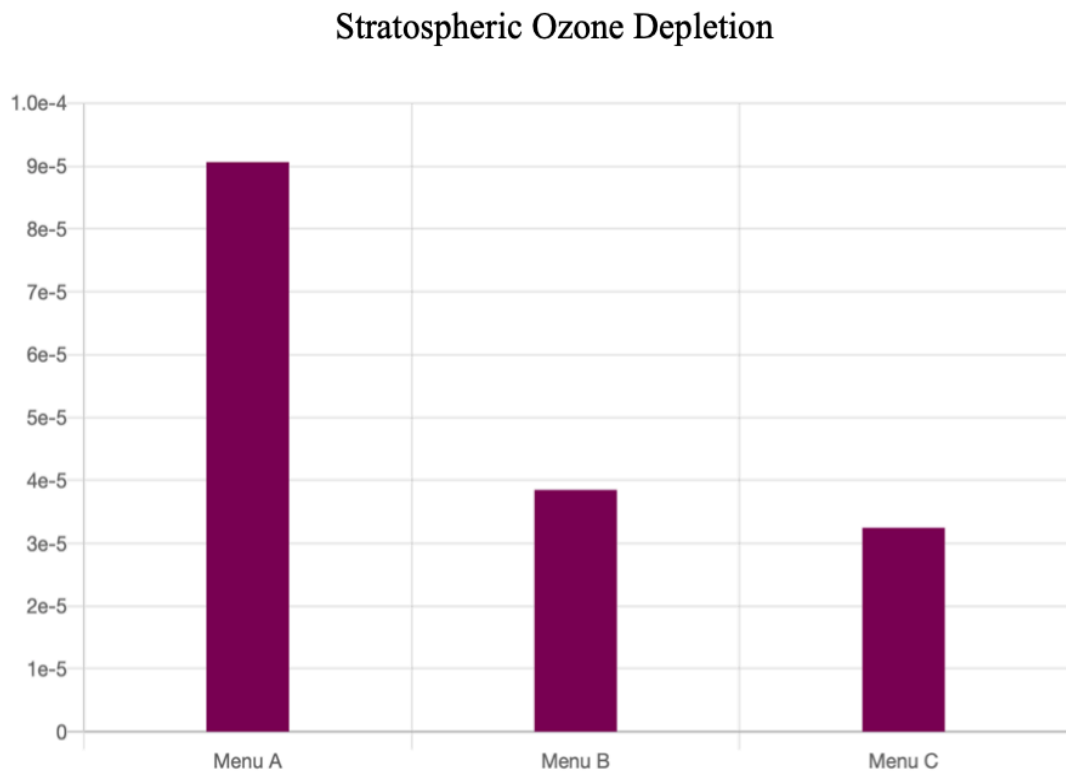


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

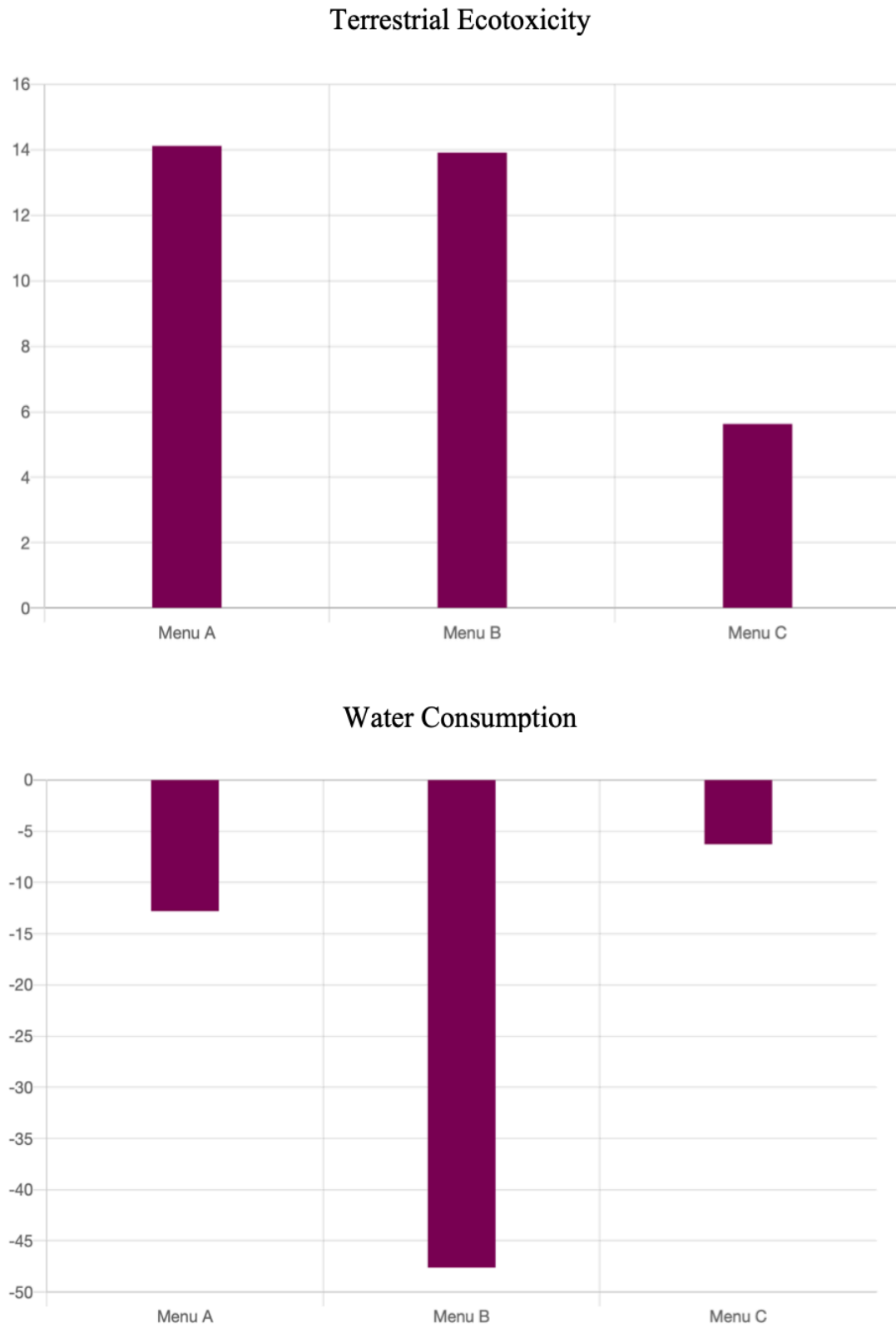
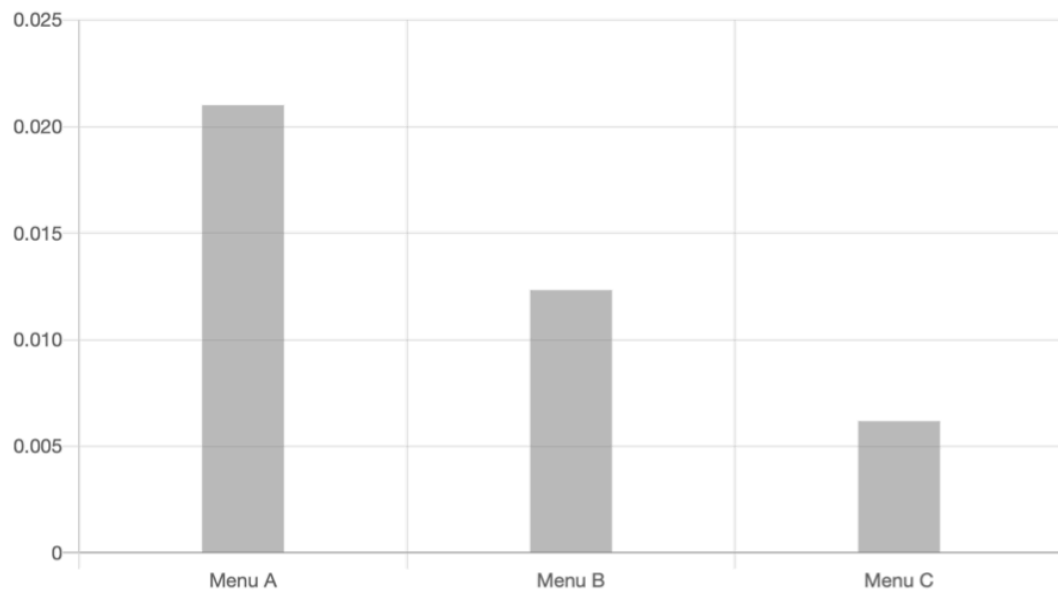


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Process Contributions

This chart shows the contributions of the selected processes in the project setup to the variant results of the selected LCIA category. As for the single indicator results, you can change the selection and the chart is dynamically updated.

Fine Particulate Matter Formation



Fossil Resource Scarcity

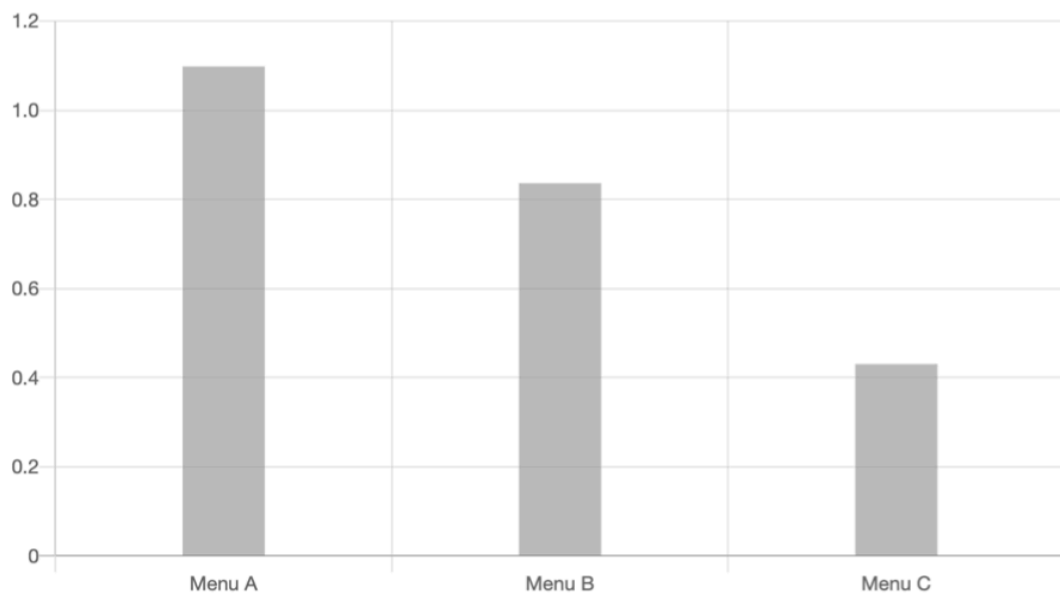


Figure A1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.)

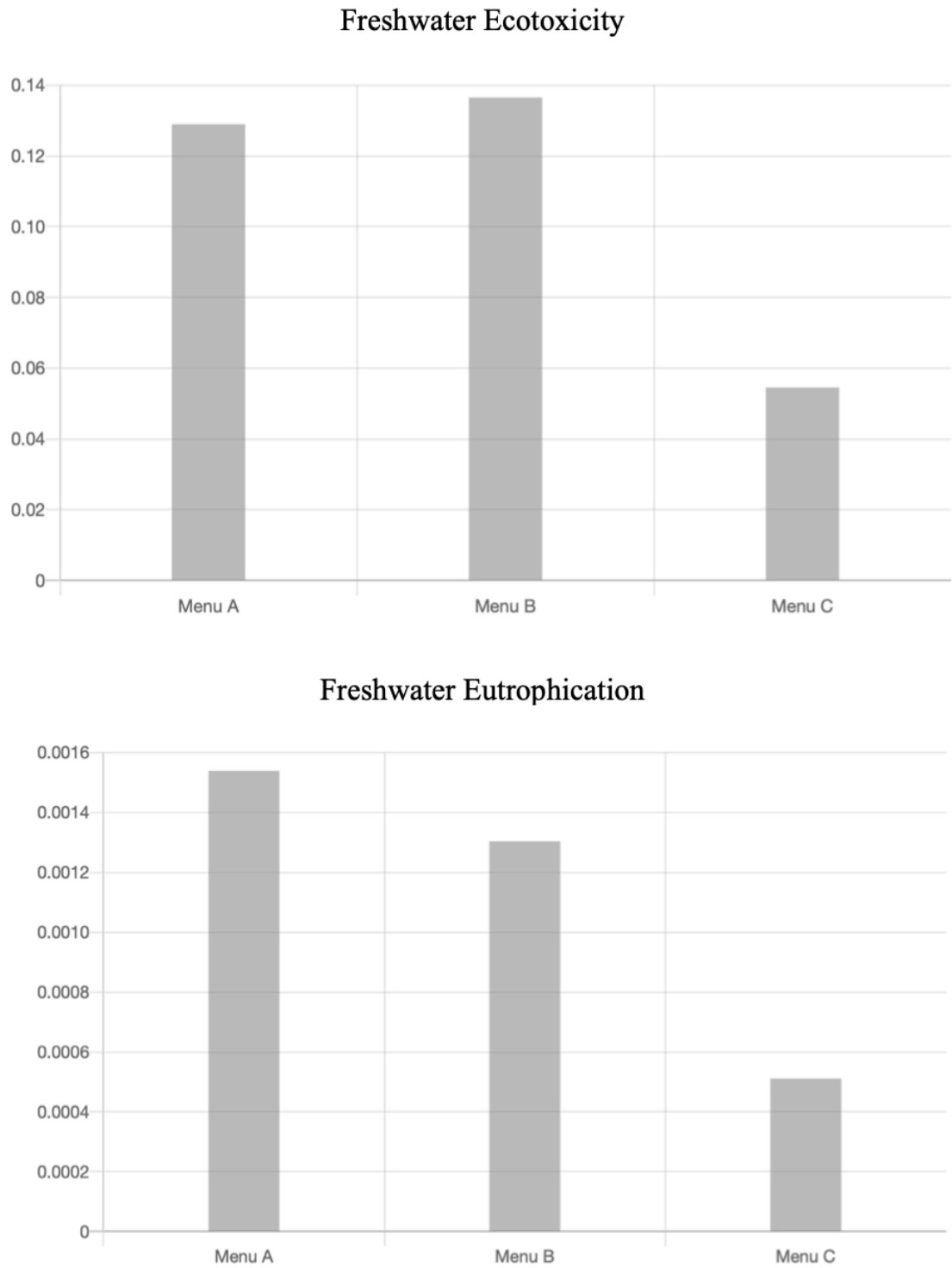
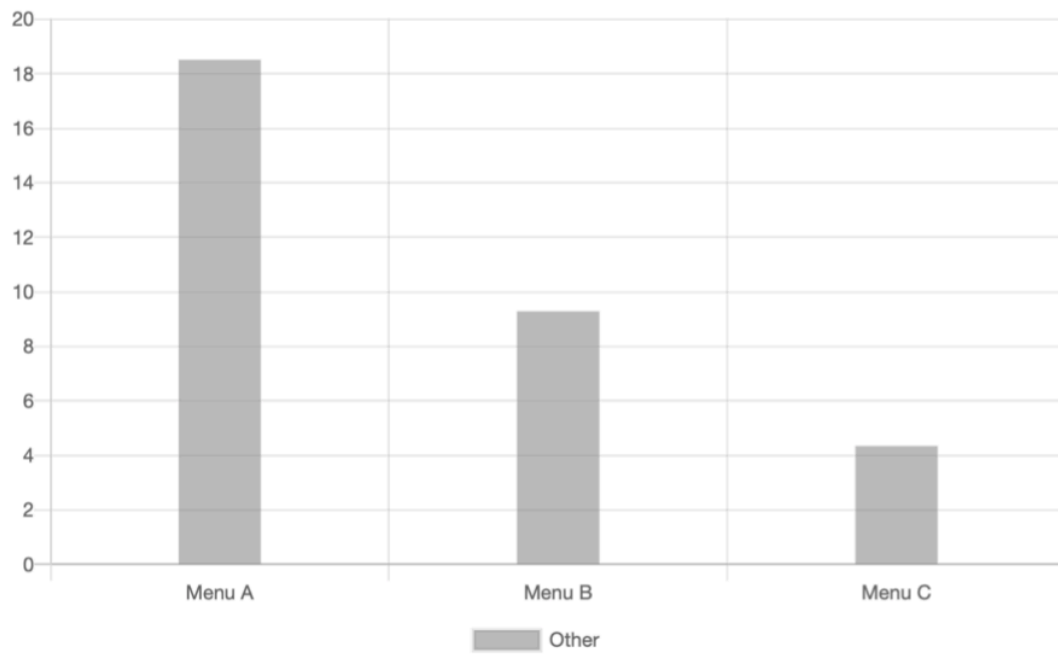


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Global Warming



Human Carcinogenic Toxicity

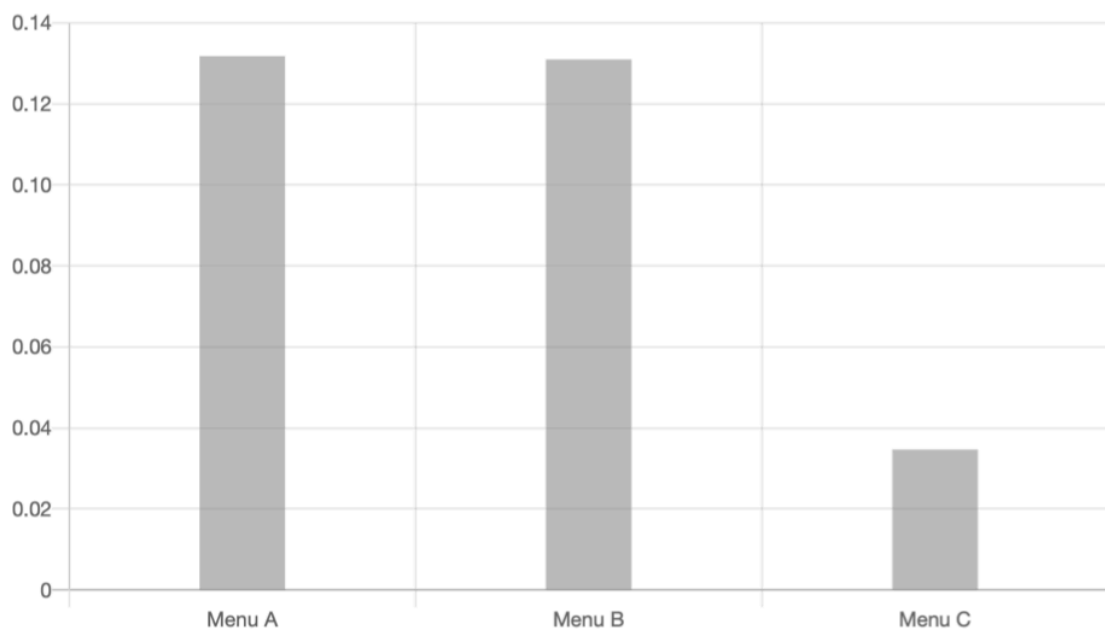


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

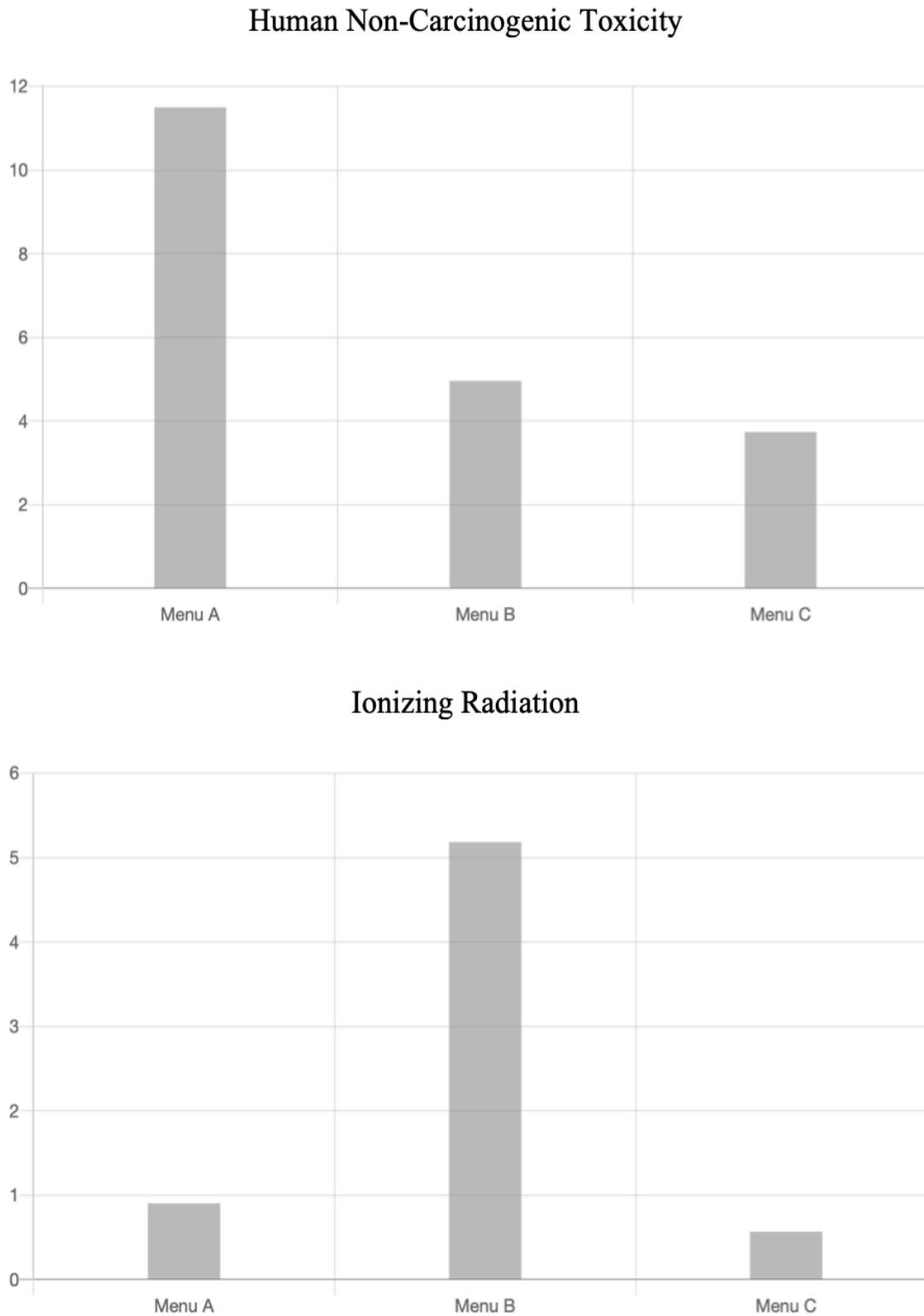
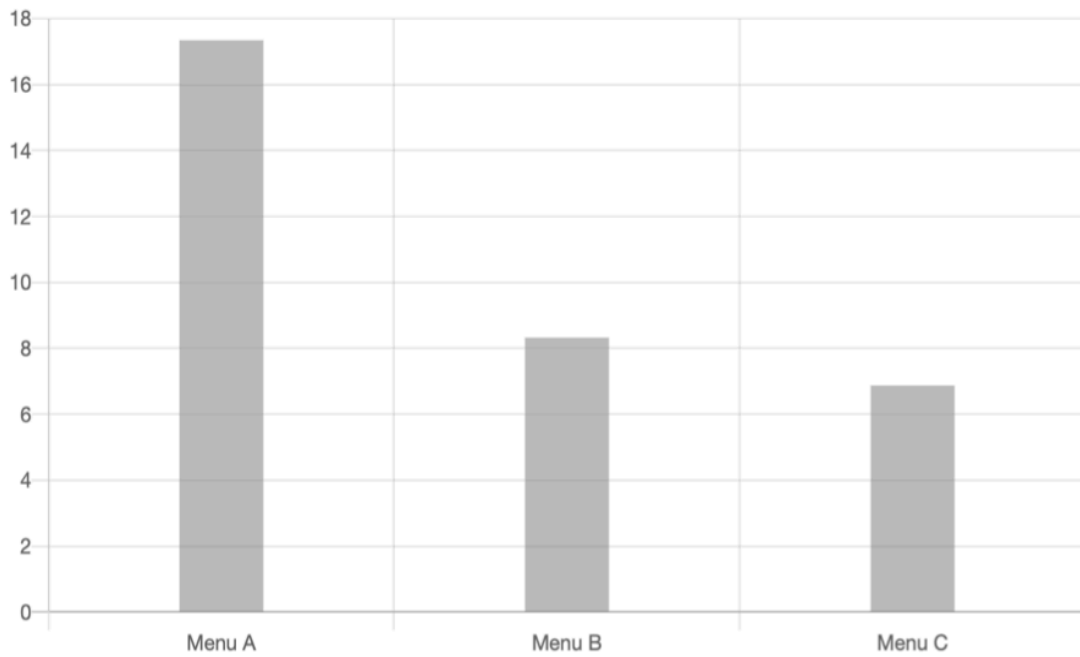


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Land Use



Marine Ecotoxicity

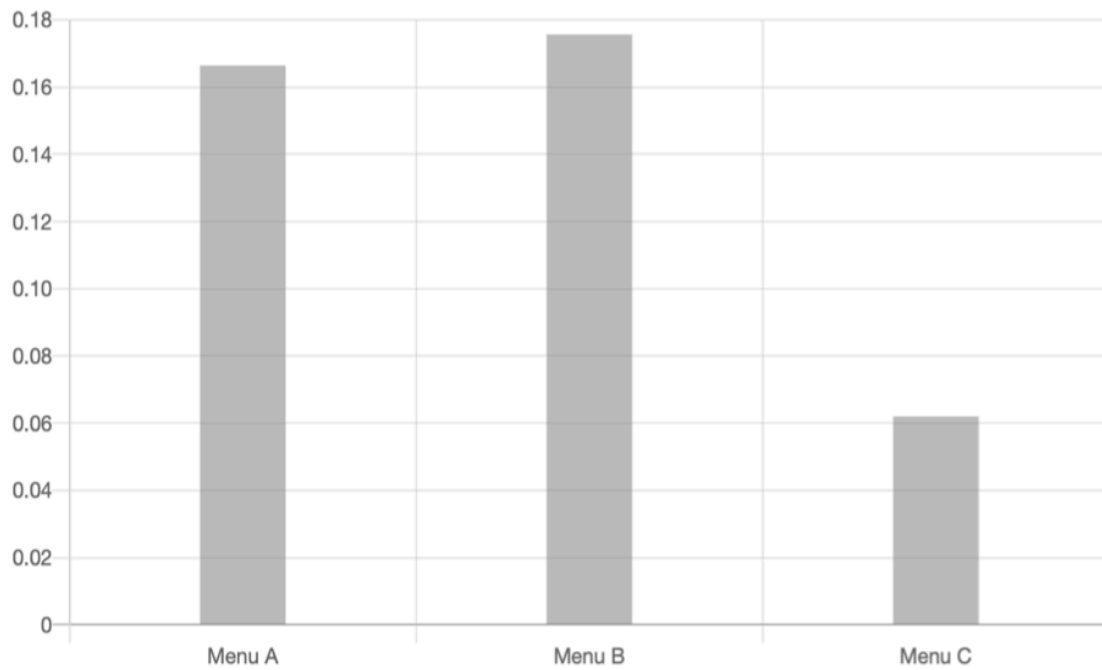
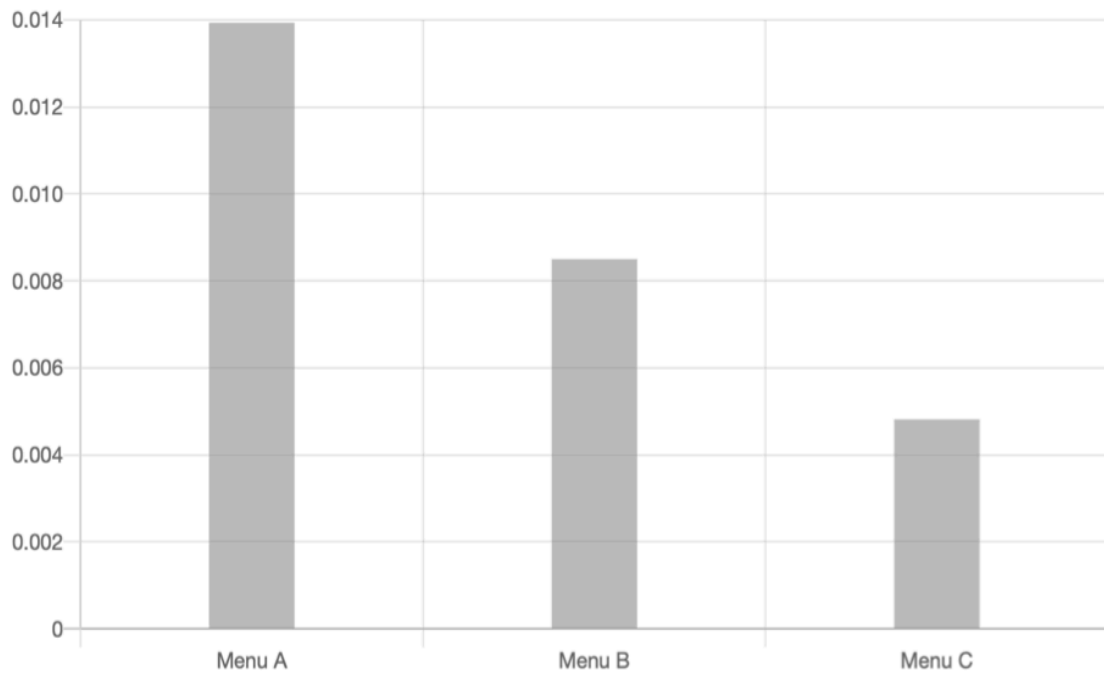


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Marine Eutrophication



Mineral Resource Scarcity

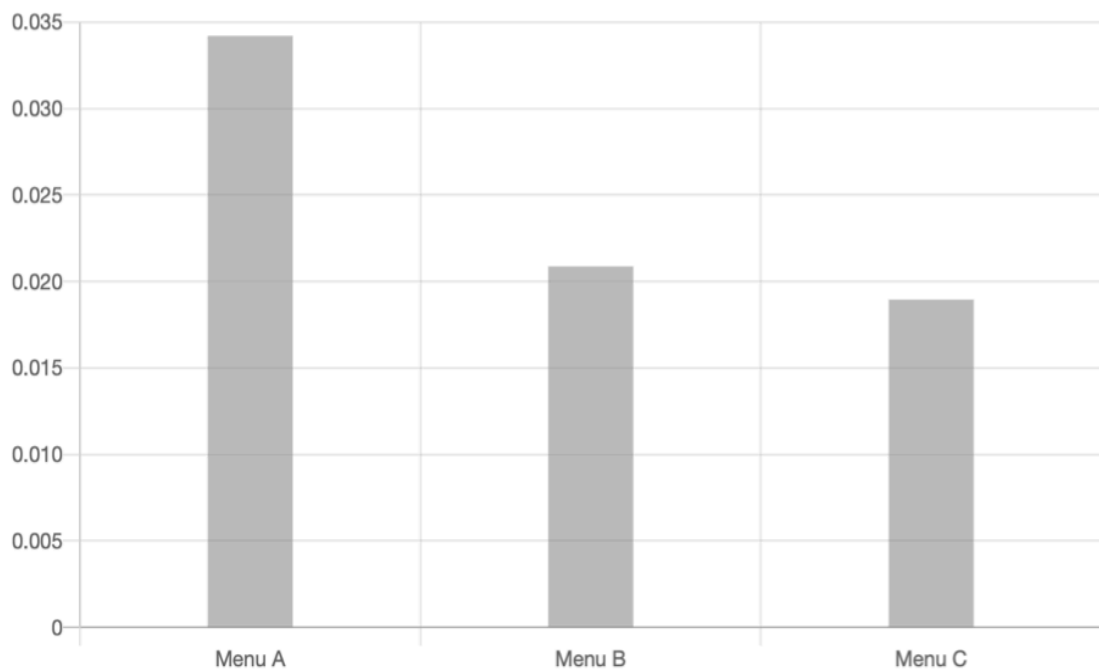
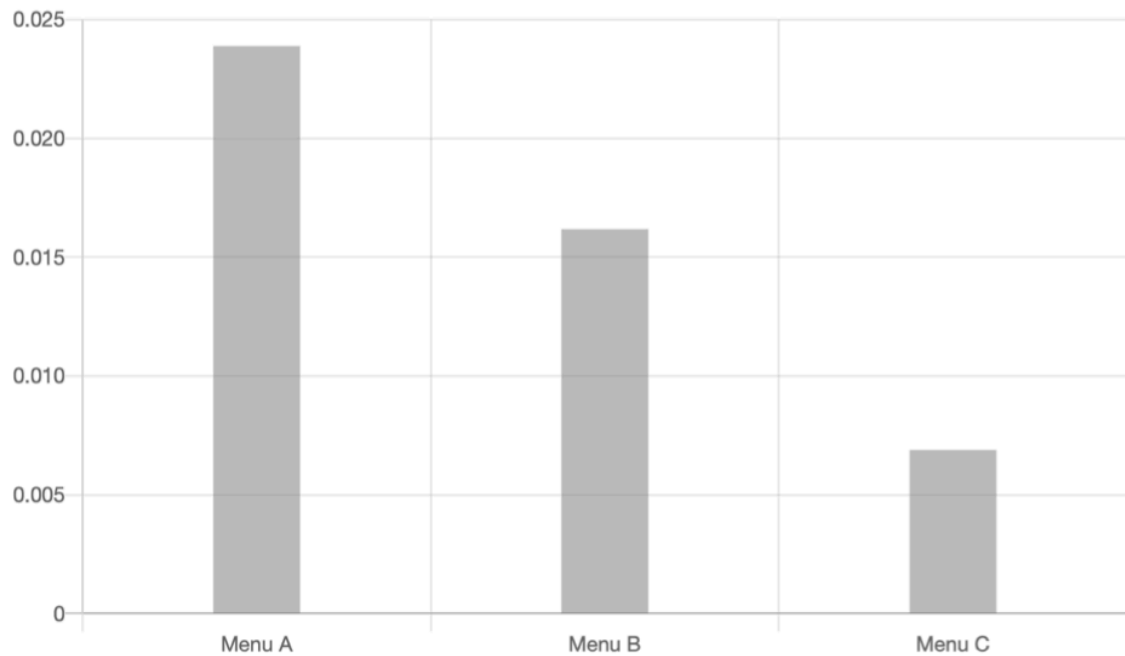


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Ozone Formation, Human Health



Ozone Formation, Terrestrial Ecosystem

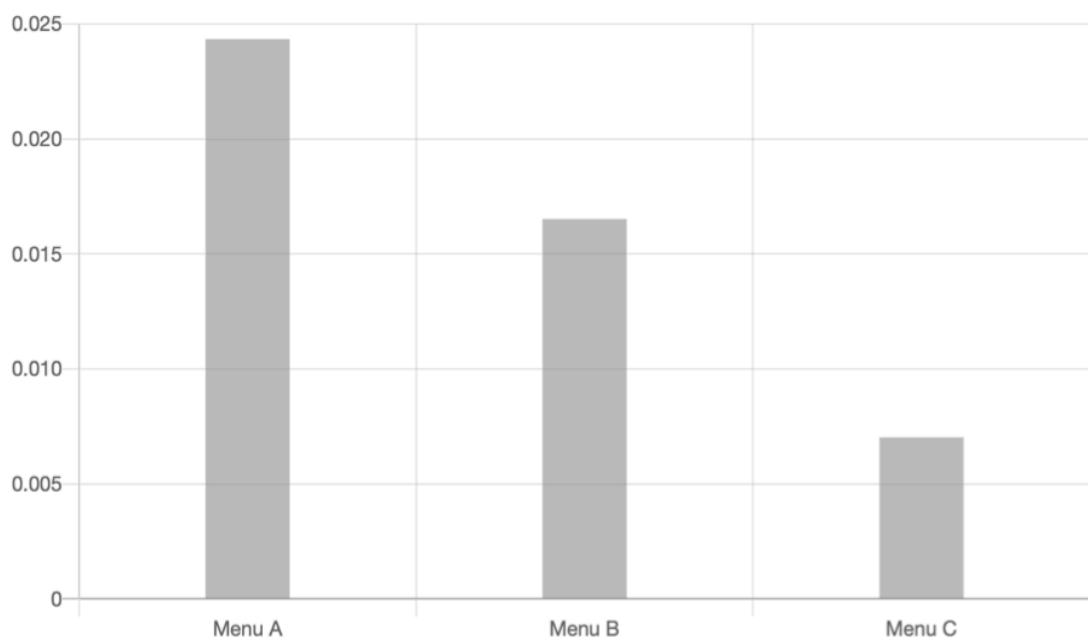
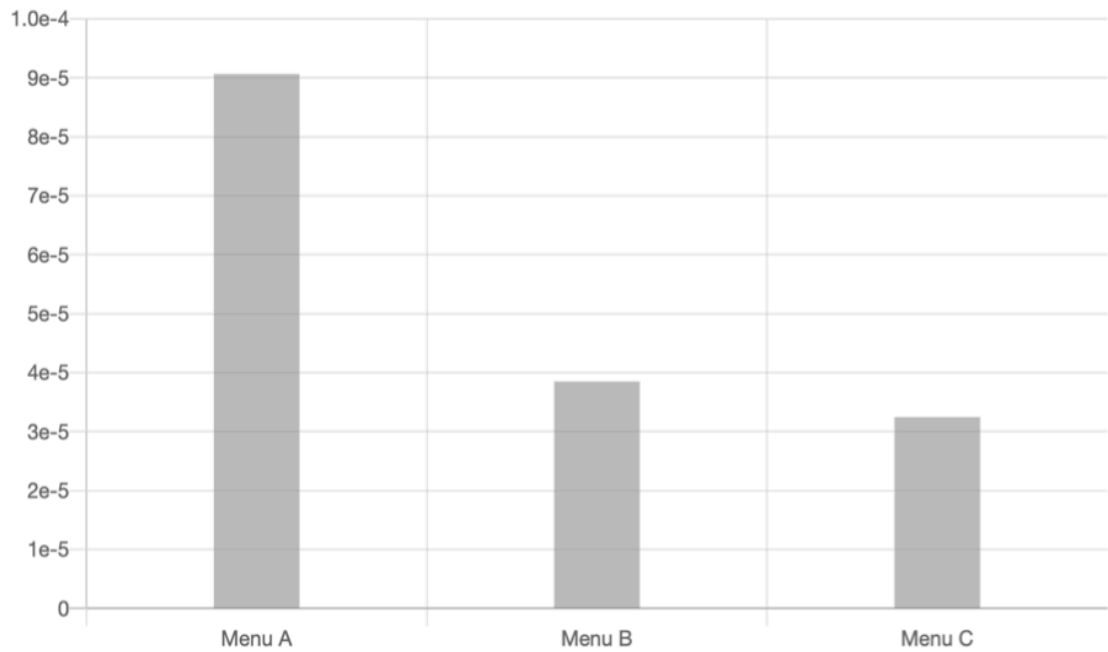


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Stratospheric Ozone Depletion



Terrestrial Acidification

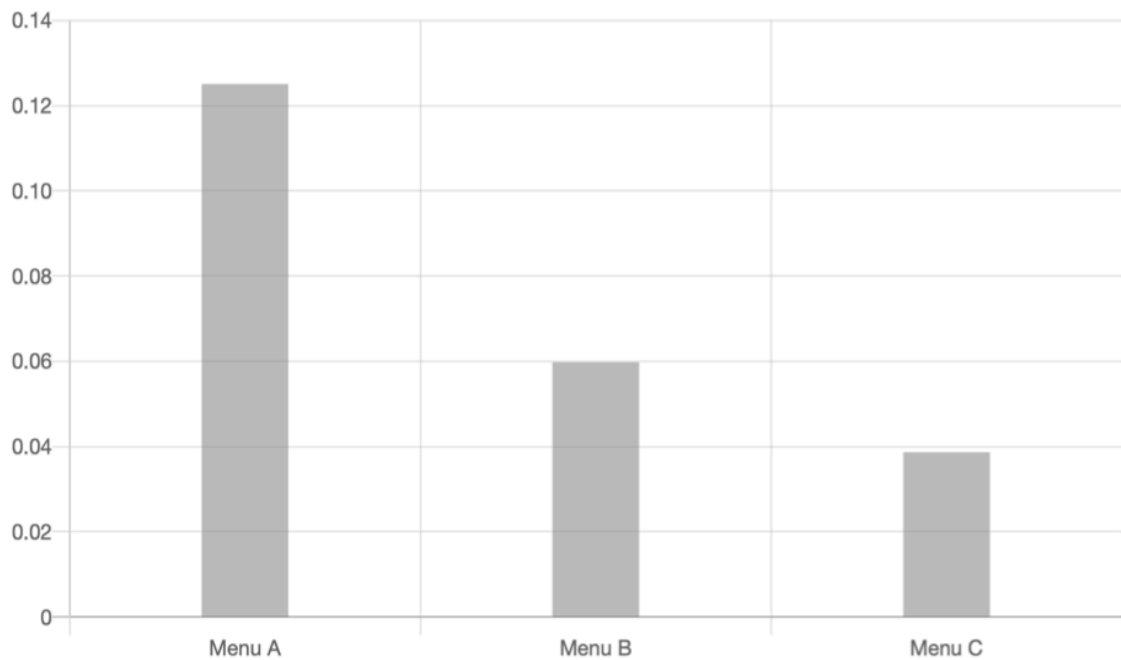
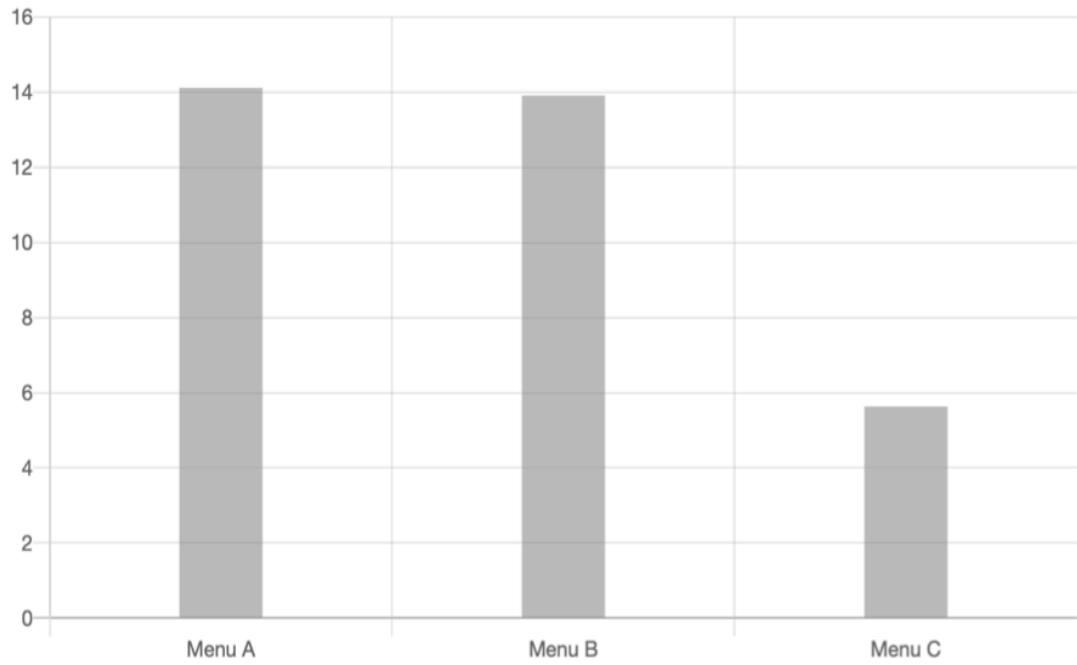


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).

Terrestrial Ecotoxicity



Water Consumption

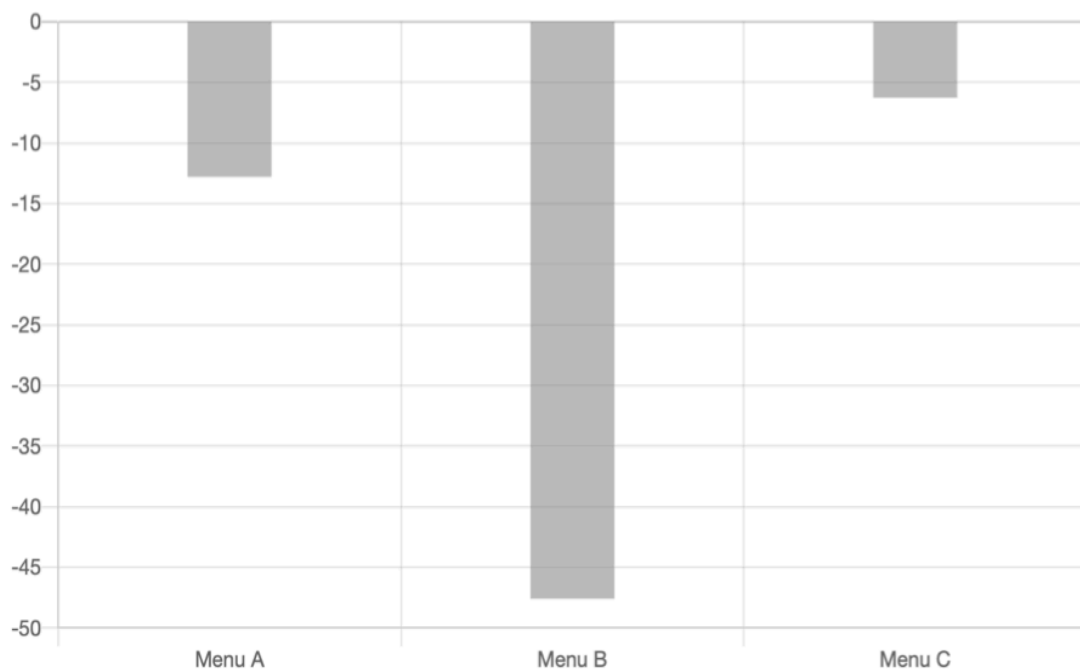


Figure A.1. OpenLCA output: result of the project: the report of life cycle assessment of Turkish, Far East and Mediterranean cuisines (cont.).