AMERICAN UNIVERSITY OF BEIRUT

# THE ECONOMIC COST AND ENVIRONMENTAL IMPACTS OF SHIFTING TO HEALTHIER DIETARY PATTERNS IN LEBANON

by
ZAHRAA MOHAMAD KHALIL

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AMERICAN UNIVERSITY OF BEIRUT

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Approved by:

| | |
|---|---|
| Dr. Nahla Hwalla, Professor<br>Department of Nutrition and Food Sciences | Advisor |
| Dr. Farah Naja, Associate professor<br>Department of Nutrition and Food Sciences | Member of Committee |
| Dr. Lamis Jomaa, Assistant professor<br>Department of Nutrition and Food Sciences | Member of Committee |
| Rachel Bahn, Instructor and Coordinator,<br>Department of Agriculture and Food Security Program | Member of Committee |

Date of thesis defense: September 2, 2020

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For my father, who taught me that I am capable of anything if I put my mind into it,
To my mother, who supported all my decisions and dreams even when she didn't agree with them,
To my brother, who guided me through his actions towards a better self,
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To my husband, to my source of energy and will power, the reason I get out of bed everyday,
To muffin, the naughty little cat, who taught me to be curious about the world to enjoy it,
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# ABSTRACT

# OF THE THESIS OF

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**Background**: Following the release of the Sustainable Development Goals (SDGs), sustainable diets – dietary patterns and guidelines with various impacts on non-communicable diseases – were explored to minimize the effects of food consumption on health and the environment, in addition to their economic implications. The objective of this study was to evaluate the cost and the environmental footprints (EFPs) of national food consumption patterns in Lebanese adults and evaluate the impact of shifting consumption in line with the Mediterranean diet (MD) and the EAT-Lancet dietary recommendations.
**Methods**: For this study, food consumption data for adults (≥20 years) were drawn from a previous national food consumption survey conducted in Lebanon (2008–2009), where dietary intake was assessed using a 61-item Food Frequency Questionnaire. Data on environmental footprints was retrieved from secondary sources. Primary data on a range of food prices was collected from food retail outlets in Beirut, Lebanon. This data was used to estimate the economic cost and EFPs of the traditional food consumption in Lebanon and assess the impact of shifting the pattern in line with the EAT-Lancet and Mediterranean recommendations. The three dietary patterns (Lebanese national consumption, EAT-Lancet and Mediterranean diets (MD)) were also compared for their EFPs including water use, energy use and greenhouse gas (GHG) emissions.
**Results**: The cost of the Lebanese national diet summed to 12,739.8 LL per person per day. Moreover, the total EFPs of Lebanese national consumption were the following for water use, energy use and GHG emissions respectively: 2,233.52 L, 32.23 MJ and 3.47 kgCO2eq. The cost of the EAT-Lancet diet was 12.9% less than the parallel cost of the Lebanese national consumption. Moreover, all three EFPs of the EAT-Lancet diet were less than that of Lebanese national consumption with the following differences in water use, energy use and GHGE respectively: 457.52 L, 2.68 MJ and 1.25 kgCo2eq. On the other hand, the cost of the MD was 47.9% higher than that of the parallel cost of the Lebanese national consumption. In addition, all three EFPs of the MD were higher than that of Lebanese consumption with the following differences in water use, energy use and GHGEs

respectively: 552.90 L, 33.68 MJ and 2.61 kgCo2eq. Therefore, shifting from national Lebanese consumption to the EAT-Lancet diet would lead to lesser cost and lower EFPs, whereas shifting from national Lebanese consumption to the MD model used would lead to higher cost and EFPs.
**Conclusions**: Evidence based adjustments of the food consumption pattern in Lebanon are needed to ensure health, environmental sustainability, as well as minimize cost. World Health Organization, MD and EAT-Lancet recommendations, along with expert opinions, can guide the process for achieving sustainable consumption with the needed tradeoffs in line with the SDGs.
**Keywords**: Non-communicable diseases, sustainable diets, cost analysis, environmental footprints, EAT-Lancet diet, Mediterranean diet, Lebanon

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# ABBREVIATIONS

| | |
|---|---|
| NCDs | Non-communicable diseases |
| MENA | Middle East and North Africa Region |
| WHO | World Health Organization |
| CVD | Cardiovascular diseases |
| EMR | Eastern Mediterranean countries |
| DALYS | Disability adjusted life years |
| GBD | global burden of disease |
| CO2 | carbon dioxide |
| GHGE | greenhouse gas emissions |
| SDGs | sustainable development goals |
| LDL | low density lipoprotein |
| HDL | high density lipoprotein |
| MD | Mediterranean diet |
| H&S | healthy and environmentally sustainable |
| MCD | minimum cost diet |
| ESD | environmentally sustainable diet |
| SD | sustainable diet |
| GDP | gross domestic product |
| EFPs | environmental footprints |
| NNCD-RF | Nutrition and Non-communicable Diseases Risk Factor |
| UNDP | United Nations Development Program |

| | |
|---|---|
| FFQ | food frequency questionnaire |
| Q | Quintile |
| SPSS | Statistical Package for the Social Sciences software |
| IRB | The Institutional Review Board |
| LCA | life cycle approach |
| Ppm | parts per million |
| FAO | Food and Agriculture Organization |
| WSI | water stress index |
| $GWP_{N2O}$ | 100-year global warming potential of $N_2O$ |
| $GWP_{CH4}$ | 100-year global warming potential of $CH_4$ |
| SE | standard error |

# CHAPTER I

# INTRODUCTION AND LITERATURE REVIEW

The Rome Declaration on World Food Security in 1996 defined its three basic dimensions as: availability, accessibility and utilization, with a focus on nutritional well-being. It also stressed the importance of sustainable management of natural resources and the elimination of unsustainable patterns of food consumption and production. In 2009, at the World Summit on Food Security, the concept of stability/vulnerability was added as the short-term time indicator of the ability of food systems to withstand shocks, whether natural or man-made, as part of the Five Rome Principles for Sustainable Global Food Security. More recently, intergovernmental processes have emphasized the importance of sustainability to preserve the environment, natural resources and agro-ecosystems (and thus the overlying social system), as well as the importance of food security as part of sustainability and vice versa. Sustainability should be considered as part of the long-term time dimension in the assessment of food security. From such a perspective, the concept of sustainable diets plays a key role as a goal and a way of maintaining nutritional well-being and health, while ensuring the sustainability for future food security. (Berry et al, 2015).

Sustainable diets, with all their different elements, fit logically into this new general framework, along with other sustainability elements in the food system. Sustainable diets are those diets with low environmental impact that contribute to food and nutrition security and to a healthy life for present and future generations. These diets are protective and

respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable, nutritionally adequate, safe and healthy, while optimizing natural and human resources (FAO, 2010).

In this work, we will evaluate the effects of current food consumption patterns, in Lebanon, on health and wellbeing, the environment and on cost. We will also look at examples of sustainable diets in order to see whether the shift to these dietary patterns would be healthy, environmentally sustainable and cost effective compared to current food consumption in Lebanon.

**A. Non-Communicable Diseases (NCDs): Worldwide, Eastern Mediterranean Region, Middle East and North Africa Region (MENA) and Arab World:**

According to the World Health Organization (WHO) report in 2016, NCDs constituted 71% of total deaths worldwide compared to around 66% of total deaths in 2008. Over three quarters of total NCD deaths (31.5 million) occurred in low- and middle-income countries. By 2030, the annual number of deaths due to NCD deaths is projected to increase from 38 to 52 million. The age-standardized NCD death rate in 2012 was 539 per 100,000 population globally, ranging from 397 per 100,000 in high-income countries to 673 per 100,000 in low income countries. Cardiovascular diseases (CVD), diabetes and hypertension are the leading causes of NCD deaths worldwide with higher prevalence in low- and middle-income countries. The prevalence of obesity, as a disease and underlying risk factor for NCDs, nearly doubled globally between 1980 and 2014. (WHO, 2016)

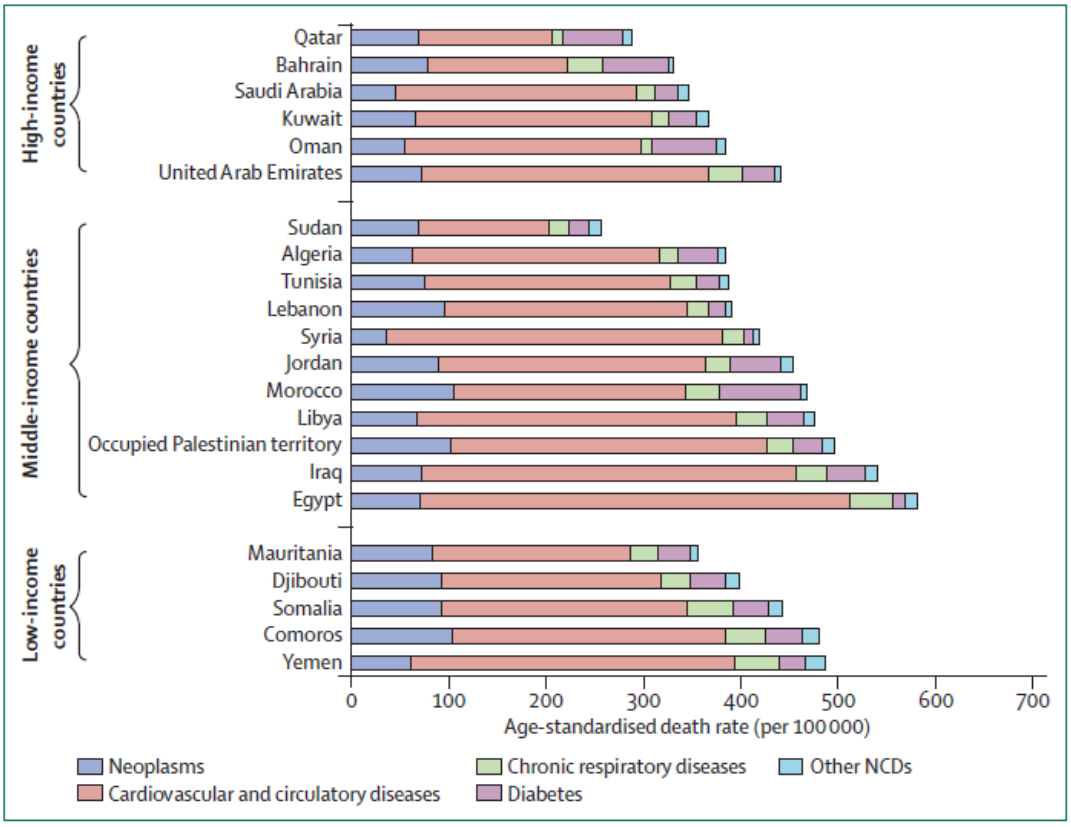
Similarly, NCDs are escalating in Eastern Mediterranean Countries (EMR) with a rate of death of 654 per 100,000 persons, which is higher than the average global rate (Turk-adawi et al, 2018). Approximately 58.4% of total deaths in the EMR were attributable to NCDs in 2015, with the primary cause being CVD (27.4% of total deaths). The highest prevalence of diabetes worldwide was reported from the WHO- EMR averaging 14% for both sexes (WHO, 2014). Kuwait, Qatar and Saudi Arabia were among the top 10 countries in the world with the highest prevalence of diabetes (Turk-adawi et al, 2018). This incidence is expected to double in countries within the EMR in the next 25 years, given that an estimated four out of ten adults with diabetes are thought to be currently undiagnosed (Turk-adawi et al, 2018).

The prevalence of obesity as an underlying factor for NCDs in the EMR is the third highest across all global regions, at an average of 23.6% for women and 14.6% for men (WHO, 2014). According to WHO, >50.0% of women in the EMR are overweight and roughly half of overweight women are obese (24%) (WHO, 2014). Within the EMR, the Gulf countries have the highest obesity rates (Eghbali et al, 2018). Among all the WHO-designated geographical regions, the prevalence of hypertension is second highest in the EMR (26%) after Africa (Eghbali et al, 2018). Within the EMR, the prevalence of hypertension is highest in Somalia (26.4%) and Morocco (25.3%), whereas the UAE has the lowest prevalence (14.7%) (Eghbali et al, 2018). In 2015, cancer was responsible for 9.4% of all deaths and 5.1% of all disability adjusted life years (DALYs) in EMR (Kulhanova et al, 2017). Incidence rates were highest in Lebanon (204 and 193 per 100,000 in males and females, respectively) (Kulhanova et al, 2017). The association between certain patterns of food consumption and different types of cancers, either as risk factors or

protective means, has been established in many studies including ones done by Schnabel et al in 2019 and Baudry et al in 2018.

Based on the global burden of disease (GBD) study, more than 1.2 million people died from non-communicable diseases in 2008 in the Arab world accounting for nearly 60% of all deaths in the region, with wide variations between countries (ranging from 27% in Somalia to about 84% in Oman and Lebanon). More than 34% of deaths from NCDs were in individuals younger than 60 years. Data for age-standardized death rates (per 100,000) for non-communicable diseases in Arab countries are presented in Figure 1 (Rahim et al, 2014). The figure shows that there exists a higher burden of non-communicable diseases in middle-income countries undergoing economic development in the region, than in high-income countries. By 2014, the region has been witnessing the second largest increase in NCD deaths (15 per cent) after Africa. (Rahim et al, 2014)

Figure 1. Age-standardized death rates from non-communicable diseases (per 100,000 population) in Arab countries in 2010 (Rahim et al, 2014).




**B. Global and MENA environmental degradation:**

Concomitant with the NCDs burden, poor agriculture and food consumption practices have resulted in environmental degradation, globally and in MENA. Deterioration of the environment occurred through depletion of resources such as air, water and soil, the destruction of ecosystems, habitat destruction, and the extinction of wildlife and pollution. Scientists assert that human activity has pushed the earth into a sixth mass extinction event. The loss of biodiversity has been attributed in particular to human overpopulation,

continued human population growth and overconsumption of natural resources. (Ceballos et al, 2017)

Burning of fossil fuels, deforestation for agriculture and industrial activities have pushed up atmospheric carbon dioxide (CO2) concentrations from 280 parts per million (ppm) 200 years ago, to about 400 ppm in 2016. That is an unprecedented rise, in both size and speed. The result is climate disruption. Carbon overloading is only one form of air pollution caused by burning coal, oil, gas and wood. (Pike, 2016) The World Health Organization recently estimated that one in nine deaths in 2012 were attributable to diseases caused by carcinogens and other poisons in polluted air (WHO, 2014).

The human population continues to grow rapidly worldwide, and this growth combined with rising affluence is putting even greater pressure on essential natural resources, like water. Humanity entered the 20th century with 1.6 billion people; in 2017, the number became about 7.6 billion. Estimates put us at nearly 9.8 billion by 2050. Most of the population growth is happening on the African continent, and in southern and eastern Asia. (UN, 2017)

Agriculture also contributes to the problem as a major user and polluter of water resources in many regions. As such, agriculture has a central role to play in addressing these challenges. Irrigated agriculture remains the largest user of water globally, a trend encouraged by the fact that farmers in most countries do not pay for the full cost of the water they use. Agriculture irrigation accounts for 70% of water use worldwide. Intensive groundwater pumping for irrigation depletes aquifers and can lead to negative environmental externalities, causing significant economic impact on the sector and beyond. In addition, agriculture remains a major source of water pollution; agricultural fertilizer

run-off, pesticide use and livestock effluents all contribute to the pollution of waterways and groundwater. (OECD, 2019)

Moreover, climate change affects the Earth's water supply in a large number of ways. It is predicted that the mean global temperature will rise in the coming years due to a number of forces affecting the climate. The amount of CO2 will rise, and both of these will influence water resources. (Tilman et al, 2011)

Roughly, one third of the food produced in the world for human consumption (approximately 1.3 billion tons) are lost or wasted every year. Food losses amount to roughly 680 billion dollars in industrialized countries and 310 billion dollars in developing ones. Fruits and vegetables, plus roots and tubers have the highest wastage rates of any food. Global quantitative food losses and waste per year are roughly 30% for cereals, 40-50% for root crops, fruits and vegetables, 20% for oil seeds, meat and dairy plus 35% for fish. Every year, consumers in rich countries waste almost as much food (222 million tons) as the entire net food production of sub-Saharan Africa (230 million tons). Consumers in sub-Saharan Africa, south and southeastern Asia, each throw away only 6-11 kg a year. In developing countries, 40% of losses occur at post-harvest and processing levels. (FAO, 2019)

To a higher extent, countries of the Middle East and North Africa are being threatened by environmental damage. Available evidence suggests that current food production and consumption patterns in MENA countries are imposing significant environmental costs, and are negatively influencing environmental sustainability. Agriculture consumes nearly 85% of all water withdrawals in MENA countries, a rate exceeding the global average of approximately 70%, and it occupies a third of all land area

in the MENA region, roughly on par with the global figure of approximately 38%. Agriculture and land use account for approximately 10% of total greenhouse gas emissions (GHGEs) in the MENA region. GHGEs from the agricultural sector increased by approximately 8% in the MENA region over the period 2000–2012, a rate higher than the global average of less than 2% over the same period. (Bahn et al, 2019)

In addition, given that the MENA region imports large amounts of food to satisfy demand, and is notably the world's largest net importer of cereals, sugar and poultry, the footprint associated with food imports to the region (the virtual water, GHGEs, and energy footprints) is expected to be significant. Moreover, the burden on limited and declining environmental resources is expected to increase as food production expands to feed a rising population in MENA, which will grow to approximately 604 million people by 2050. As demand rises, food imports are expected to increase, and therefore, the ecological footprint associated with MENA's food consumption is likely to fall outside its geographic borders, thereby raising its virtual water[1], GHGEs, and energy footprints. (Bahn et al, 2019)

### C. Role of diet in etiology of NCDs, and the effect of current consumption on environmental degradation:

The MENA region is struggling with increased malnutrition, an elevation in diet-related NCDs, and an acceleration in environmental degradation. Recent research has

[1] Virtual water is the volume of water used to produce consumer products. The total volume of water refers to all of the water used in the production of a product. For example, the total volume of water used in a food product would include the water used in the agricultural process, but also the water used in packaging and shipping. Virtual water is essentially all of the "hidden" water behind a product. (Hoekstra and Hung, 2003)

shown that the rise in NCDs is largely driven by modifiable risk factors, including diet, physical activity, overweight and obesity. Food consumption was shown to exert a great influence both on the risk of NCDs and environmental sustainability. These findings have been widely used to inform national and international dietary guidelines targeted at preventing NCDs. (Afshin et al, 2019)

Modern evidence suggests that a major driver of increased caloric intake across diverse populations has been a deterioration in the quality of diet consumed: Changes in the type and quality of foods together influence long-term energy balance. Some of the key factors that characterize diet quality include carbohydrate quality, intakes of whole foods such as nuts, beans, fruits, vegetables and specific fats and oils. (Mozaffarian, 2017)

According to a longitudinal investigation that included over 120,000 men and women from three different cohort studies that followed individuals for 20 years with repeated measures of diet and weight, the foods most associated with weight gain were potato chips, potatoes (including boiled, baked and mashed potatoes), meats, refined grains, sweets and desserts. An important finding was that the weight gain associated with sweets and desserts was about the same as weight gain associated with refined grains. In other words, similar weight gain was seen whether one ate a serving of candy or of white bread. One can therefore see that most of the foods that were associated with weight gain were rich in refined carbohydrates. This is consistent with metabolic evidence showing that the rapidity of digestion and metabolic responses of white bread are similar to that of sugar. Among beverages, sugar-sweetened drinks and alcohol were each positively associated with weight gain. Foods that were relatively neutral in terms of long-term weight gain included cheese, both low-fat and whole-fat milk and diet soda. Increased intake of these

foods did not result in weight gained or lost. Finally, there were several foods for which increased intake was associated with less weight gain; these foods included vegetables, nuts, whole grains, fruits and yogurt. Thus, studies have shown that there is difference in the effects of diets that are of different quality, even if they contain the same calories. Same results have been present for risk of type II diabetes. Carbohydrate quality was therefore reported as a major contributor to long-term weight gain and risk of diabetes. It is thus recommended to shift consumption from refined to whole grains, which induce low glycemic response, are high in fiber and are in solid form. (Mozaffarian, 2017).

The GBD studies measured the intake of adults 25 years or older of 15 specific foods, and estimated their effect on the risk of non-communicable disease and cardiovascular disease related mortality. The goal was to provide comprehensive results on the relationship between suboptimal diet and health in the studied countries. An interesting finding was that 1 in 5 deaths globally could be prevented through only improving the diet. The 15 dietary factors were responsible for 11 million deaths among adults and 255 million disability adjusted life years (DALYs) in 2017. Cardiovascular disease was the leading cause of these diet-related deaths and DALYs, followed by cancers and then type II diabetes. Also, the findings revealed that unlike other risk factors of NCDs, dietary factors affected people regardless of their age, sex and sociodemographic situation. The impact of individual dietary factors varied across countries, however the suboptimal intake of three dietary factors; which are whole grains, fruits and sodium accounted for more than 50% of deaths and 66% of DALYs attributable to diet. More than any other risk including smoking, suboptimal diet was shown to be responsible for the rise in NCD deaths and illnesses

around the world. This, again, stresses the need for policies that enhance the quality of food intake in populations. (Afshin et al, 2019)

In 2019, Afshin et al released a significant study that incorporated the effect of diet on mortality and DALYs, the relationship between food intake and socio-demographic status and a measurement of how much the 15 dietary factors that met the criteria for the GBD risk were being consumed in 21 regions in the world. The dietary factors were the following as shown in Table 1 below:

Table 1. The 15 dietary factors that met the criteria for the GBD risk and were studied for their intake globally and in the MENA (Afshin et al, 2019).

| **A diet low in:** | **A diet high in:** |
|---|---|
| Fruits | Red meat |
| Vegetables | Processed meat |
| Legumes | Sugar-sweetened beverages |
| Whole grains | Trans-fat |
| Nuts and seeds | Sodium |
| Milk | |
| Calcium | |
| Fiber | |
| Omega 3 | |
| Polyunsaturated fatty acids | |

Globally, the intake of nearly all healthy foods and nutrients was below optimal levels in 2017 especially in the case of nuts and seeds, milk and whole grains. The consumption of nuts and seeds was 12% of the optimal level, that of milk was 16% and that of whole grains was 23%. On the other hand, the intake of all unhealthy foods and nutrients was higher than the optimal levels. For example, the consumption of processed meats was 90% higher than the optimal level, and that of sodium was 86% higher. High intake of sodium and low intake of whole grains and fruits were associated with more than half the deaths and two thirds of the DALYs that are attributable to the diet. As for the MENA region, similar to the global average, the intake of all healthy foods and nutrients was below optimal. With respect to unhealthy foods, the intake of sugar-sweetened beverages, sodium and trans fats was higher than recommended, while the intake of red meat and processed meat did not exceed recommended levels. (Afshin et al, 2019)

Overall, in 2017, the highest rates of all diet-related deaths and DALYs were observed in countries of low- and high-middle socio-demographic status. On the other hand, the lowest burden of exposure to the dietary factors was observed in high socio-demographic countries. Countries of high-middle and middle socio-demographic status were at risk of deaths and DALYs attributable to high consumption of sodium, whereas countries of high and low-middle socio-demographic status had the greatest risk coming from a diet low in whole grains. In countries of low sociodemographic status, low intake of fruits was the significant dietary risk for deaths and low intake of whole grains was the leading dietary risk for DALYs. Interesting to note that low- and high-middle class countries had greatest risk attributable to a diet low in whole grains. (Afshin et al, 2019).

Many studies have assessed the environmental effects of different diets to conclude that the most sustainable shift would be the complete replacement of animal foods with plant-based foods. Vegetarian and vegan diets have the greatest effect on decreasing greenhouse gas emissions and the use of land, while vegetarian diets alone lead to a decrease in water use. Moreover, replacing red meat with other alternatives, such as fish and poultry, has resulted in positive environmental effects that are, however, less significant than following a plant-based diet. These studies show that a diet that includes more plant-based foods than animal-based foods would lead to both environmental benefits and improved health and wellbeing. (Willet et al, 2019) The American Dietetic Association stated in 2009 that appropriately planned vegetarian diets, including total vegetarian or vegan diets, are healthful, nutritionally adequate, and may provide health benefits in the prevention and treatment of certain diseases. The results of evidence-based reviews have showed that vegetarian diets are associated with lower risk of death from ischemic heart disease. Vegetarians also appear to have lower low-density lipoprotein cholesterol levels, lower blood pressure, and lower rates of hypertension and type 2 diabetes than non-vegetarians. Furthermore, vegetarians tend to have a lower body mass index and lower overall cancer rates. (Craig and Mangles, 2009).

The consumption of meat, according to the United Nations Food and Agriculture Organization, has more than doubled between 1961 and 2014, as it increased from 20 kg to 43 kg per capita worldwide. This by itself, along with other aspects of the Western diet are leading to environmental stress. Thirty percent of global land is used nowadays for animal rearing mainly aimed for meat and dairy production. Some of these lands were originally rain forests, and thus were cut in order to expand the area of production. In addition to the

lost land, high levels of greenhouse gases are being emitted during the production processes. For example, animal waste releases methane and nitrous oxide, which are 30 and 300 times more potent than carbon dioxide, respectively. About one-third of the world's water consumption is for producing animal products. Moreover, the major sources of water pollution come from animal wastes, hormones, chemicals, fertilizers and pesticides used for feed crops. Consequently, high meat consumption plays a significant role in depleting and polluting the world's scarce resources. That is in addition to its negative health effects on wellbeing mentioned earlier. (Stoll-Kleemann and O'Riordan, 2015) Interestingly, a review done in 2016 has shown that adopting a more environmentally sustainable diet that is based mainly on plants rather than meat, would lead to more than 70% reduction in greenhouse gas emissions and 50% decrease in water use globally (Aleksandrowicz et al, 2016).

**D. The EAT-Lancet and Mediterranean diets: Impacts on health and environment:**

Based on the above evidence, efforts were made to decrease the environmental impact – as well as increase the healthiness – of food consumption in a region that suffers from depleted resources, in terms of water scarcity, land degradation and high-energy use. This attempt is, moreover, consistent with the Sustainable Development Goals (SDGs), which called for sustainable consumption and production and brought "sustainable diets" to the forefront of the sustainability agenda (Naja et al, 2018).

***1. EAT-Lancet Diet:***

In 2019, the EAT-Lancet Commission quantitatively described a universal healthy reference diet (summarized in Table 2) to provide a basis for estimating the health and

environmental effects of adopting an alternative diet to standard current diets, many of which are high in unhealthy foods. Scientific targets for a healthy reference diet are based on extensive literature on foods, dietary patterns and health outcomes. This healthy reference diet largely consists of vegetables, fruits, whole grains, legumes, nuts and unsaturated oils, includes a low to moderate amount of seafood and poultry, and includes no or a low quantity of red meat, processed meat, added sugar, refined grains and starchy vegetables. The global average intake of healthy foods is substantially lower than the reference diet intake, whereas overconsumption of unhealthy foods is increasing. Using several approaches, the EAT-Lancet Commission found, with a high level of certainty, that global adoption of the reference dietary pattern would provide major health benefits, including a large reduction in total mortality. The diet proposed by EAT-Lancet is detailed in terms of the food groups on which most dietary guidelines are based, and is considered nutritionally adequate and healthy. In addition to these main food groups, the diet takes into consideration added fats, added sugar, and salt. The EAT-Lancet diet is based on the daily energy consumption of 2,500 kcal per day, which is the average energy need of a 70 kg male or 60 kg female of the age of 30 years doing moderate to high physical activity. The daily protein requirements in the EAT-Lancet diet are based on the adequate protein intake for adults, which is 0.8 g per kg of body weight. Although most foods contain some protein, meat, dairy, fish, eggs, legumes and nuts are high in protein and are often considered as alternatives to each other. (Willet et al, 2019)

The EAT-Lancet diet is an integrated agenda of human health and environmental sustainability of the global food system that has clear scientific targets using the concept of

a safe operating space for food systems. The concept of a safe operating space for humanity, proposed by Rockstrom and colleagues in 2009, originates from the planetary boundaries framework and is defined as “the safe operating space for humanity with respect to the Earth system and are associated with the planet’s biophysical subsystems or processes”. The planetary boundaries framework are thus used as a guide to propose a safe operating space for food systems that encompasses human health and environmental sustainability. This space is defined by scientific targets that set ranges of planetary boundaries for food production to ensure a stable Earth system. These boundaries include the total global amount of cropland use, biodiversity loss, water use, greenhouse-gas emissions and nitrogen and phosphorus pollution that can be due to food production. (Willet et al, 2019)

The largest study carried out on humans on vegetarian and vegan diets, showed that people following these diets have a 12% lower overall mortality than do omnivores. Using another approach, a plant-based diet was inversely and linearly associated with type II diabetes and coronary heart disease in humans. Thus, a shift towards a dietary pattern that emphasizes whole grains and legumes, fruits and vegetables, and nuts is favorable. Consumption of processed red meat on the other hand was associated in studies with increased risk of cardiovascular disease. The consumption of red meat was associated with increased risk of coronary heart disease especially when compared with the consumption of poultry and fish. Conversely, the consumption of white meat (poultry and fish) was not correlated with increased mortality. (Willet et al, 2019)

The required amount of dairy foods recommended by the EAT-Lancet diet is equivalent to 500 mg per day in order to sustain bone health. Although studies did not show

that the increase in the consumption of dairy products was linked to mortality and cardiovascular disease, it was shown that replacing dairy foods with nuts or other planet-based sources of protein would decrease mortality. The adequate intake of fish provides the required amount of omega 3 fatty acids that is associated with a decrease in the risk of cardiovascular disease. Therefore, the EAT-Lancet diet proposes the intake of one to two servings of fatty fish per week. Although the daily consumption of eggs did not lead to an increase in cardiovascular disease in the studies done on humans, except in people with diabetes, the EAT-Lancet diet recommends a limit on the intake of eggs. (Willet et al, 2019)

Table 2. The EAT-Lancet Healthy reference diet, with possible ranges, for an intake of 2500 kcal/day, 2019.

| | Macronutrient intake (possible range), g/day | Caloric intake, kcal/day |
|---|---|---|
| **Whole grains*** | | |
| Rice, wheat, corn, and other† | 232 (total gains 0–60% of energy) | 811 |
| **Tubers or starchy vegetables** | | |
| Potatoes and cassava | 50 (0–100) | 39 |
| **Vegetables** | | |
| All vegetables | 300 (200–600) | .. |
| Dark green vegetables | 100 | 23 |
| Red and orange vegetables | 100 | 30 |
| Other vegetables | 100 | 25 |
| **Fruits** | | |
| All fruit | 200 (100–300) | 126 |
| **Dairy foods** | | |
| Whole milk or derivative equivalents (eg, cheese) | 250 (0–500) | 153 |
| **Protein sources‡** | | |
| Beef and lamb | 7 (0–14) | 15 |
| Pork | 7 (0–14) | 15 |
| Chicken and other poultry | 29 (0–58) | 62 |
| Eggs | 13 (0–25) | 19 |
| Fish§ | 28 (0–100) | 40 |
| Legumes | | |
| Dry beans, lentils, and peas* | 50 (0–100) | 172 |
| Soy foods | 25 (0–50) | 112 |
| Peanuts | 25 (0–75) | 142 |
| Tree nuts | 25 | 149 |
| **Added fats** | | |
| Palm oil | 6·8 (0–6·8) | 60 |
| Unsaturated oils¶ | 40 (20–80) | 354 |
| Dairy fats (included in milk) | 0 | 0 |
| Lard or tallow\|\| | 5 (0–5) | 36 |
| **Added sugars** | | |
| All sweeteners | 31 (0–31) | 120 |

For an individual, an optimal energy intake to maintain a healthy weight will depend on body size and level of physical activity. Processing of foods such as partial hydrogenation of oils, refining of grains, and addition of salt and preservatives can substantially affect health but is not addressed in this table. *Wheat, rice, dry beans, and lentils are dry, raw. †Mix and amount of grains can vary to maintain isocaloric intake. ‡Beef and lamb are exchangeable with pork and vice versa. Chicken and other poultry is exchangeable with eggs, fish, or plant protein sources. Legumes, peanuts, tree nuts, seeds, and soy are interchangeable. §Seafood consist of fish and shellfish (eg, mussels and shrimps) and originate from both capture and from farming. Although seafood is a highly diverse group that contains both animals and plants, the focus of this report is solely on animals. ¶Unsaturated oils are 20% each of olive, soybean, rapeseed, sunflower, and peanut oil. ||Some lard or tallow are optional in instances when pigs or cattle are consumed.

***Table 1:*** **Healthy reference diet, with possible ranges, for an intake of 2500 kcal/day**

The amount of nuts and seeds mentioned above in Table 2 of the EAT-Lancet diet requirements is based on the notion that their adequate intake decreased low density lipoprotein (LDL) cholesterol, LDL to high density lipoprotein (HDL) cholesterol ratio and triglycerides in a meta-analysis carried on humans. (Willet et al, 2019)

Moreover, several studies have previously shown that the high consumption of nuts is associated with reduced risk of cardiovascular disease, type II diabetes and overall mortality. When it comes to grains and tubers, it is recommended to keep them as less than 60% of daily energy, with an emphasis on whole grain foods. Similar to nuts, high intake of whole grains has been correlated with a decrease in the risk of coronary heart disease, type II diabetes and overall mortality. On the other hand, daily consumption of potatoes has been associated with weight gain, hypertension and type II diabetes, so it is recommended to keep it as maximum as 50 g per day. Five servings of both fruits and vegetables are recommended daily by the EAT-Lancet diet. Thus, the diet contains around 300 g per day of vegetables and 200 g of fruits. (Willet et al, 2019)

Cohort studies and randomized trials have not shown benefit from reducing total fat intake, however, replacing saturated fat with unsaturated vegetable oils has shown to decrease the risk of cardiovascular disease. Thus it is recommended to replace saturated fat with polyunsaturated fat intake especially omega 3 and omega 6 fatty acids. Plant sources of fat are thus more favorable than animal fat. The diet recommends a maximum of 50 g of fat daily while encouraging that they come from unsaturated plant oils. As for sugar and other sweeteners, the intake of 31 g per day is allowed in a way that it does not exceed 5% of energy per person daily. (Willet et al, 2019)

To recap, the EAT-Lancet diet can be summarized by the following: 1) Protein sources mainly coming from plants, legumes, nuts and fish while limiting the intake of red meat and processed meats, and sticking to a modest consumption of poultry; 2) Daily fat coming from unsaturated vegetable oils and limiting the intake of animal fats; 3) Carbohydrates coming primarily from whole grains with low intake of refined grains and less than 5% of energy coming from sugar and other sweeteners; 4) At least five servings of fruits and vegetables per day, (excluding potatoes); and 5) Moderate dairy consumption. (Willet et al, 2019)

***2. The Mediterranean Diet:***

The Mediterranean diet (MD) was first defined as being low in saturated fat and high in vegetable oils, observed in Greece and Southern Italy during the 1960s. It has been redefined later on into advanced versions. Longitudinal studies have shown that this diet is associated with reduced risk of coronary heart disease when compared to the common diet in other European countries and the United States. The key components that characterize this diet are the emphasis on the intake of vegetables including leafy green vegetables, fruits, whole grain cereals, nuts and legumes, the moderate intake of fish and other meat and dairy products, and the low intake of eggs and sweets. The description of the Mediterranean diet pyramid indicates the frequency of the consumption of each food, such as every day or every week. (Davis, 2015)

Table 3. Frequency of consumption and portion size of the Mediterranean diet used by Germani et al in 2014, with the equivalence of the quantities in grams per day.

| Food Groups and Items | g/portion (portion– frequency) | g/day |
|---|---|---|
| **Fruit** | 150 (3p/d) | 450 |
| **Seasonal vegetables** | 200 (2p/d) | 400 |
| **Nuts** | 15 (3p/weekly) | 6.4 |
| **Pulses** | 50 (2p/d) | 100 |
| **Pasta or rice** | 80 (1p/d) | 80 |
| **Bread** | 50 (3p/d) | 150 |
| **Potatoes** | 200 (2p/weekly) | 57 |
| **Extra Virgin Olive oil (EVO oil)** | 10 (3p/d) | 30 |
| **Red meat** | 100 (1p/weekly) | 14.3 |
| **White meat** | 100 (2p/weekly) | 28.5 |
| **Processed meat** | 50 (2p/weekly) | 14.3 |
| **Cheese fresh** | 100 (2p/weekly) | 28.5 |
| **Eggs** | 50 (2p/weekly) | 14.3 |
| **Fish** | 150 (2p/weekly) | 42.8 |
| **Milk** | 125 (1p/d) | 125 |
| **Yogurt** | 125 (p/d) | 125 |
| **Cookies** | 30 (1p/d) | 30 |
| **Sugar** | 5 (1p/d) | 5 |
| **Dessert** | 100 (1p/weekly) | 14.3 |

Table 3 presents the version of the MD used in this study, which is the complete Mediterranean diet model that is the result of a scientific consensus among experts who developed a new revised edition of the Mediterranean pyramid model in 2012. This model (www.CIISCAM.org; Del Balzo et al., 2012) has an energy intake of about 2000 Kcal/d with the following nutrients shares: 55–60% of energy from carbohydrates, 10–12% of energy from proteins and 30% of energy from fats (Table 3). (Germani et al, 2014)

The MD dietary model has been confirmed by the scientific community as a successful model for the prevention of non-communicable diseases. It promotes bio-diversity and the local cultural heritages. Indeed, in 2010, the UNESCO has adopted the MD as a cultural heritage of the humanity, not only for its nutritional characteristics but also for the economic, environmental and socio-cultural impacts in different areas of agricultural vocation and ecologic interest. Despite the reported benefits, adherence to the MD is decreasing in the countries of the Mediterranean basin with loss of attention not only to health but also to the environmental sustainability. In the latest survey of 2005-2006 on food consumption for Italian households, it has been observed that the Italian population has a high consumption in foods of animal origin and a low consumption in products of vegetable origin such as fruits and vegetables, thus drifting from the Mediterranean model. In the study done by Germani et al in 2014, three environmental indices (Carbon Footprint, Water Footprint and Ecological Footprint) of the Mediterranean Diet and real consumption of the Italian population for a period of 7 days were measured. The study highlighted that the MD has a lower environmental impact compared to the actual diet of the Italian population when considering all three indices. This was mainly linked to larger portion sizes consumed by the Italians and higher frequencies of consumption than those recommended in the MD, especially regarding foods of animal origin (meat, processed meat and meat substitutes). (Germani et al, 2014)

**E. Effects of current consumption vs. healthier food patterns on cost worldwide:**

Moreover, to address the ability of people to access the recommended healthier and environmentally sustainable diet recommendations, several studies investigated the cost of

healthier diets compared to that of currently adopted ones. The cost of the diet is one of the three main pillars of a sustainable diet which encompasses economic, environmental and social aspects. These studies have showed that healthier diets are generally more expensive than typical consumption.

Rao et al. (2013) carried out a systemic review and meta-analysis to study the prices of healthier versus less healthy diet patterns based on the results of 27 studies conducted primarily in developed or high-income countries. 14 of these studies were conducted in the USA, 2 in Canada, 6 in Europe and 5 in other countries including South Africa, New Zealand, Japan and Brazil. Results showed that healthier diets cost $1.48 per day more than less healthy foods. Thus, the study concluded that there is a need for a public health intervention that works on lowering the price of heathy food patterns in order to encourage people to adopt them. As for the reasons why healthier food costs more, the study argued that most agricultural subsidies are directed towards less healthy foods such as corn and soy. Many decades of policies focused on producing inexpensive, high volume commodities have led to a complex network of farming, storage, transportation, processing, manufacturing and marketing capabilities that favor sales of highly processed food. Other potential barriers to a healthier diet exist, such as availability and cultural acceptability. Thus the study concluded that a wholesome approach should be carried out that tackles the production of food, its availability, its transportation and its marketing in order to promote healthier food patterns. Table 4 presents six examples of the studies included in the meta-analysis; five carried out in the USA and one in France: (Rao et al, 2013)

Table 4. Selected food prices studies included in meta-analysis of Rao et al. (2013) comparing prices of healthy vs. unhealthy foods.

| **Study** | **Study Scope/Area** | **Assessment of Healthfulness** | **Main Method** | **Price Assessment** |
|---|---|---|---|---|
| Cassady et al, 2007 | 35 foods from 25 stores in California | Fruit and vegetable basket meeting 2005 Dietary Guidelines vs 1995 Thrifty Food Plan fruit and vegetable basket | Comparison between the prices of the two baskets | Cross-sectional price survey conducted in chain supermarkets and small independent grocery Stores |
| Jetter and Cassady, 2006 | 133 foods from 25 stores in California | Market basket with four times the amount of fiber and one-fifth the grams of total fat vs 1995 Thrifty Food Plan market basket | Comparison between the prices of the two baskets | Cross-sectional price survey conducted in chain supermarkets and small independent grocery Stores |
| Katz DL et al, 2011 | 131 foods in 8 food categories from 6 stores in Missouri | Nutrition Detectives program* criteria for healthfulness | Meeting vs not meeting the criteria | Prices collected from chain grocery stores |
| Krukowski et al, 2010 | 20 foods from 42 stores in Arkansas and Vermont | 10 high-fiber, low-fat, low-sugar foods vs low-fiber, high-fat, high-sugar foods | Comparison between the two patterns | Overweight individuals entering a behavioral weight loss research |

| Study | Study Scope/Area | Assessment of Healthfulness | Main Method | Price Assessment |
|---|---|---|---|---|
| | | | | program self-reported their primary grocery store. |
| Liese et al, 2007 | 8 foods from 75 stores in South Carolina | Lean ground beef vs high-fat ground beef; skinless and boneless chicken breasts vs chicken drumsticks; high-fibre bread vs low-fibre bread; low-fat/non-fat milk vs whole milk | Comparison between the two patterns | Prices reported by store type (supermarket, grocery store, convenience store) |
| Drewnowski et al, 2004 | 837 participants in France; 57 foods | Fats and sweets intake, fruit and vegetables intake, total fat intake and sucrose intake | Comparison between combinations of these dietary factors | Diet cost calculated from food prices from French National Institute of Statistics |

*Nutrition detectives criteria: Subjectively determined to not have an unhealthy ingredient such as sugar or white flour listed first on ingredient list, does not contain partially hydrogenated oil or high-fructose corn syrup and does not have a long ingredient list relative to other items in the same food category. For grain-based products only, they should contain at least 2 g fiber per serving. (Rao et al, 2013)

In this part of the section, five studies on costs of diets are reviewed and summarized in Table 6. Published in November 2019, Hirvonen et al carried out a study on the cost of the EAT-Lancet diet in 159 countries worldwide. Note that the study did not include Lebanon. The researchers estimated the median daily cost in international dollars of an EAT-Lancet reference diet to be 2.84$ in 2011. The cost was larger in high-income countries (2.66$) than in low-income countries (2.42$), and among geographical regions, the median cost was highest in the Latin America and Caribbean region (3.42$) and lowest in sub-Saharan Africa (2.45$), with considerable variation within regions and income groups. The study showed that the EAT-Lancet reference diet is not affordable for much of the world's low-income population. In the 26 countries (0.50 billion people) classified as low-income by the World Bank, obtaining enough of the least expensive locally available items to meet the EAT-Lancet targets would require 89.1% of the mean per capita household income. In the 47 countries (2.97 billion people) classified as lower-middle income, these diets would cost 52.4% of the mean per capita household income. The study estimated that at least 1.58 billion individuals, mostly located in sub-Saharan Africa and south Asia, could not afford the EAT-Lancet diet as the diet exceeded total household per capita income. This is mainly because the diet recommends a consumption pattern containing less meat and more fruits and vegetables than diets currently consumed by richer people but includes more animal-source foods, fruits and vegetables than the world's poor could afford. (Hirvonen et al, 2019).

A study conducted in South Africa in 2011 showed that people favored high-energy low nutrient density foods such as fast foods, candies and chocolates over low-energy high nutrient density foods such as oats, beans, carrots and apples. Although the latter are

healthier, the two main factors that made people prefer less healthy options were taste and cost. Energy-dense foods are tastier and cheaper sources of energy. The study compared the cost of a healthier diet to that of the typical South African diet, to conclude that the healthier diet would cost 69% more. This was done by formulating a typical menu based on the foods commonly eaten by much of the South African population, and then modified these foods based on dietary recommendations. The typical menu included six commonly consumed foods that were replaced with healthier food options (Table 5). The researchers recorded the price of 54 foods, which included the most commonly consumed foods in South Africa and healthy alternatives. Food prices were recorded at three supermarkets in areas of different socio-economic status. However, the study noted that the cost of healthier foods could be decreased by around 15% if choices were made wisely. The researchers concluded that it is important not only to educate people on the significance of a healthy diet, but to teach them also how to choose affordable healthier options. Moreover, the role of the government was found to be essential to intervene and influence food prices in a way that makes healthy options more affordable (Temple and Steyn, 2011).

Table 5. Six commonly consumed food by South African population, and their alternative healthy options used in the study by Temple and Steyn in 2011.

| Typical consumed foods | Healthier options |
|---|---|
| Hamburger (full-fat) | Lean hamburger |
| Full-cream milk | Fat-free milk |
| Corn flakes | Bran flakes |

| | |
|---|---|
| Brick margarine | Lower-fat margarine |
| White rice | Brown rice |
| White bread | Brown bread |

Barosh et al (2014) worked on estimating the cost of a healthy and environmentally sustainable (H&S) hypothetical food basket to test for affordability and accessibility in Australia in 2014, as affordability is key in adopting a healthy diet. The cost of the H&S food basket was then compared to the price of another food basket that represented the typical less healthy diet. Each food basket was designed to reflect the weekly purchasing of food by a hypothetical household formed of an adult male, an adult female, a 15 year old boy and a 4 year old girl. The H&S food basket was constructed based on the Australian Dietary Guidelines whereas the typical basket was based on the 1995 national nutrition survey that reflects household's habitual food consumption pattern. The prices of the typical and H&S food baskets were measured in five different locations across Sydney based on surveys. The surveys were used to record availability, price, weight, unit of measurement and price per unit weight for each food item. Several quintiles were formed based on the socio-economic status of the areas. Costs were obtained from industrial food systems including supermarkets, large and small grocery stores, and alternative outlets such as food cooperatives and farmers markets. The prices of different food items were recorded from the industrial and alternative food outlets within the quintiles. The cost of each food item was converted into its price per unit of weight measurement (kilogram or milliliter), and then the price of its required weight within the basket was calculated. In case of a

missing food item, an average of its price from all districts was used. Eventually, the total price of the food basket was measured by summing the averages of the price per required weight of each food item. To estimate affordability, the price of each basket was compared to the average weekly income of households of the different quintiles. The average household income information was obtained for couples with two dependent children. Thus, the cost of each basket was expressed as a percentage of average household income across the quintiles and comparisons between the percentage of the H&S basket and that of the typical basket were established. The results showed that the average price of the H&S basket costs more than the typical basket in all quintiles, ranging from 4% to 30% more. The greatest difference was witnessed in the most disadvantaged quintile with the H&S basket being 30% more expensive than the regular basket. In addition, inequalities were shown in the affordability of each basket at the level of households of different income. In the lowest income quintile, households would have to spend around 33% to 44% of their weekly income to buy a typical basket, and 40% to 48% of it to buy the H&S basket. On the other hand, households in the highest income quintile would have to spend significantly less, particularly around 6% to 8% for the typical basket, and 8% to 9% for the H&S basket. (Barosh et al, 2014)

Germani et al (2014) carried out a study that compared the environmental impact and the costs of the current food consumption pattern of the Italian population to the Mediterranean model in order to investigate its overall sustainability. The costs (Euro) per person of the MD and of the current Italian household food expenditure were considered on a weekly basis according to the 2013 data from the Observatory prices and tariffs of the Ministry of Economic Development and the service SMS consumers of the Ministry of

Agriculture, Food and Forestry. Data on the current food consumption of the Italian populations were derived from the 2005 to 2006 INRAN-SCAI survey. The study showed that Italians expend the largest part of the food budget to buy meat (24.03%), followed by bread and cereals (17.38%) and dairy products and eggs (14.06%). Only 16.36% of their monthly budget was allocated to buy fruits, potatoes and vegetables. All in all, the study concluded that the monthly food and beverages budget of the Italian families, considering a group of four people, was around 586 Euro, whereas the cost of MD would be about 596 Euro. Therefore, it emerged that there were no substantial differences in the total budget but there was a considerable difference allocating the budget according to the different food groups. In particular, the actual monthly expense that a family would spend to purchase vegetables and fruits was 18% lower than the one that should be dedicated to this food group according to the MD model. Also for the purchase of milk, cheese and eggs there was a 6% reduction compared to the MD model. On the contrary, the average Italian family would spend every month 8% more to purchase meat and 2% to purchase fish than what should be spent according to the MD model. Regarding bread, pasta, other cereals and dressings, there were no substantial budget differences. Moreover, Italians would spend around 50 Euro to purchase drinks, including water. According to the authors, this budget should be better dedicated to purchase other foods, such as fruits and vegetables, milk and dairy product that are consumed in lower quantities by the Italian population compared to the MD recommendations. Regarding the sweets group, the budget dedicated was almost double compared to what would be expected adhering to the MD. (Germani et al, 2014)

In the study done by Donati et al (016), dietary information was collected from 104 young adults in the last year of high school in Parma (Italy). Diet was monitored with 7-day

dietary records. Subsequently, food items were decoded to obtain nutritional, economic and environmental impact data. An optimization tool based on mathematical programming (Multi-Objective Linear Programming) was used to identify sustainable diet. Three different 7-day diets were identified, based on nutrition recommendations for the healthy Italian adult population, characterized by different targets and optimizing different impacts: first the diet at the lowest cost (Minimum Cost Diet – MCD), then the Environmentally Sustainable Diet (ESD) obtained by minimizing the three environmental indicators ($CO_2e$ emissions, $H_2O$ consumption and amount of land to regenerate the resources – $m^2$). Finally, the Sustainable Diet (SD) was identified by integrating environmental and economic sustainability objectives. The results showed that the current diet would cost 40.48 Euro/week, the Minimum Cost Diet 31.07 Euro/week, the Environmentally Sustainable Diet 49.04 Euro/week and the Sustainable Diet would cost 40.49 Euro/week. The results showed that the modelled sustainable diet was not more expensive than the current diet, therefore it was fully affordable for the population under study. (Donati et al, 2016)

Table 6. Summary of the reviewed studies on costs of diets.

| Study | Area/Scope of Study | Types of Diets Assessed | Method of Assessment | Results |
|---|---|---|---|---|
| Hirvonen et al, 2019 | 159 countries worldwide | EAT-Lancet diet | Comparing the cost of local EAT-Lancet diet to average income in the different countries | The researchers estimated the median daily cost in dollars of an EAT-Lancet diet to be 2.84$ in 2011. Therefore, at least 1.58 billion |

| | | | | |
|---|---|---|---|---|
| | | | | individuals could not afford the EAT-Lancet diet as it exceeded total household per capita income |
| Temple and Steyn, 2011 | South Africa | A typical menu based on the foods commonly eaten by much of the South African population vs. a modified menu of these foods based on South-African dietary recommendations | The researchers recorded the price of 54 foods, which included the most commonly consumed foods in South Africa and healthy alternatives. Food prices were recorded at three supermarkets in areas of different socio-economic status. | The healthier diet cost 69% more than typical diet |
| Barosh et al, 2014 | Australia | A healthy and environmentally sustainable (H&S) hypothetical food basket constructed based on the Australian Dietary Guidelines vs. a typical basket that was based on the 1995 national nutrition survey that reflects household's habitual food consumption pattern | The prices of the typical and H&S food baskets were measured in five different quintiles across Sydney based on surveys. The surveys were used to record availability and price per food item. Costs were obtained from industrial food systems including supermarkets, large and small grocery stores, | The results showed that the average price of the H&S basket costs more than the typical basket in all quintiles, ranging from 4% to 30% more |

| | | | | |
|---|---|---|---|---|
| | | | and alternative outlets such as food cooperatives and farmers markets. | |
| Germani et al, 2014 | Italy | A constructed model of the Mediterranean diet (MD) vs. actual Italian consumption | The costs of both diets were calculated according to the 2013 data from the form the Ministry of Economic Development and the Ministry of Agriculture, Food and Forestry. Data on the current food consumption of the Italian populations were derived from the 2005 to 2006 INRAN-SCAI survey | No substantial differences in cost between the two diets were detected |
| Donati et al, 2016 | Italy | Three diets were compared: Minimum Cost Diet (MCD), the Environmentally Sustainable Diet (ESD) obtained by minimizing three environmental indicators, and the Sustainable Diet (SD) which was identified by integrating environmental and economic | Dietary information was collected from 104 young adults in the last year of high school in Italy. Diet was monitored with 7-day dietary records. Subsequently, food items were decoded to obtain nutritional, economic and | The results showed that the current diet would cost 40.48 Euro/week, the MCD 31.07 Euro/week, the ESD 49.04 Euro/week and the SD would cost 40.49 Euro/week. Thus the modelled sustainable diet was not more |

| | | | | |
|---|---|---|---|---|
| | | sustainability objectives | environmental impact data | expensive than the current diet |

**F. Research Context – Lebanon:**

Lebanon is a small middle-income country of the Middle-East. With high literacy rates and a traditional mercantile culture, Lebanon is an important commercial hub in the region, although economic and social development was hampered by a long civil conflict from the mid-seventies until beginning of the nineties. The Lebanese population is young, with a relatively high life expectancy at birth (72 years), reflecting a good access to health care and a full access to safe water and sanitation. (FAO, 2007)

Lebanon's health outcomes show that diet-related NCDs are significant and impose a high burden on the country. The percent of total deaths due to NCDs in Lebanon was 91% in 2016 (WHO, 2016). Moreover, the age-standardized prevalence of raised blood pressure in adults aged 18 years and over was 22.1% (WHO, 2014). The prevalence of diabetes in adults aged 18 years and over, was 12.6 %. (WHO, 2014). The risk of developing cancer before the age of 75 years for both sexes was 22.8% in Lebanon in 2018 (WHO, 2018). Moreover, the risk of dying from cancer before the age of 75 years for both sexes was 11.3% in 2018 (WHO, 2018). The standardized prevalence of obesity (BMI $\geq$30 kg/m$^2$) in adults aged 18 years and over, was 31.9% in Lebanon in 2014 (WHO, 2014). The average BMI (in kg/m$^2$) in Lebanon which was 27.4 for males, 27.1 for females and 27.3 for both sexes in 2010, increased to 28.0 for males, 27.6 for females and 27.8 for both in 2014 (WHO, 2014). In addition, the percentages of overweight and obesity in Lebanese children

aged 13 to 15 years old in 2017 were 35% and 13% respectively for both sexes combined (Toshiko and El-Saharaty, 2017).

Lebanon, which has a relatively fragile political, social and economic system that increases its risk of food insecurity, has recently suffered the repercussions of Arab Spring movements, including the Syrian war. The latter is one of the largest humanitarian crises in today's world that have led to an unprecedented large influx of Syrian refugees through the borders of Lebanon further taxing the limited economic resources of the country and contributing to its political and social instability. With the escalating Syrian humanitarian crisis, international agencies operating in Lebanon have been mostly concerned with exploring the food security status of refugees. However, the food security status of Lebanese households has not been adequately explored nor was the association between household food security and nutritional status of vulnerable groups, particularly mothers. By 2017, two published studies in Lebanon, primarily validating the use of food security assessment tools, have shown that moderate to severe household food insecurity were as high as 34% (Jomaa et al, 2017) and 42% among Lebanese households in the rural Bekaa region (Sahyoun et al, 2014) and those in a semi-urban area in the South of Lebanon, respectively. In parallel to the heightened economic and social challenges threatening to compromise the food security status of Lebanese households, the country has witnessed a significant increase in micronutrient deficiencies among at-risk population groups, mainly children and women of reproductive age. Results of the study done by Jomaa et al in 2017 on household food insecurity of Lebanese, have showed that approximately 50% of interviewed Lebanese households were food secure while 8% were mildly food insecure, 16% were moderately food insecure, and 26% were severely food insecure. It was noticed

that mothers from food insecure households had a significantly higher percent daily energy intake from bread and cereals, eggs, and sweets and sugar-sweetened beverages compared to mothers from food secure ones. However, the percent daily energy intake from nuts, dairy products, fruits and alcoholic beverages was significantly higher among mothers from food secure compared to insecure households. Compared to mothers in food secure households, mothers in food insecure households had significantly lower mean daily intakes of key micronutrients, including calcium, potassium and vitamin C. Additionally, a significantly higher percentage of mothers in food insecure households than food secure ones was consuming less than 2/3rds the daily-recommended intakes for potassium, folate, vitamin C and vitamin B6. As for macronutrient intake, it was found that mean daily intake of protein was significantly lower among mothers in food insecure than food secure households. In conclusion, findings from the study showed that almost 50% of interviewed Lebanese households reported food insecurity with 42% suffering from moderate to severe food insecurity and 8% living with mild food insecurity. The prevalence of moderate to severe food insecurity among Beirut residents was found to be higher than that reported earlier by rural households in the Bekaa region and another semi-urban Southern Lebanese population (34% and 42%, respectively). (Jomaa et al, 2017)

Prior the Syrian conflict, nearly 1 million Lebanese were estimated to be poor. Data from the World Bank in 2015 showed that the number of people living under the poverty line in Lebanon has risen by 66% since the start of the Syrian refugee crisis, pushing additional 170,000 Lebanese into poverty and doubling unemployment to over 20%, especially among the unskilled youth (Jomaa et al, 2018). A baseline study conducted in 2015 among Lebanese households showed that in order to cope with emerging shortfalls,

56 per cent of the Lebanese households reported employing food related coping strategies, of which 5 per cent were heavily reliant on severe food coping strategies. Over 50 per cent of households incurred debts mainly to purchase food and acquire agricultural inputs. In general, 49 percent of Lebanese households interviewed reported worrying about not having enough food and some 38 percent reported eating fewer kinds of food groups, while others reported being unable to access healthy and nutritious food. (UNHCR, 2019)

The cost of environmental degradation in Lebanon ranged between 3.1% and 5.5% of gross domestic product (GDP) in 2018. The mean estimate (4.4%) is equivalent to about 2.35 billion dollars in 2018, as compared to a mean estimate of 3.4% of GDP in 2000, which is equivalent to 0.56 billion dollars in 2000, without considering the global environment (UNDP, 2019). The agricultural sector in Lebanon is responsible for 3.56% of national GHGE. The main GHGE from this sector are $N_2O$ and $CH_4$ generated mainly from agricultural soils, manure management and enteric fermentation. The direct soil emissions are considered the major source of emissions from the sector (26%) (UNDP, 2020). Unfortunately, the policy followed by the Lebanese government since the 1950s has always been based on the extension of the field of industry and the encouragement of exports, without regard to environmental concerns.

Non-industrial solid wastes and wastewater are a primary factor in freshwater, sea water and soil pollution in Lebanon. Wastewater is poured into the sea and freshwater without any treatment. Uncontrolled qualities and quantities of pesticides, insecticides, herbicides and fertilizers, and the bad utilization of animal fertilizers on agricultural lands result in both water and soil pollution. (Hajar et al, 2010)

Soil degradation, soil deterioration and soil pollution are caused by the release of toxic matters, untreated wastewaters, and the uncontrolled use of pesticides, herbicides, insecticides, and fertilizers in agriculture. (Hajar et al, 2010)

In 2018, it was shown that the average Lebanese per-person water use (2,451 L/day) was slightly lower than the global average (2,799 L/day) and similar to estimates obtained for Finland (2,377 L/day). Water use of food consumption in the United States and Italy had higher estimates (3,998 L/day and 3,469 L/day, respectively). Regarding energy, the estimate obtained in 2018 (35 MJ/day) was higher than that of the United States (28 MJ/day). As for GHGEs associated with food consumption in Lebanon, it was shown that it's value is 3.9 Kg $CO_2$ eq/day which is similar to other Mediterranean countries such as Greece (3.6 Kg CO2 eq/day) and to the United States (3.56 Kg CO2 eq/day), but higher than in France. (Naja et al, 2018)

Lebanon, like other countries of the Middle East and North Africa Region (MENA), is currently witnessing a fast rate of development and modernization with concurrent shifts in diet, physical activity and body composition. These changes provide an understanding of the multidimensional phenomenon of the nutrition transition, which is characterized by increased consumption of energy, fat (especially of animal origin), added sugars and salty foods and decreased intakes of complex carbohydrates, dietary fiber, fruits and vegetables. (Nasreddine et al, 2014)

In the study conducted by Afshin et al published in 2015, non-optimal systolic blood pressure was the leading metabolic risk factor for cardio-metabolic mortality in Lebanon in 2010, followed by sub-optimal diet, then overweight and obesity and after that non-optimal fasting blood glucose. The intake of protective dietary levels of omega 3 fatty

acids in Lebanon was found to be the lowest compared to 19 other countries in the Middle East (seafood omega-3 fatty acids level was 8.3 mg/day), and was considered the leading dietary risk factor for mortality followed by the low intake of fruits. The levels of intake of other protective dietary factors (vegetables and beans, whole grains and polyunsaturated fatty acids) were also below optimal levels in Lebanon. Only for the intake of nuts and seeds that the levels of intake were higher than recommended levels (>16 g per day). On the other hand, the intake levels of processed meat, red meat, trans-fatty acids, sugar-sweetened beverages and sodium were all higher than recommended levels, with the levels of sugar-sweetened beverages being the highest in Lebanon (185 g/day) compared to the other countries. (Afshin et al, 2015)

In order to address the environmental sustainability of healthier recommendations mentioned above in the Afshin et al study of 2015, we mention below two studies carried out in the MENA region and in Lebanon to examine the effect of the current consumption and that of healthier diet patterns on environmental footprints.

Bahn et al (2019) studied the effects of the over-consumption of red meat (harmful food) and under-consumption of vegetables/beans, fruits and nuts and seeds (protective foods) on the environment of the MENA region (including Lebanon). The researchers carried out an analysis on four different environmental footprints: total (blue, green, and grey) water, blue water, energy use and greenhouse gas emissions, and their relationship with the intake of the four protective versus harmful food groups. The results showed that the reduction in the intake of red meat only would lead to savings in total water, blue water, energy use and greenhouse gas emissions by around 78%. In addition, decreasing the consumption of red meat and simultaneously increasing that of vegetables and beans would

result in savings in total water, blue water and greenhouse gas emissions. Furthermore, if we were to combine the reduction in the consumption of red meat with the increase in the consumption of protective foods in the MENA region, this would lead to savings in total water. This saving exceeds the increase in water expenditure as a result of the increase in intake of the three protective foods (vegetables/beans, nuts/seeds and fruits) combined. Also, if we were to replace the intake of red meat with that of vegetables and beans, being good sources of protein, this would further lead to savings of total water, blue water and greenhouse gas emissions in the region. The study thus showed that, at the level of the MENA region, shifting to a more plant-based diet leads to health benefits and is more environmentally sustainable. The results were in accordance with other studies worldwide that address the effects of shifting to sustainable diets on the environment. (Bahn et al, 2019)

Naja et al worked in 2018 on the environmental impact of guidelines that promote protective foods in the Lebanon. Previous research in the country had studied dietary intake and food consumption patterns in terms of their effect on health and wellbeing. The results of these investigations consistently identified two main dietary patterns: ‘Western’ and ‘Lebanese- Mediterranean’, where, the Western pattern had been associated with adverse health outcomes, including obesity, hypertension and metabolic syndrome. On the other hand, the Lebanese-Mediterranean pattern showed protective effects against metabolic abnormalities and type II diabetes. The aim of the study was thus to evaluate the environmental footprints (EFPs) of overall food consumption and to examine the association of these EFPs with dietary patterns previously identified in Lebanon. Data for the study was drawn from the cross-sectional National Food Consumption Survey (2008–

2009). The national cross-sectional Nutrition and Non-communicable Diseases Risk Factor (NNCD-RF) survey was conducted in Lebanon between May 2008 and April 2009. The study sample was based on the sampling frame provided by the National Survey of Household Living Conditions, which was conducted by the Ministry of Social Affairs/ Central Administration of Statistics in collaboration with United Nations Development Program (UNDP). It covered primary residences across the Lebanese territory (Chamieh et al, 2015). Three dietary patterns were considered for their environmental footprints as shown in Table 7: (Naja et al, 2018

Table 7. Food items/groups constituting the three dietary patterns prevalent in the study population of Naja et al (2018).

| **Western** | **Lebanese-Mediterranean** | **High-Protein** |
|---|---|---|
| Pizza, pies and refined grains | Fruits | Poultry |
| Fast food sandwiches | Legumes | Meat |
| Sweets | Whole dairy products | Fish |
| Regular Soda | Olives | Low fat dairy products |
| Mayonnaise | Vegetables | Hot drinks |
| Nuts and seeds | Burghol | Breakfast cereals |
| Eggs | Dried fruits | Light soda |
| Fats and oils | Traditional suits | |

| | | |
|---|---|---|
| Ice cream | | |
| Bottled fruit juice | | |
| Alcoholic beverages | | |

Results showed that among the three dietary patterns prevalent in the study population (Table 6), the Lebanese-Mediterranean diet had the lowest water use and greenhouse gas emissions (GHGE) per 1000 Kcal. Water use (L/Kg) was 443.61 ± 197.15, 243.35 ± 112.0, 264.72 ± 161.67, for the Western, Lebanese-Mediterranean and High-Protein, respectively. As for greenhouse gas emissions (KG $CO_2$ eq/day), the results for the Western, Lebanese-Mediterranean and High- Protein were 0.58 ± 0.32, 0.38 ± 0.24, 0.57 ± 0.37, respectively. The scores of the High-Protein dietary pattern were associated with higher odds of the three EFPs, whereas the Lebanese-Mediterranean dietary pattern was associated with lower odds of energy use (4.60 ± 2.87). Furthermore, scores of the Western pattern were associated with higher water use. (Naja et al, 2018)

The researchers concluded that these results, coupled to earlier findings of the Lebanese-Mediterranean pattern's beneficial effects on health, lend evidence for the notion that what is healthy for people may also be healthy for ecosystems and highlight the need for nutrition recommendations to take into consideration the nexus of water, food and energy, in addition to health.

In Lebanon, recent events have placed increased economic stress on Lebanese households, including their ability to satisfy their food needs. The WFP launched a random and anonymized web survey targeting the Lebanese population as well as Syrian and

Palestinian refugees during June of 2020. This survey contributed to a first complete picture of the impacts of the economic crisis and COVID-19 on the livelihoods and food security of people in Lebanon. Due to a combination of containment measures for COVID-19 and a worsening economic crisis, two out of every three Lebanese households suffered from a reduced income compared to the previous year, while about 10 percent across all groups reported that their households are resorting to alternative income sources to make ends meet. The COVID-19 outbreak and related containment measures have pushed nearly one out of every three Lebanese into unemployment so far, while one in five respondents saw that the purchasing power if their salaries was being drastically reduced. Lebanese women as well as young adults between 25-34 years of age have been particularly affected by reduced salaries. (WFP, 2020)

With food prices soaring in Lebanon, food has been a major source of concern for a large proportion of respondents across all three groups. Fifty percent of Lebanese, 63 percent of Palestinians and 75 percent of Syrians felt worried they would not have enough food to eat over the past month. Those who have lost their jobs – either since or prior to the outbreak – have shown to be more distressed than others. To meet their food needs, Lebanese, Syrians and Palestinians are applying one or more food-based coping strategies. (WFP, 2020)

In summary, Lebanon, similar to other neighboring countries, is thus witnessing an increase in the prevalence of diet-related diseases, food insecurity, a rapid nutrition transition coupled with scarcity and poor management of natural resources. The SDGs called for sustainable diets. Previous studies have demonstrated the impact of shifting to healthier food choices on the environment, and in this study, the research is extended to

determine the impact of that shift on cost, in addition to the environmental impact. This study appears to be the first of its kind in the region, and complements previous studies that identified healthy dietary guidelines by assessing the affordability and environmental sustainability of these healthy shifts in consumption. The results from our study will thus encourage policy makers to adopt dietary recommendations that are healthy, environmentally sustainable and affordable allowing the Lebanese to mitigate the economic and health burdens ailing the population.

**G. Objectives of the study:**

The objectives of this study are the following:

- Calculate the cost of actual food consumption in Lebanon based on national consumption data.
- Calculate the local cost of foods based on the EAT-Lancet and Mediterranean dietary recommendation.
- Identify and evaluate the cost of shifting consumption in line with the recommendations of the EAT-Lancet and Mediterranean diets.
- Calculate three EFPs (water use, energy use, GHGE) of national Lebanese food consumption and compare to that of the EAT-Lancet and Mediterranean diets.
- Determine the effect of the shift on the environmental footprints.
- Finally, identify affordable dietary changes to maintain health, and environmental sustainability.

# CHAPTER II

# METHODS

The methods covered in this work include both primary and secondary data. For the collection of the costs of the three diets; particularly Lebanese national consumption, EAT-Lancet diet and Mediterranean diet, prices of food items were collected using a quantitative cross-sectional survey. This survey was based on a food frequency questionnaire (FFQ) derived from Chamieh et al study that was conducted in 2009 and explained further below. On the other hand, for the calculation of environmental footprints of the diets, the EFPs/kg of all food groups included in the diets were derived as secondary data from a previous study done in 2018 by Naja et al. After that, the total EFPs (total water use, total energy use and total GHGEs) of each of the three diets were calculated as explained also below.

**A. Dietary Data (Food Frequency Questionnaire)**

In order to collect prices of the food items that constitute each of the three diets, the food items were drawn from the cross-sectional National Nutrition and Non-Communicable Disease Risk Factor Survey (2008–2009). Following the WHO STEPwise guidelines, a national survey was conducted in Lebanon in 2008–2009. Households were selected randomly from all Governorates based on stratified cluster sampling method (Chamieh et al, 2015). One adult aged 20 years and over was randomly selected from each household for the interview. At the participants' homes, data collection included socio-demographic

and lifestyle questionnaires, anthropometric measurements, biochemical assessment, as well as a food frequency questionnaire for the evaluation of dietary intake (n = 337). The final sample included 1244 men and 1453 women. The study protocol was reviewed and approved by the Institutional Review Board of the American University of Beirut, and informed consent was obtained from all participants in the study. The 61-item FFQ is listed in Appendix 1. This FFQ measured dietary intake over the 1 year preceding the interview in 2009. For each food item listed in the FFQ, a standard portion size was specified and five frequency choices were given (never, daily, weekly, monthly or yearly). The FFQ was designed by a panel of nutritionists and included culture specific dishes and recipes. It was tested on a convenient sample of Lebanese adults to check for clarity and cultural sensitivity. It covered food items across all major food categories (fruits, vegetables, cereals/grains, roots/tubers, meat/poultry, fish, dairy products, fats and oils, desserts and beverages) as well as selected prepared foods. The 61 food items included in the list were grouped into 25 food groups based on similarities in ingredients, nutrient profile, and/or culinary usage and were entered in the factor analysis (Naja et al, 2018). Food items having a unique composition (e.g. eggs, olives, and mayonnaise) were classified individually.

## B. Methods for Calculation of Cost

### *1. Data Collection and Entry*

A market survey of food items sold in the Lebanese market was conducted and prices of specific food items were recorded in Beirut in 2019. Food items in the FFQ used for collecting prices were specified by type, size, and preferred brand (when relevant) to

ensure consistency in data collection across stores. A preliminary version of the food items list was piloted in a grocery store prior to its wider use. Data collection was structured to obtain price information from a range of food retail outlets. A total of 12 types of food retail outlets within Beirut were contacted. These included privately-owned supermarkets, publicly-owned COOP supermarkets, (*dekkene)* or corner stores, greengrocers, butchers, fish markets, dairy stores, bakeries, (*furn)* or traditional bakeries selling a limited range of ready-to-eat bread-based products), roasteries (for coffee and selected sweets products), Arabic sweets shops and restaurants. For each type of food retail outlet, the categories of foods to be selected were specified. For example, data collection at greengrocers was limited to fruits, vegetables, and roots/tubers while at butchers it was limited to meat, poultry, fats and oils.

To account for variation in prices that might reasonably be linked to differences in customers' purchasing power and/or retailers' operating costs (including rent), data were collected from throughout the city using the following sampling strategy: A list of the 60 administrative sectors in the city was obtained (Lebanese Arabic Institute, 2018). Then, a list of residential real estate prices (normalized at price per square meter) for different neighborhoods in Beirut was obtained (Lebanese Examiner, 2017). the research team matched the neighborhoods to the appropriate administrative sectors, excluding five non-residential sectors for which no residential price data was available (e.g., Nouveau Secteur comprised entirely of Beirut's port). Administrative sectors were then assigned to one of five quintiles based on the residential real estate price per square meter (Q1 the highest price, Q5 the lowest price). One administrative sector from within each quintile was then

randomly selected for data collection. The plan for data collection was to obtain prices from 12 food retail outlets in each of the selected administrative sectors, for a total of 60 food retail outlets.

Data collection was performed by a team of four researchers, each responsible for one or two administrative sectors. Data collection was conducted from April to July 2019. It was halted during June to account for Ramadan thereby avoiding fluctuations in prices associated with the holy month and variation in shopping patterns during that time. Researchers visited the first food retail outlet per type, which they encountered within the administrative sector. They presented outlet owners/managers with a formal explanation of the research objectives and obtained their consent to conduct data collection. Most of outlet owners were cooperative, but in few cases, shop owners refused to share prices of their products, so the team had to visit another store. In case the team did not find the specified food item because the preferred brand was unavailable, they recorded data for the similar brand that had similar characteristics and noted the brand difference. In case neither the brand nor anything similar to it were found, researchers visited another food retail outlet of the same type within the same administrative sector. In each quintile, around 12 to 16 venues were contacted. To be more representative of usual price listings, the prices recorded were for only non-sale items as reported in previous studies of food prices and cost of individual diets (Monsivais and Drewnowski, 2003; Drewnowski and Monsivais, 2007; Monsivais, Rehm, and Drewnowski, 2013).

### *2. Data Analysis: Comparison between National Lebanese Consumption and EAT-Lancet Diet Recommendations*

The EAT-Lancet diet specifies daily macronutrient intake in grams for each food group of the following: whole grains, starchy vegetables, vegetables, fruits, dairy foods, protein sources, legumes, added fats and added sugars. In this study, we included all mentioned food groups of the EAT-Lancet diet except for the following: pork, soy foods, lard and palm oil, as they are not commonly consumed in the Lebanese diet, in addition to the limited information available regarding their intake. In order to compare between national Lebanese consumption and the EAT-Lancet recommendations, the macronutrient intakes in grams of the daily Lebanese national consumption data were taken into consideration, exclusively for the food groups specified by the EAT-Lancet. Moreover, the percentage of energy of each food group in the Lebanese diet was also calculated, by summation of the total intake to 2000 Kcal/d (with the items that are not included in the EAT-Lancet diet placed under miscellaneous category and summing to 8.5% of total energy of the Lebanese national consumption). For comparison purposes between the EAT-Lancet recommendations and the intake of the Lebanese national consumption, the macronutrient intake in grams of the specified food groups of the EAT-Lancet diet were converted to their corresponding values based on a diet of 2000 Kcal/day instead of 2500 Kcal/day, thus making the two diets isocaloric. The conversion of each food group of the EAT-Lancet diet in grams to a total diet of 2000 calories was highlighted in yellow in the relevant table in results. Similarly, the percentage of energy of each food group in the EAT-Lancet diet was calculated, with the omitted items (pork, soy foods, lard and palm oil) placed under miscellaneous category.

### *3. Data Analysis: Comparison between National Lebanese Consumption and Mediterranean Diet Recommendations*

In order to compare between national Lebanese consumption and the Mediterranean diet recommendations, the macronutrient intakes in grams of the daily Lebanese national consumption data were taken into consideration, exclusively for the food groups specified by the Mediterranean diet (MD) model described before in the literature. The percentages of energy of each food group of both diets were also calculated, with the summation of total intake to 2000 Kcal/d. The groups of the Lebanese national consumption that were not included were placed under miscellaneous category and accounted for 14.4% of energy of total Lebanese consumption. The two diets are isocaloric, which allowed for easy comparison without the need for any conversion.

### *4. Analytical Analysis: Calculation of Prices per gram, Diet Costs, and Diet Affordability*

The recorded price of each available food item was converted into its price per one gram using the Statistical Package for the Social Sciences software (SPSS). The average price of each item across different venues within the same Q and across all Qs was calculated to get the "total" price of the item per gram across Beirut. Furthermore, the price per gram of each food category was obtained by averaging the prices per gram of the items within each category.

To calculate the prices of each of the three diets, two steps were followed: 1) the grams of each food category specified by the three diets (Lebanese national consumption, EAT-Lancet and MD) were multiplied by the price per gram of each food category. 2) The sum of the prices of all food categories within each diet was calculated. The cost of the national Lebanese consumption (Chamieh et al, 2015) was compared to the cost of the parallel food groups of the EAT-Lancet (Willett et al, 2019), and of the Mediterranean diet (Germani et al, 2014). Note that when comparing between the EAT-Lancet diet and Lebanese diet, only the prices of the food groups specified by the EAT-Lancet were taken into consideration. Similarly, when comparing between the MD and Lebanese diet, only the food groups included in the MD were included. The percentage difference in price of each food group of the total price of each of the three diets was calculated. Difference in price between each food group of the EAT-Lancet and Lebanese diet, and that between the MD and Lebanese diet were calculated. The total difference in price between the EAT-Lancet diet and Lebanese diet, and that between the MD and Lebanese diet were obtained. The values were then divided by the total cost of the Lebanese diet and multiplied by 100. This allowed for estimating percentage difference in price between the three diets.

The minimum wage in Lebanon is 30,000 LL per day, or 675,000 LL (450$) per month according to Country Reports on Human Rights Practices for 2017. Moreover, the average income is around 51,000 LL per day, or 1,156,375 LL (770$) per month according to the World Economic Outlook Database of October 2019. To calculate the affordability of each diet out of minimum wage, the cost of each diet per day in LL was multiplied by 100, and then was divided by the daily minimum wage to obtain a percentage. Moreover, to

calculate the affordability of each diet out of average income, the cost of each diet per day in LL was multiplied by 100, and then was divided by the daily average income to obtain another percentage. This way, the percentages of the cost of each diet per day were obtained, either out of minimum wage, or out of average income, as found appropriate. This is similar to methods reported in other studies such as Barosh et al in 2014 and Hirvonen et al in 2019.

### *5. Ethical Considerations*

The Institutional Review Board (IRB) at the American University of Beirut (AUB) provided approval for this study via an exemption from its review, as the data collection process was designed to collect non-personal information and therefore does not fall under IRB regulations for the protection of human subjects in research.

## C. Calculation of Environmental Footprints

### *1. Deriving EFP/kg of water use, energy use and GHGEs*

To compare the effect of consumption of the specified diets on the environment, three environmental footprints (total water (L), energy (MJ) and greenhouse gas emissions (kgCO2eq)) of the three diets were calculated. The three indices of all relevant food items and groups per kg were obtained using the life cycle approach (LCA) that was reported by Naja et al in 2018.

**-Water use:**

The water use environmental metric consisted of the total water use in liters (blue and green water combined) per kilogram of food consumed. Two important elements were considered in the calculation of the water use metric:

1) Consideration of the domestically produced vs imported proportion of each foods: The Food and Agriculture Organization (FAO) data and the United Nations Comtrade database were used to identify foods that are produced locally versus those that are imported. In addition, for imported foods, we have considered the top two countries by amount from where a certain food is imported.

2) Use of a water stress-based impact assessment method: Following step (1), water use was adjusted for each country using the water stress index (WSI) developed by Pfister et al., 2009. WSI is considered an impact assessment component that allows accounting for crop production in water stressed areas.

In light of these two aforementioned considerations, the water use metric estimation in this study was adjusted using the below formula:

Water use (adjusted)=(Water use∗%produced∗ WSILebanon)+(Water Use∗%importedTotal ∗%importedCountry1∗ WSICountry1)+(Water Use∗%importedTotal∗%importedCountry2∗ WSICountry2)Water use (adjusted)=(Water use∗%produced∗ WSILebanon)+(Water Use∗ %importedTotal∗%importedCountry1∗ WSICountry1)+(Water Use∗%importedTotal∗%im portedCountry2∗ WSICountry2).

**-GHGEs:**

The GHGE metric was calculated in kg CO2 eq/kg food consumed. Most LCAs used in our study reported GHGE in terms of CO2eq. However, a few LCAs reported $CH_4$ and $N_2O$ separately, in addition to $CO_2$. For these LCAs, emissions from $N_2O$ and $CH_4$ were converted to kgCO2eq using the following two equations:

$$CO2eqN2O=XN2O*GWPN2OCO2eqN2O=XN2O*GWPN2O$$

$$CO2eq\ CH4=XCH4*GWPCH4CO2eq\ CH4=XCH4*GWPCH4$$

where $X_{N2O}$ is the amount of $N_2O$ released in kg, $X_{CH4}$ is the amount of $CH_4$ released in kg, $GWP_{N2O}$ is the 100-year global warming potential of $N_2O$, and $GWP_{CH4}$ is the 100-year global warming potential of $CH_4$, $GWP_{N2O} = 265$, and $GWP_{CH4} = 28$.

The total CO2eq was calculated by adding $CO_{2eq\ N2O}$ and $CO_{2eq\ CH4}$ to the $CO_2$ emissions. It is important to note that CH4 emissions from decomposing organic waste in landfills was not directly considered in this analysis due to a lack of specific data for each food item. Fluorinated gases are also not considered as their contributions to the accumulated GHGs of food products may be considered negligible.

**-Energy use:**

'Energy use' is referred to industrial energy consumption while 'energy intake' referred to human energy consumption. Energy use was estimated in MJ/kg food consumed. For all foods considered in this study, energy values and GHG emissions were sourced separately.

***2. Analytical Analysis: Calculation of Environmental Footprints***

The corresponding EFPs of each diet were then calculated with their corresponding standard deviations. This was done by multiplying the EFP/kg of each food group by the grams consumed according to each diet and dividing by 1000. To get total water use, energy use and GHGEs emissions of each diet, each index was then calculated by the summation of its corresponding values across all food groups. Subsequently, the footprints of the Lebanese consumption was compared to that of both the EAT-Lancet diet, and the MD. All comparisons were done based on an average diet of 2000 calories per capita per day. For comparison purposes in the discussion, the EFPs of the national Lebanese food consumption were also calculated based on a hypothetical intake of 2500 kcal/person, to be able to compare the indices with other countries.

***3. Statistical analysis:***

Descriptive statistics were presented as means and standard error (SE) for continuous variables, and as proportions and frequencies for categorical variables. Two one sample T tests were run on SPSS to study the significance of the differences in environmental footprints between: 1) National Lebanese consumption versus the EAT-Lancet diet, and 2) National Lebanese consumption versus the Mediterranean diet.

# CHAPTER III

# RESULTS

## A. National Lebanese Consumption data, 2008-2009 Survey

Table 8 shows the national consumption data for the Lebanese adult. As shown from the table, the highest contribution to energy from the food groups consumed corresponds to refined grains (34.5%), followed by dairy products (8.7%), desserts (8.1%), vegetables (6.9%) and then red meat (6.6%).

**Table 8. Lebanese national food group consumption (in grams) for adults (≥20 years) based on an average total intake of 2000 calories, 2009 (n=2156).**

| Food Groups | Mean intake ±SE (g/day) | Mean % E |
|---|---|---|
| **Grains** | | |

| | | |
|---|---|---|
| **Refined grains** | **279.9±4.9** | **34.5** |
| **Whole grains** | **12.2±1.0** | **1.9** |
| **Starchy vegetables (potato)** | **43.5±1.9** | **3.9** |
| **Vegetables, Total** | **197.1±4.7** | **6.9** |
| **Fruits, Total** | **138.9±4.0** | **4.8** |
| **Dairy products** | **181.3±5.2** | **8.7** |
| **Meat, poultry, sea food** | | |
| **Meat** | **51.0±2.0** | **6.6** |
| **Processed meat** | **5.6±0.5** | **0.7** |
| **Poultry** | **36.7±2.0** | **4.2** |
| **Fish** | **15.7±1.4** | **1.1** |
| **Eggs** | **9.5±0.7** | **0.8** |
| **Legumes** | **47.1±3.0** | **3.6** |
| **Nuts** | **11.0±1.0** | **2.4** |
| **Added Fats & Oils** | **19.0±0.8** | **4.8** |
| **Desserts, added sugars** | **52.4±1.9** | **8.1** |
| **Sugar sweetened beverages** | **163.7±5.6** | **3.7** |
| **Unsweetened beverages** | **16.7±1.9** | **0.02** |
| **Hot beverages (Coffee, Tea)** | **11.2±0.3** | **0.03** |

| | | |
|---|---|---|
| **Fast Food** | **21.0±1.9** | **2.3** |
| **Salty snacks (chips, popcorn)** | **3.8±0.3** | **0.9** |
| **Total** | **--** | **100** |

**B. Total Cost of National Lebanese Consumption per day**

Table 9 shows the total cost of the Lebanese national diet and the percentage contribution of various food groups to the total cost. The average cost of total daily food and beverage consumption sums up to 12,739.8 LL per adult person per day with the following official conversion rate: 1$ = 1515 LL. The first column of the table shows the complete macronutrient intake in grams of each food group specified in the Lebanese national consumption data without any omission. The second column specifies the price (LL) per gram of each of the studied food groups. The third column then displays the total cost of each food group calculated by multiplying the price per g (LL) with the number of grams consumed daily in the Lebanese diet. The last column shows the percentage of cost of each food group from the total cost of the diet (12,739.8 LL). The highest percent contributors to cost corresponded to dairy foods (20.6%), followed by refined grains (15.2%), red meat (13.6%) and then desserts (10.2%).

**Table 9. Prices in LL (1$ = 1515 LL) of food groups of Lebanese national consumption[2].**

| Food Groups | Mean intake (g/day) | Cost per g of food groups (LL) | Cost of national Lebanese consumption (LL) | % Cost of food groups per total cost of diet (LL) |
|---|---|---|---|---|
| **Grains** | | | | |
| Refined grains | 279.9 | 6.9 | 1931.3 | 15.2 |
| Whole grains | 12.2 | 8.1 | 98.8 | 0.8 |
| **Starchy vegetables (potato)** | 43.5 | 2.0 | 87.0 | 0.7 |
| **Vegetables** | 197.1 | 6.7 | 1320.6 | 10.4 |
| **Fruits, Total** | 138.9 | 8.5 | 1180.7 | 9.3 |
| **Dairy products** | 181.3 | 14.5 | 2628.9 | 20.6 |
| **Meat, poultry, sea food** | | | | |
| Meat | 51.0 | 33.9 | 1728.9 | 13.6 |
| Processed meat | 5.6 | 13.8 | 77.3 | 0.6 |
| Poultry | 36.7 | 9.9 | 363.3 | 2.9 |

[2] Prices were collected between the spring and summer of 2019.

| | | | | |
|---|---|---|---|---|
| Fish | 15.7 | 25.2 | 395.6 | 3.1 |
| **Eggs** | 9.5 | 12.5 | 118.8 | 0.9 |
| **Legumes** | 47.1 | 3.3 | 155.4 | 1.2 |
| **Nuts** | 11.0 | 28.3 | 311.3 | 2.4 |
| **Added Fats & Oils** | 19.0 | 9.1 | 172.9 | 1.4 |
| **Desserts, added sugars** | 52.4 | 24.9 | 1304.8 | 10.2 |
| **Sugar sweetened beverages** | 163.7 | 2.2 | 360.1 | 2.8 |
| **Unsweetened beverages** | 16.7 | 2.3 | 38.4 | 0.3 |
| **Hot beverages (Coffee, Tea)** | 11.2 | 12.9 | 144.5 | 1.1 |
| **Fast Food** | 21.0 | 12.8 | 268.8 | 2.1 |
| **Salty snacks (chips, popcorn)** | 3.8 | 13.8 | 52.4 | 0.4 |
| **Total** | ---- | ---- | **12,739.8** | **100** |

**C. Total EFPs of Lebanese National Consumption per day**

Table 10 shows three environmental footprints (total water (L), energy (MJ) and greenhouse gas emissions (kgCO2eq)) of all food groups in the Lebanese national diet per kg (Naja et al, 2018) and the means of these indices per grams consumed per person per day in Lebanon, with their corresponding standard deviations. The highest water use (561.42) in the diet corresponds to the intake of meat (455.47 L) followed by the intake of dairy foods (307.321 L). In case of GHGEs, the highest contributor in the diet correspond to the intake of meat (1.04 kgCO2eq), whereas the highest energy (MJ) corresponds to the intake of sugar sweetened beverages (8.66 MJ) followed by refined grains (4.76 MJ). The total water use, energy and greenhouse gas emissions of the Lebanese diet were 2,233.52 L, 32.23 MJ and 3.47 kgCO2eq respectively.

**Table 10. Environmental footprints associated with Lebanese national consumption, per day.**

| | **EFP/kg** | | | **EFP of Lebanese national consumption (per grams consumed per person per day)** | | |
|---|---|---|---|---|---|---|
| **Food Groups** | **Water (L)** | **Energy (MJ)** | **GHGE (CO2eq)** | **Water (L)**<br>**Mean ± SD** | **Energy (MJ)**<br>**Mean ± SD** | **GHGE (kgCO2eq)**<br>**Mean ± SD** |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Grains** | | | | | | |
| Refined grains | 686.1 | 17 | 1.3 | 192.0431 ± 157.5356 | 4.7584 ± 3.9034 | 0.3639 ± 0.2985 |
| Whole grains | 686.1 | 17 | 1.3 | 8.364 ± 30.8083 | 0.2072 ± 0.7634 | 0.0158 ± 0.0584 |
| **Starchy vegetables (potato)** | 248.7 | 0.5 | 0.12 | 10.811 ± 21.9481 | 0.0217 ± 0.0441 | 0.0052 ± 0.0106 |
| **Vegetables** | | | | | | |
| Dark green vegetables | 334.8 | 26.9 | 1.8 | 16.2528 ± 47.4362 | 1.3059 ± 3.8113 | 0.0874 ± 0.255 |
| Red and orange vegetables | 22.0 | 16 | 0.5 | 0.5757 ± 1.4158 | 0.4187 ± 1.0297 | 0.0131 ± 0.0322 |
| Other vegetables | 188.4 | 24.2 | 0.6 | 23.0298 ± 33.7835 | 2.9582 ± 4.3395 | 0.0733 ± 0.1076 |
| **Fruits, Total** | 1,294.7 | 27.1 | 1.8 | 179.7809 ± 240.2778 | 3.7631 ± 5.0294 | 0.2499 ± 0.3341 |
| **Dairy products** | 1,695 | 12.3 | 1.2 | 307.321 ± 407.7017 | 2.2301 ± 2.9585 | 0.2176 ± 0.2886 |
| **Meat, poultry, sea food** | | | | | | |
| Meat | 8938.7 | 43 | 20.4 | 455.4715 ± 846.5889 | 2.1911 ± 4.0726 | 1.0395 ± 1.9321 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Processed meat | 8938.7 | 43 | 20.4 | 49.9748 ± 226.3256 | 0.2404 ± 1.0887 | 0.1141 ± 0.5165 |
| Poultry | 3256.5 | 22 | 3.7 | 119.6584 ± 303.052 | 0.8084 ± 2.0473 | 0.136 ± 0.3443 |
| Fish | 1246 | 79.8 | 3.5 | 19.5144 ± 82.4852 | 1.2498 ± 5.2828 | 0.0548 ± 0.2317 |
| **Eggs** | 2710 | 11 | 3.5 | 25.6615 ± 91.8292 | 0.1042 ± 0.3727 | 0.0331 ± 0.1186 |
| **Legumes** | 4855.7 | 11.4 | 0.9 | 228.9425 ± 669.8461 | 0.5375 ± 1.5726 | 0.0424 ± 0.1242 |
| **Nuts** | 4942.7 | 5 | 0.4 | 60.9338 ± 235.7741 | 0.0616 ± 0.2385 | 0.0049 ± 0.0191 |
| **Added Fats & Oils** | 1971.7 | 44 | 1.6 | 37.4436 ± 73.1353 | 0.8356 ± 1.6321 | 0.0304 ± 0.0593 |
| **Desserts, added sugars** | 2,185.2 | 23.7 | 4 | 114.5624 ± 196.4468 | 1.2425 ± 2.1306 | 0.2097 ± 0.3596 |
| **Sugar sweetened beverages** | 1741.3 | 52.9 | 2.6 | 284.9919 ± 453.207 | 8.6579 ± 13.7682 | 0.4255 ± 0.6767 |
| **Unsweetened beverages** | 627 | 13.7 | 0.5 | 10.4693 ± 56.036 | 0.2288 ± 1.2244 | 0.0083 ± 0.0447 |
| **Hot beverages (Coffee, Tea)** | 2775.2 | 1.7 | 0.3 | 31.0822 ± 36.8763 | 0.019 ± 0.0225 | 0.0034 ± 0.004 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Fast Food** | 2439.7 | 17 | 16.2 | 51.2419 ± 210.6958 | 0.3571 ± 1.4681 | 0.3403 ± 1.3991 |
| **Salty snacks (chips, popcorn)** | 1244.4 | 6 | 0.5 | 4.6738 ± 18.9988 | 0.0225 ± 0.0916 | 0.0019 ± 0.0076 |
| **Total** | -- | -- | -- | **2,233.5228 ± 890.6654** | **32.2293 ± 17.9673** | **3.4721 ± 2.5495** |

**D. Difference between grams of food groups of daily national Lebanese consumption and EAT-Lancet diet recommendations**

As shown in Table 11, the Lebanese national consumption exceeds the recommended intake of the EAT-Lancet diet when it comes to grains, starchy vegetables, red meat, processed meat, chicken and other poultry, legumes and total sweeteners, whereas, the vegetable, fruit, dairy food, eggs, fish, nuts and unsaturated oil consumption were higher in the EAT-Lancet diet than in national Lebanese consumption patterns. While the recommended intake (185.6 g) of grains of the EAT-Lancet diet is basically whole grains, the majority of the grains consumed in the Lebanese diet is refined (279.9 g of the total 292.1 g), with only 12.2 g in the form of whole grains, which accounts for approximately 6.5% of the recommended amount and 4% of total consumption of grains.

**Table 11. Mean food intake (g/person/day) and percentage contribution to energy of the EAT-Lancet diet as compared to the Lebanese national consumption.**

| | EAT-Lancet diet (Daily intake of 2500 kcal/day) | | Adjustment of EAT-Lancet diet to 2000 kcal/day | Lebanese National Consumption (Daily intake of 2000 kcal/day) | |
|---|---|---|---|---|---|
| **Food Groups** | **Macronutrient intake, g/day** | **Mean Percentage of energy intake (%)** | **Macronutrient intake, g/day** | **Macronutrient intake, g/day** | **Mean percentage of energy intake (%)** |
| Grains | | | | | |
| Rice, wheat, and other | 232 | 32.4 | 185.6 | 279.9<br>Refined | 34.2<br>refined |
| | | | | 12.2<br>Whole | 1.9<br>whole |
| Tubers or starchy vegetables | | | | | |
| Potatoes and cassava | 50 | 1.6 | 40.0 | 43.5 | 3.9 |
| Vegetables | | | | | |
| All vegetables | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Dark green vegetables | 100 | 0.9 | 80.0 | 48.5 | 2.3 |
| Red and orange vegetables | 100 | 1.2 | 80.0 | 26.2 | 0.4 |
| Other vegetables | 100 | 1.0 | 80.0 | 122.2 | 4.0 |
| Fruits | | | | | |
| All Fruit | 200 | 5.0 | 160.0 | 138.9 | 4.8 |
| Dairy Foods | | | | | |
| Whole milk or derivative equivalents (eg, cheese) | 250 | 6.1 | 200.0 | 181.3 | 8.6 |
| Protein sources | | | | | |
| Beef and lamb | 7 | 0.6 | 5.6 | 56.5 | 6.6 |
| Processed meat | 0 | 0.0 | 0.0 | 5.6 | 0.7 |
| Chicken and other poultry | 29 | 2.5 | 23.2 | 36.7 | 4.2 |
| Eggs | 13 | 0.8 | 10.4 | 9.5 | 0.8 |
| Fish | 28 | 1.6 | 22.4 | 15.7 | 1.1 |
| Legumes | | | | | |
| Dry beans, lentils, and peas | 50 | 6.9 | 40.0 | 47.1 | 3.6 |

| | | | | | |
|---|---|---|---|---|---|
| Peanuts | 25 | 5.7 | 20.0 | 12.3 | 2.4 |
| Tree nuts | 25 | 5.8 | 20.0 | | |
| Added fats | | | | | |
| Unsaturated oils | 40 | 14.2 | 32.0 | 12.2 | 4.8 |
| Desserts. added sugars | | | | | |
| All sweeteners | 31 | 4.8 | 24.8 | 52.4 | 8.1 |
| Miscellaneous [3] | -- | 8.9 | -- | -- | 7.6 |

**E. Daily Cost of Lebanese National Consumption as compared to the EAT-Lancet Diet**

Table 12 compares between the costs of the Lebanese national consumption and the EAT-Lancet diet. The total cost of food groups recommended in the EAT-Lancet diet is 10,018.1 LL. whereas the cost of the same food groups in the Lebanese national consumption data summed up to 11,510 LL. As expressed in the table, the EAT-Lancet diet is cheaper than the

[3] The percentage of the miscellaneous group of the EAT-Lancet diet includes pork, soy foods, lard and palm oil. On the other hand, the miscellaneous group of the Lebanese national consumption in the table include hot beverages, sugar-sweetened beverages, unsweetened beverages, salty snacks and fast food.

Lebanese diet (difference of 1,491.9 LL). Table 12 also shows the percentage of difference in cost between the EAT-Lancet diet and the Lebanese national diet for each food group. There is an overall difference of 12.9% in cost between the two diets, with the EAT-Lancet diet being the cheaper. Total grains, starchy vegetables, other vegetables, red meat, processed meat, poultry, legumes and desserts and added sugars are identified as the drivers of higher cost in the Lebanese diet. On the other hand, dark green vegetables, red and orange vegetables, fruits, dairy products, fish, eggs, nuts and added fats and oils are more expensive in the EAT-Lancet diet.

**Table 12. Daily Cost (LL) of EAT-Lancet diet and Lebanese national consumption.**

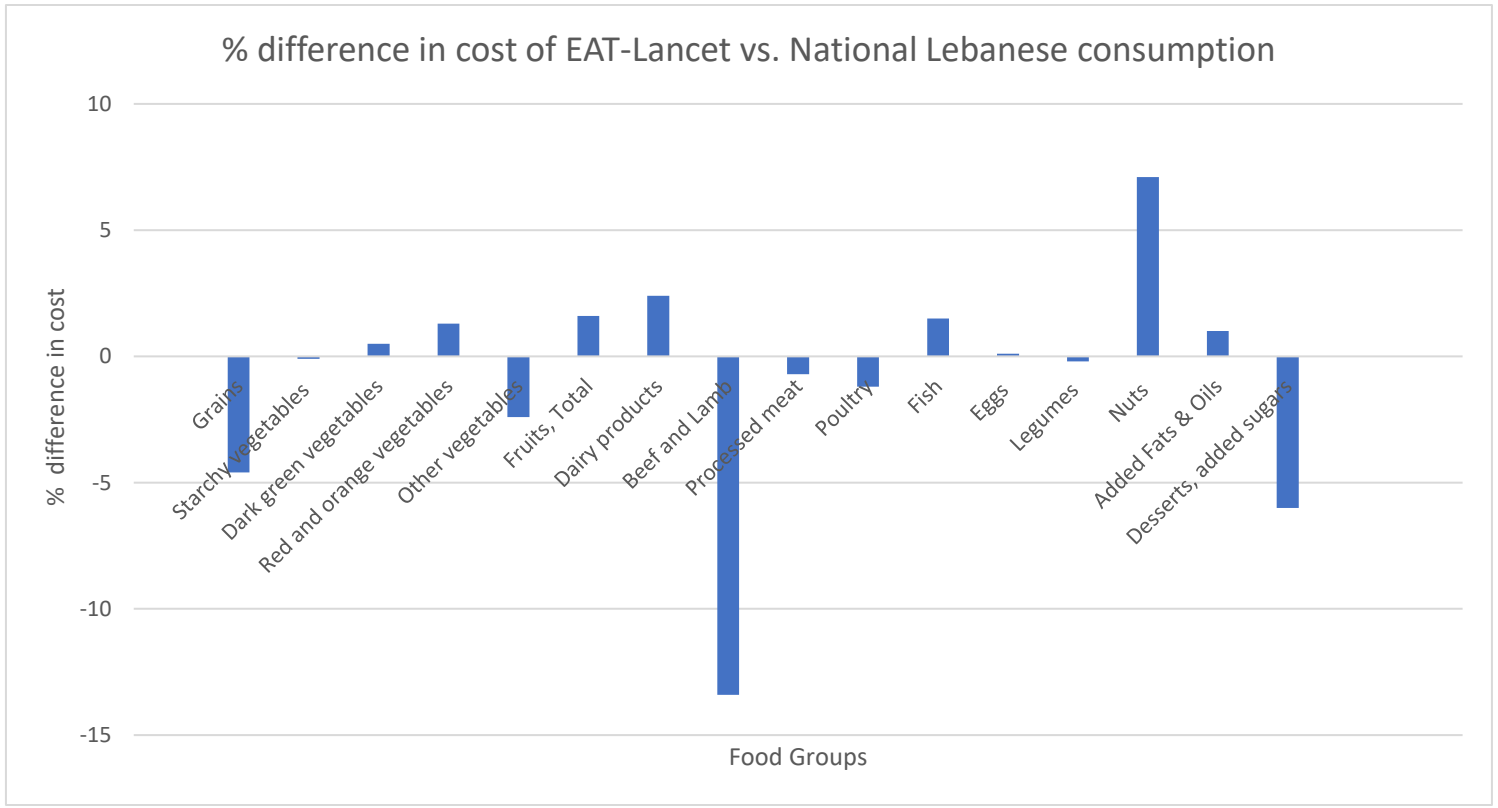
| **Food Groups** | **EAT-Lancet Diet (Daily intake of 2000 Kcal/day)** | | **Lebanese National Consumption (Daily intake of 2000 Kcal/day)** | | **Difference in Cost (EAT-Lancet –Lebanese national consumption)** | |
|---|---|---|---|---|---|---|
| | **Cost (LL)** | **% of cost of food group from total cost of diet** | **Cost (LL)** | **% of cost of food group from total cost of diet** | **Cost Difference (LL)** | **% difference in cost** |
| **Grains** | 1503.4 | 15.0 | 2030.1 | 17.6 | -526.7 | -4.6 |
| **Starchy vegetables** | 80.0 | 0.8 | 87.0 | 0.8 | -7.0 | -0.1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Vegetables** | | | | | | |
| Dark green vegetables | 144.0 | 1.4 | 87.3 | 0.8 | 56.7 | 0.5 |
| Red and orange vegetables | 224.0 | 2.2 | 73.4 | 0.6 | 150.6 | 1.3 |
| Other vegetables | 520.0 | 5.2 | 794.3 | 6.9 | -274.3 | -2.4 |
| **Fruits, Total** | 1360.0 | 13.6 | 1180.7 | 10.3 | 179.3 | 1.6 |
| **Dairy products** | 2900.0 | 29.0 | 2628.9 | 22.8 | 271.1 | 2.4 |
| **Meat, poultry, sea food** | | | | | | |
| Beef and Lamb | 189.8 | 1.9 | 1728.9 | 15.0 | -1539.1 | -13.4 |
| Processed meat | 0 | 0 | 77.3 | 0.7 | -77.3 | -0.7 |
| Poultry | 229.7 | 2.3 | 363.3 | 3.2 | -133.6 | -1.2 |
| Fish | 564.5 | 5.6 | 395.6 | 3.4 | 168.9 | 1.5 |
| **Eggs** | 130.0 | 1.3 | 118.8 | 1.0 | 11.2 | 0.1 |
| **Legumes** | 132.0 | 1.3 | 155.4 | 1.4 | -23.4 | -0.2 |
| **Nuts** | 1132.0 | 11.3 | 311.3 | 2.7 | 820.7 | 7.1 |
| **Added Fats & Oils** | 291.2 | 2.9 | 172.9 | 1.5 | 118.3 | 1.0 |
| **Desserts, added sugars** | 617.5 | 6.2 | 1304.8 | 11.3 | -687.3 | -6.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Total** | **10,018.1** | **100** | **11,510** | **100** | **-1,491.9** | **-12.9** |

Figure 2 graphically displays the percentage difference between the cost of the EAT-Lancet diet and the Lebanese diet for each food group. The columns pointing downwards show how much cheaper the EAT-Lancet diet compared to the Lebanese diet, and the columns pointing upwards express the food groups that are more expensive in the EAT-Lancet diet compared to the Lebanese diet. The relative costs of grains, meat and desserts are substantially less in the EAT-Lancet diet compared to the Lebanese diet, as these food groups are over-consumed in the Lebanese diet. On the other hand, the relative costs of nuts would be higher if the EAT-Lancet diet recommendations were to be followed, as this food group is under-consumed in the Lebanese diet.

**Figure 2. Percentage difference in cost of each food group of the EAT-Lancet diet and Lebanese national consumption[4].**




[4] The percentage difference in cost of each food group between the EAT-Lancet diet and national Lebanese consumption represented in the figure is calculated according to the following: (EAT-Lancet cost of food group - National Lebanese consumption cost of same food group), divided by the total cost of the national Lebanese consumption (11,510 LL), and multiplied by 100.

**F. Comparison between the EFPs of National Lebanese Consumption and that of the EAT-Lancet diet per day**

Table 13 shows three environmental footprints (total water (L), energy (MJ) and greenhouse gas emissions (kgCO2eq)) of all food groups in the EAT-Lancet diet. The total water, energy and GHGE footprints per day based on the recommended grams of the EAT-Lancet diet are 1,379.42 L, 20.26 MJ and 1.44 kgCO2eq respectively. The total of each of the three indices is higher in the Lebanese diet than in the EAT-Lancet diet with the following differences in water use, energy and GHGE respectively: 457.52 L, 2.68 MJ and 1.25 kgCo2eq. The higher differences in water use and GHGEs in the Lebanese diet are mainly driven by the higher intake of meat and desserts, whereas that of energy use is mainly driven by the higher intake of meat and grains.

**Table 13. The environmental impact statements for three environmental indices (Water Footprint, Energy Footprint and Greenhouse gas emissions Footprint) of the EAT-Lancet diet vs. Lebanese national consumption calculated for one day.**

| | **EFP of EAT-Lancet diet (per total grams recommended per person per day)** | | | **EFP of Lebanese national consumption (per total grams consumed per person per day)** | | |
|---|---|---|---|---|---|---|
| **Food Groups** | **Water (L)** | **Energy (MJ)** | **GHGE (CO2eq)** | **Water (L) Mean ± SD** | **Energy (MJ) Mean ± SD** | **GHGE (kgCO2eq) Mean ± SD** |
| **Grains** | 127.3402 | 3.1552 | 0.2413 | 200.4072 ± 156.2501 | 4.9656 ± 3.8715 | 0.3797 ± 0.2961 |
| **Starchy vegetables (potato)** | 9.948 | 0.02 | 0.0048 | 10.811 ± 21.9481 | 0.0217 ± 0.0441 | 0.0052 ± 0.0106 |
| **Vegetables** | | | | | | |
| Dark green vegetables | 26.748 | 2.152 | 0.144 | 16.2528 ± 47.4362 | 1.3059 ± 3.8113 | 0.0874 ± 0.255 |
| Red and orange vegetables | 1.76 | 1.28 | 0.04 | 0.5757 ± 1.4158 | 0.4187 ± 1.0297 | 0.0131 ± 0.0322 |
| Other vegetables | 15.072 | 1.936 | 0.048 | 23.0298 ± 33.7835 | 2.9582 ± 4.3395 | 0.0733 ± 0.1076 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Fruits, Total** | 207.152 | 4.336 | 0.288 | 179.7809 ± 240.2778 | 3.7631 ± 5.0294 | 0.2499 ± 0.3341 |
| **Dairy products** | 339 | 2.46 | 0.24 | 307.321 ± 407.7017 | 2.2301 ± 2.9585 | 0.2176 ± 0.2886 |
| **Meat, poultry, sea food** | | | | | | |
| Meat | 50.0567 | 0.2408 | 0.1142 | 455.4715 ± 846.5889 | 2.1911 ± 4.0726 | 1.0395 ± 1.9321 |
| Processed meat | 0 | 0 | 0 | 49.9748 ± 226.3256 | 0.2404 ± 1.0887 | 0.1141 ± 0.5165 |
| Poultry | 75.551 | 0.5104 | 0.0847 | 119.6584 ± 303.052 | 0.8084 ± 2.0473 | 0.136 ± 0.3443 |
| Fish | 27.9104 | 1.7882 | 0.0782 | 19.5144 ± 82.4852 | 1.2498 ± 5.2828 | 0.0548 ± 0.2317 |
| **Eggs** | 28.184 | 0.1144 | 0.036 | 25.6615 ± 91.8292 | 0.1042 ± 0.3727 | 0.0331 ± 0.1186 |
| **Legumes** | 194.2264 | 0.456 | 0.036 | 228.9425 ± 669.8461 | 0.5375 ± 1.5726 | 0.0424 ± 0.1242 |
| **Nuts** | 197.7076 | 0.2 | 0.0168 | 60.9338 ± 235.7741 | 0.0616 ± 0.2385 | 0.0049 ± 0.0191 |
| **Added Fats & Oils** | 63.0932 | 1.408 | 0.05 | 37.4436 ± 73.1353 | 0.8356 ± 1.6321 | 0.0304 ± 0.0593 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Desserts, added sugars** | 15.6711 | 0.1984 | 0.0176 | 114.5624 ± 196.4468 | 1.2425 ± 2.1306 | 0.2097 ± 0.3596 |
| **Total** | **1,379.421** | **20.2554** | **1.4396** | **1,850.9452 ± 1246.6082** | **22.9397 ± 12.1642** | **2.692 ± 2.1285** |

**G. Difference between grams of food groups of Daily National Lebanese Consumption and Mediterranean Diet Recommendations**

As shown in Table 14, the Lebanese food consumption exceeds the recommended intake of the MD in cheese, red meat, white meat, nuts, sugar and desserts. On the other hand, bread, pasta or rice, starchy vegetable, total vegetable, fruit, milk, yogurt, processed meat, eggs, fish, legumes, unsaturated oil and cookies consumption are higher in the MD than in current Lebanese consumption data. Note that while the recommended intake (150 g) of bread and pasta or rice (80 g) groups of the MD are all whole grains, the majority of the bread consumed in the Lebanese diet is refined (117.2 g of the total 129.6 g), and all of the pasta or rice group is of the refined type.

**Table 14. Mean food intake (g/person/day) and percentage contribution to energy of the Mediterranean diet as compared to the Lebanese national consumption.**

| | Mediterranean Diet (Daily intake of 2000 kcal/day) | | Lebanese National Consumption (Daily intake of 2000 Kcal/day) | |
|---|---|---|---|---|
| **Food Groups** | **Macronutrient intake (g/day)** | **Mean share of energy intake (%)** | **Macronutrient intake (g/day)** | **Mean share of energy intake (%)** |
| Grains | | | | |
| Bread | 150.0 | 20.1 | 129.6 | 23.7 |
| Pasta or Rice | 80.0 | 4.4 | 61.2 | 6.3 |
| Tubers or starchy vegetables | | | | |
| Potatoes | 57.0 | 2.2 | 43.5 | 1.9 |
| Vegetables | | | | |
| All vegetables | 400.0 | 13.0 | 197.1 | 6.8 |

| | | | | |
|---|---|---|---|---|
| Fruits | | | | |
| All Fruit | 450.0 | 11.7 | 138.9 | 4.8 |
| Dairy Foods | | | | |
| Milk | 125.0 | 3.8 | 16.4 | 1.5 |
| Yogurt | 125.0 | 3.7 | 32.9 | 1.5 |
| Cheese | 28.5 | 5.3 | 29.2 | 5.4 |
| Protein sources | | | | |
| Red meat | 14.3 | 1.0 | 56.5 | 6.6 |
| Processed meat | 14.3 | 1.0 | 5.6 | 0.7 |
| White meat | 28.5 | 3.1 | 36.7 | 4.2 |
| Eggs | 14.3 | 1.1 | 9.5 | 0.8 |
| Fish | 42.8 | 2.5 | 15.7 | 1.1 |
| Legumes | | | | |
| Dry beans, lentils, peas | 100.0 | 4.1 | 47.1 | 3.6 |
| Nuts | 6.4 | 1.3 | 12.3 | 2.4 |
| Added fats | | | | |
| Unsaturated oils | 30.0 | 11.6 | 12.2 | 4.8 |
| Desserts. added sugars | | | | |

| | | | | |
|---|---|---|---|---|
| Sugar | 5.0 | 0.9 | 8.7 | 1.6 |
| Dessert | 14.3 | 2.3 | 43.7 | 7.0 |
| Cookies | 30.0 | 6.9 | 2.0 | 0.7 |
| Miscellaneous [5] | -- | -- | -- | 14.6 |

**H. Daily Cost of Lebanese National Consumption as compared to the Mediterranean Diet**

Table 15 compares the costs of the MD and the Lebanese national consumption, taking into account specifically all foods specified by the MD. The total cost of the Mediterranean diet was found to be 13,667.5 LL. For the sake of comparison, the costs of the same food groups and food items were obtained from the Lebanese national consumption data, summing to 9,239.3 LL. As expressed in the table, the MD is 47.9% more expensive than the Lebanese diet (total difference is 4,428.2 LL). The last column of the table shows the percentage of difference in cost between the MD and the Lebanese diet for each food group. The grains, starchy vegetables, vegetables, fruits, milk, yogurt, processed meat, fish, eggs, legumes, added fats and oils and cookies are the

[5] The percentage of the miscellaneous group of the Lebanese national consumption in the table includes: hot beverages, sugar-sweetened beverages, unsweetened beverages, salty snacks, fast food, and grains and dairy foods other than the types included in Table 13.

food groups that are consumed more in the MD and thus are more expensive. On the other hand, the cheese, red meat, poultry, nuts, added sugars and desserts are the groups were more expensive in the Lebanese diet.

**Table 15. Daily Cost (LL) of Mediterranean diet and Lebanese national consumption.**

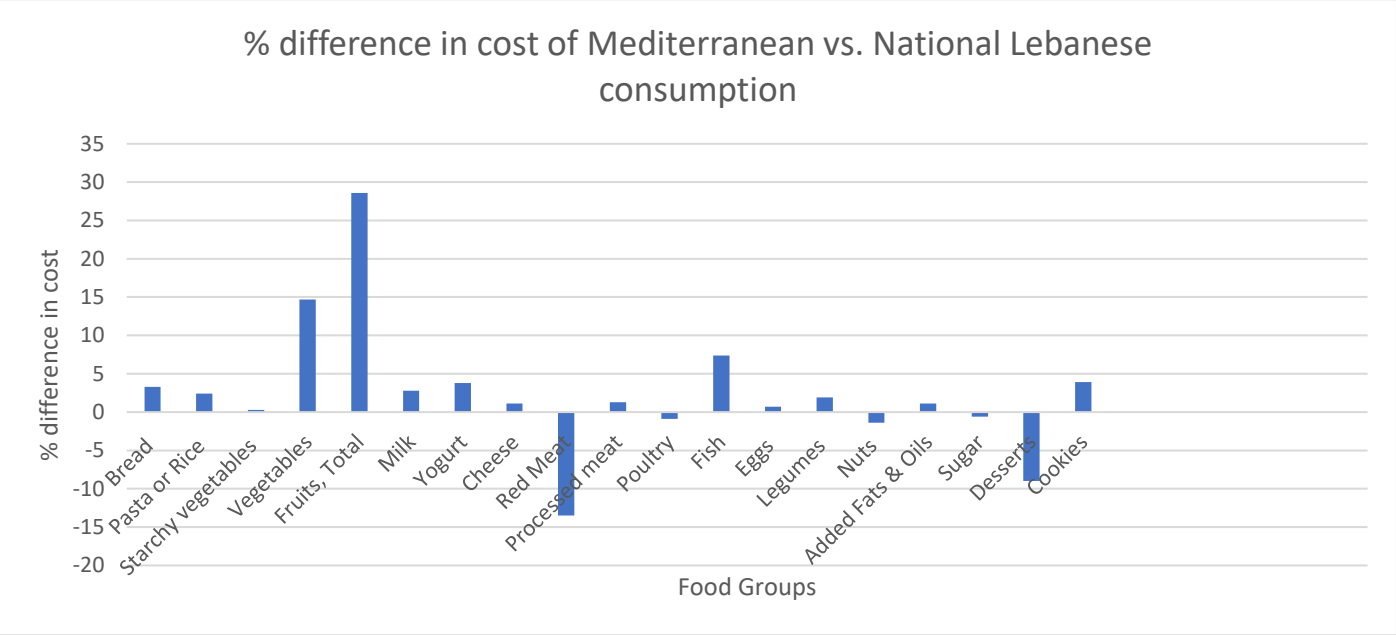
| | **Mediterranean Diet (MD) Recommendations (Daily intake of 2000 kcal/day)** | | **Lebanese National Consumption (Daily intake of 2000 Kcal/day)** | | **Difference in Cost (MD – Lebanese national consumption)** | |
|---|---|---|---|---|---|---|
| **Food Groups** | **Cost (LL)** | **% of cost of food group from total cost** | **Cost (LL)** | **% of cost of food group from total cost of diet** | **Cost Difference (LL)** | **% difference in cost** |
| **Grains** | | | | | | |
| Bread | 1215.0 | 8.9 | 909.2 | 9.8 | 305.8 | 3.3 |
| Pasta or Rice | 648.0 | 4.7 | 422.1 | 4.6 | 225.9 | 2.4 |
| **Starchy vegetables** | 114.0 | 0.8 | 87.0 | 0.9 | 27 | 0.3 |
| **Vegetables** | 2680.0 | 19.6 | 1320.6 | 14.3 | 1359.4 | 14.7 |
| **Fruits, Total** | 3825.0 | 28.0 | 1180.7 | 12.8 | 2644.3 | 28.6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Dairy products** | | | | | | |
| Milk | 300.0 | 2.2 | 39.4 | 0.4 | 260.6 | 2.8 |
| Yogurt | 475.0 | 3.5 | 124.9 | 1.4 | 350.1 | 3.8 |
| Cheese | 522.5 | 3.8 | 424.4 | 4.6 | 98.1 | 1.1 |
| **Meat, poultry, sea food** | | | | | | |
| Red Meat | 484.8 | 3.5 | 1728.9 | 18.7 | -1244.1 | -13.5 |
| Processed meat | 197.3 | 1.4 | 77.3 | 0.8 | 120 | 1.3 |
| Poultry | 282.2 | 2.1 | 363.3 | 3.9 | -81.1 | -0.9 |
| Fish | 1078.6 | 7.9 | 395.6 | 4.3 | 683 | 7.4 |
| **Eggs** | 178.8 | 1.3 | 118.8 | 1.3 | 60 | 0.7 |
| **Legumes** | 330.0 | 2.4 | 155.4 | 1.7 | 174.6 | 1.9 |
| **Nuts** | 181.1 | 1.3 | 311.3 | 3.4 | -130.2 | -1.4 |
| **Added Fats & Oils** | 273.0 | 2.0 | 172.9 | 1.9 | 100.1 | 1.1 |
| **Desserts, added sugars** | | | | | | |
| Sugar | 87.5 | 0.6 | 144.6 | 1.6 | -57.1 | -0.6 |
| Desserts | 404.7 | 3.0 | 1236.7 | 13.3 | -832 | -9.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Cookies | 390.0 | 2.9 | 26.2 | 0.3 | 363.8 | 3.9 |
| **Total** | **13,667.5** | **100** | **9,239.3** | **100** | **4,428.2** | **47.9** |

Figure 3 summarizes the percentage difference between the MD and the Lebanese diet for each food group. The columns pointing downwards indicate food groups or items for which the MD is less expensive than the Lebanese diet, and the columns pointing upwards express the food groups that are more expensive in the MD compared to the Lebanese diet. The percentage cost of vegetables, fruits and fish are higher in the Mediterranean diet because these food groups are under-consumed in the Lebanese diet compared to MD. On the other hand, the percentage costs of meat and desserts are substantially less in the MD compared to the Lebanese diet because these groups are over-consumed in the Lebanese diet.

**Figure 3. Percentage difference in cost of each food group of the Mediterranean diet and Lebanese national consumption[6].**




[6] The percentage difference in cost of each food group between the Mediterranean diet and national Lebanese consumption represented in the figure is calculated according to the following: (Mediterranean diet cost of food group - National Lebanese consumption cost of same food group), divided by the total cost of the national Lebanese consumption (9,239.3 LL), and multiplied by 100.

**I. Comparison between the EFPs of National Lebanese Consumption and that of the Mediterranean diet per day**

Table 16 shows three environmental footprints (total water (L), energy (MJ) and greenhouse gas emissions (kgCO2eq)) of all food groups and items in the Mediterranean diet (Germani et al, 2014). The total water, energy and GHGEs footprints per day based on the recommended grams of the MD are 2,191.62 L, 53.44 MJ and 5.02 kgCO2eq respectively. On the other hand, the table shows the same indices as per Lebanese national consumption based on the same food groups and items specified in the MD, with their corresponding standard deviations. The total of each index is higher in the MD than in the Lebanese diet with the following differences in water use, energy and GHGEs respectively: 552.90 L, 33.68 MJ and 2.61 kgCo2eq. The higher difference in water use in the MD is mainly driven by the higher intake of fruits and legumes, whereas that of energy and GHGEs are mainly driven by the higher intake of fruits and yogurt. These values exceed the higher water, energy and GHGEs indices in the Lebanese national consumption driven by higher consumption of meat and sugar compared to the Mediterranean diet.

**Table 16. The environmental impact statements for three environmental indices (Water Footprint, Energy Footprint and Greenhouse gas emissions Footprint) of the Mediterranean diet vs. Lebanese national consumption calculated for one day.**

| | **EFP of Mediterranean diet ( per total grams recommended per person per day)** | | | **EFP of Lebanese national consumption (per total grams consumed per person per day)** | | |
|---|---|---|---|---|---|---|
| **Food Groups** | **Water (L)** | **Energy (MJ)** | **GHGE (CO2eq)** | **Water (L) Mean ± SD** | **Energy (MJ) Mean ± SD** | **GHGE (kgCO2eq) Mean ± SD** |
| **Grains** | | | | | | |
| Bread | 76.1955 | 2.925 | 0.129 | 66.4809 ± 60.3898 | 2.1071 ± 1.914 | 0.1126 ± 0.1022 |
| Pasta or Rice | 41.7072 | 1.4216 | 0.1064 | 57.1026 ± 113.8236 | 1.1352 ± 2.2628 | 0.1195 ± 0.2382 |
| **Starchy vegetables (potato)** | 14.1759 | 0.0285 | 0.0068 | 10.811 ± 21.9481 | 0.0217 ± 0.0441 | 0.0052 ± 0.0106 |
| **All Vegetables** | 73.366 | 9.131 | 0.342 | 36.1557 ± 40.2398 | 4.4998 ± 5.0081 | 0.1685 ± 0.1876 |
| **Fruits, Total** | 582.6162 | 12.195 | 0.8099 | 179.7809 ± 240.2778 | 3.7631 ± 5.0294 | 0.2499 ± 0.3341 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Dairy products** | | | | | | |
| Milk | 68.4675 | 3.9663 | 0.1875 | 9.0706 ± 32.7171 | 0.5254 ± 1.8953 | 0.0613 ± 0.221 |
| Yogurt | 115.0738 | 11 | 1.75 | 30.8192 ± 84.5746 | 0.1942 ± 0.5328 | 0.0136 ± 0.0373 |
| Cheese | 125.1478 | 2.508 | 0.399 | 129.4842 ± 234.4522 | 0.171 ± 0.3097 | 0.012 ± 0.0217 |
| **Meat, poultry, sea food** | | | | | | |
| Meat | 127.8236 | 0.6149 | 0.2917 | 455.4719 ± 846.5897 | 2.1911 ± 4.0726 | 1.0395 ± 1.9321 |
| Processed meat | 127.8236 | 0.6149 | 0.2917 | 49.9748 ± 226.3256 | 0.2404 ± 1.0887 | 0.1141 ± 0.5165 |
| Poultry | 92.8105 | 0.627 | 0.104 | 119.6584 ± 303.052 | 0.8084 ± 2.0473 | 0.136 ± 0.3443 |
| Fish | 53.3288 | 3.4167 | 0.1494 | 19.5144 ± 82.4852 | 1.2498 ± 5.2828 | 0.0548 ± 0.2317 |
| **Eggs** | 38.7523 | 0.1573 | 0.0495 | 25.6615 ± 91.8292 | 0.1042 ± 0.3727 | 0.0331 ± 0.1186 |
| **Legumes** | 485.566 | 1.14 | 0.09 | 228.9425 ± 669.8461 | 0.5375 ± 1.5726 | 0.0424 ± 0.1242 |
| **Nuts** | 31.6332 | 0.032 | 0.0027 | 60.9338 ± 235.7741 | 0.0616 ± 0.2385 | 0.0049 ± 0.0191 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Added Fats & Oils** | 59.1499 | 2.7 | 0.1812 | 37.4436 ± 73.1353 | 0.8356 ± 1.6321 | 0.0304 ± 0.0593 |
| **Desserts, added sugars** | | | | | | |
| Sugar | 3.1595 | 0.04 | 0.0036 | 5.5124 ± 10.1223 | 0.0698 ± 0.1281 | 0.0062 ± 0.0114 |
| Dessert | 31.2484 | 0.3389 | 0.0572 | 112.4696 ± 224.9206 | 1.2085 ± 2.4168 | 0.2089 ± 0.4178 |
| Cookies | 43.575 | 0.585 | 0.072 | 2.9408 ± 17.0589 | 0.039 ± 0.2261 | 0.0031 ± 0.0181 |
| **Total** | **2,191.621** | **53.4421** | **5.0236** | **1,638.7185 ± 1204.2753** | **19.7652 ± 11.9663** | **2.4167 ± 2.1235** |

# CHAPTER IV

# DISCUSSION

This study is one of the few to analyze the economic cost, health aspects, and environmental footprints of the Lebanese diet and the impact of shifting to internationally recommended guidelines. It aimed at analyzing the quantitative environmental and economic impacts of shifting the national food consumption pattern of Lebanese adults, to that of alternative healthier diets, selected as the EAT-Lancet and Mediterranean diets.

In this paper, and based on the food consumption survey conducted in Lebanon in 2008-2009, Lebanese adults consume less than the WHO recommended 400 g of fruits and vegetables per day and exceed the acceptable intake of 10% of free sugar, as defined by the WHO. In accordance with data reported from other parts of the world, these findings suggest that the adult population in Lebanon is at an increased risk of adopting the westernized dietary pattern. This pattern is characterized by low intake of fiber, as the majority of grains consumed in the Lebanese diet are refined. It is also characterized by low intake of fruits and vegetables and high intake of fats and sugars.

The average cost of the Lebanese diet in 2019 is calculated at 12,739.8 LL per capita per day. This cost encompasses all food elements included in the 2008-2009 national survey (Table 9). This figure corresponds to approximately 42% of Lebanon's daily minimum wage and 25% of daily average income. This relatively high proportion is not atypical, as there are only eight countries in the world that spend less than 10% of their household income on food (USDA, 2015). Four of these are in Europe: the UK is third at 8.2%,

followed by Switzerland at 8.7%; Ireland spends 9.6% and Austria 9.9%. The remaining four countries are spread across the globe. The US spends the least at 6.4%, Singapore spends the second lowest amount at 6.7%. Canada spends 9.1% on food, while Australia spends 9.8%. On the other hand, middle and low income countries spend more on food. Nigeria spends over half of household income on food, and there are nine other countries that spend over 40% on food. Four of them are in Africa: Nigeria 56.4%; Kenya 46.7%; Cameroon 45.6%; and Algeria 42.5%. Four are in Asia: Kazakhstan 43.0%; Philippines 41.9%; Pakistan 40.9%; and Azerbaijan 40.1%. Guatemala is the only South American country to appear in the list and spends 40.6% of its household income on food. The figures do not mean that food is more expensive in Nigeria than in the US, but it is the cost of food as relative to income that leads to the difference. Below in Table 17, is the ranking of these countries according to the percentage of income spent on food in ascending order. In Lebanon, the highest cost percentages of the food groups in the diet in a descending order correspond to dairy foods (20.6%), followed by refined grains (15.2%), red meat (13.6%) and then desserts (10.2%).The volumes of intake of red meat and desserts are both high, and their corresponding prices are also relatively elevated compared to the rest of the food groups. The price of refined grains is relatively low, but the average amount that is consumed on daily basis is very high. Compared to other non-alcoholic beverages, both price and volume of intake of hot beverages are elevated. This is consistent with analysis of patterns of Lebanese spending, which shows that the “Non-alcoholic drinks” segment, including coffee, tea, cocoa, water, soft drinks and fruit/vegetable juices is forecast to grow by an average of 7.1% over the period between 2019 and 2023. Although the amount of dairy foods consumed is less than recommended by FAO for Lebanon (three servings per

day), the relatively high price of this food group means that it accounts for the highest percentage from total price of diet. WHO states that there are no global recommendations for milk or dairy consumption. Therefore, most countries have developed their own national dietary guidelines, including Lebanon (Houalla et al, 2012).

Table 17. Percentage of consumer expenditure spent on food in different countries in ascending order.

| Country | Percentage of income spent on food |
|---|---|
| 1. United States of America | 6.4% |
| 2. Singapore | 6.7% |
| 3. United Kingdom | 8.2% |
| 4. Switzerland | 8.7% |
| 5. Canada | 9.1% |
| 6. Ireland | 9.6% |
| 7. Australia | 9.8% |
| 8. Austria | 9.9% |
| 9. Lebanon | 25.0% |
| 10. Azerbaijan | 40.1% |
| 11. Guatemala | 40.6% |
| 12. Pakistan | 40.9% |
| 13. Philippines | 41.9% |

| | |
|---|---|
| 14. Algeria | 42.5% |
| 15. Kazakhstan | 43.0% |
| 16. Cameroon | 45.6% |
| 17. Kenya | 46.7% |
| 18. Nigeria | 56.4% |

The EFPs of the Lebanese food consumption (Table 10) were calculated and compared to the EFPs of other countries. The numbers for the EFPs from other countries were obtained from the previously mentioned study of Naja et al in 2018, and the calculations of the EFPs are all for a diet of 2500 calories per capita per day. For water use, in this study, the average per-person water use (2,791.9L/day) was equal to the global average (2,799 L/day) and higher than estimates obtained for Finland (2,377 L/day). Note that Finland is ranked among the top few countries when it comes to water and environmental management. Water use of food consumption in the United States and Italy had higher estimates (3998 L/day and 3469 L/day, respectively). This consumption in Lebanon is ought to be taken into consideration especially in view of the scarcity of natural resources. Lebanon together with other countries of the MENA region are among the most water stressed areas of the world, whereby the water availability per person is more than six times below the global average (1383 m3 to 8462 m3). The within-range estimate for water use associated with food consumption in this study, coupled with water scarcity in the country, is alarming in view of the high water cost of agricultural production. Particularly due to the fact that the forecasted climate change is expected to further reduce rainfall by 6–

8%, snow cover by 40%, and prolong drought periods for every 1 °C of temperature rise. Regarding energy, the estimate obtained in this study (40.2 MJ/day) is higher than that of the United States (28 MJ/day). This finding is alarming especially that Lebanon relies almost solely on imported energy, whether in the form of gas or oil, while its average citizen consumes greater kWh as compared to global estimate. As for GHGEs associated with food consumption in Lebanon, the results of the study revealed an estimate (4.3 kgCO2eq) that is higher than other Mediterranean countries such as Greece (3.6 kg CO2eq/day) and than the United States (3.56 kg CO2eq/day), and closer to estimates reported in France (4.8 kg CO2eq/day). Such differences could be explained by variations in processes of agricultural practices/food production, or composition of food consumption. In this study, the main contributors to EFPs, in terms of foods and food groups, were identified. Within the Lebanese dietary pattern, meat, refined grains, hot and sugar-sweetened beverages contributed most to EFPs. In many countries, red meat was identified as the greatest contributor to diet-related as well as overall agricultural GHGE. For example, Hendrie et al (2014) showed that red meat and non-core foods (which included processed meats, hot drinks and other energy-dense food items) accounted for the greatest contribution to GHGEs in the Average Australian Diet. Although in general, grains are reported to be low on environmental impact, however, their high consumption by Lebanese adults led to their large contribution to the EFPs of the current dietary pattern.

In comparison to the EAT-Lancet diet, the Lebanese individual consumes less fruits and vegetables. The Lebanese national dietary consumption survey of 2009 also documented a lower consumption of nuts. On the other hand, the amount of red meat, processed meat and grains consumed daily by the average Lebanese was found to be higher

than that recommended by the EAT-Lancet diet. Moreover, the daily-allowed amount of total sweeteners by the EAT-Lancet diet is less than the amount consumed in the national Lebanese consumption.

In this study, we compared the individual's daily cost of the EAT-Lancet diet with the one typically consumed by the Lebanese population, after adjusting the number of calories of both diets to 2000 calories per day. The comparison incorporated the food groups specified by the EAT-Lancet diet only, without miscellaneous groups of both diets (Table 11). The comparison showed that the EAT-Lancet diet, if followed, would be less expensive than the typical Lebanese diet with a substantial difference in allocating the budget to different food groups. In particular, the actual daily expense that the Lebanese individual spends to purchase meat (beef and lamb) is 13.4% more than the one that should be dedicated to this food group according to the EAT-Lancet recommendations. Moreover, there is a 6% increase in dessert' purchases in the Lebanese diet compared to the EAT-Lancet. The intake of grains (with the majority of them being of the refined type), is 4.6% higher than the recommended in the EAT-Lancet diet. On the contrary, to meet the EAT-Lancet guidelines, the average Lebanese individual would be spending daily 7.1% more of the budget to purchase nuts, 2.4% more to purchase dairy foods, 1.5% more to purchase fish, 1.6% more for fruits and 1.3% more for red and orange vegetables, than what is already spent in the Lebanese diet. Regarding eggs, legumes and starchy vegetables, there were no substantial budget differences. Overall, the EAT-Lancet diet is 12.9% less expensive than the actual Lebanese diet, if we were to take into consideration the food groups specified by the EAT-Lancet diet only without miscellaneous groups. Therefore, the Lebanese ought to decrease their intake of red meat and desserts to achieve health,

environmental, and economic outcomes. This budget could be better dedicated to purchase other foods, such as fruit and vegetables, milk and dairy products, and nuts that are consumed by the Lebanese population in lower quantities compared to the EAT-Lancet recommendations. It appears that the food choices of the Lebanese population are thus far from the EAT-Lancet recommendations, but not for budgetary reasons, as adopting the EAT-Lancet recommendations would be cost effective compared to actual consumption.

In their 2019 study, Hirvonen et al did not compare the cost of the EAT-Lancet diet to the actual consumption of the populations of the countries involved. Instead, they constructed an EAT-Lancet model and compared its cost to household income and to the least-cost combination of foods that meet daily requirements of 20 essential nutrients. According to our study, the cost of the EAT-Lancet diet in Lebanon is 6.61$ in 2019, however the actual Lebanese consumption that takes into account the food groups recommended by the EAT-Lancet diet only (Table 12) costs 7.60$. Importantly, Hirvonen et al. constructed their EAT-Lancet model based on the least cost items. However, in our study, the data collectors obtained prices from a spectrum of food items and brands and then obtained an average of their overall prices, which could thus explain why the total cost of the EAT-Lancet diet is significantly higher in this study. This is also evident by studies that show that the cost of healthier foods could be decreased substantially if choices were made wisely (Temple & Steyn, 2011). Moreover, the prices in our study were collected in the area of Beirut, a city of high cost living in Lebanon. In the study by Hirvonen et al, the largest share of total cost of the EAT-Lancet diet was the cost of fruits and vegetables (31.2%), followed by legumes and nuts (18.7%), meat, eggs, and fish (15.2%), and dairy (13.2%). The researchers concluded that fruits, vegetables and animal source foods are the

most expensive components of the EAT-Lancet diet. However, in the current study, the largest share of the cost of the EAT-Lancet diet was the cost of dairy foods (29%) followed by whole grains (15%) and then fruits (13.6%). Nevertheless, the share of dairy foods in the Lebanese diet is 22.8%, that of grains is 17.6% and that of fruits is 10.3%. What accounted for the difference making the Lebanese diet more expensive despite less intake of fruits and dairy foods is the high share of meat (15%) and added sugars and desserts (11.3%) in the total cost of the Lebanese diet, along with the higher intake of refined grains. Thus, consuming less meat and added sugars and desserts, which are relatively more expensive than other food groups, can easily account for the EAT-Lancet recommendations of higher intake of dairy foods, fruits and nuts in Lebanon. This would also account for replacing refined grains in the actual Lebanese consumption with whole grains as per the recommendations of the EAT-Lancet diet.

The affordability of the EAT-Lancet diet, in the study by Hirvonen et al mentioned above, as a proportion of mean daily household income per capita, was 27.5% (19.5–32.5) in upper-middle-income countries. In our study, the percentage of cost of the EAT-Lancet diet from daily average income per capita is around 20% in Lebanon. Moreover, the Hirvonen et al study estimated that the cost of the EAT-Lancet diet exceeds total income for at least 1.58 billion people, out of which 80% (1.26 billion) are in middle income countries (Hirvonen et al, 2019). However, this current study shows that in Lebanon, the EAT-Lancet diet costs one-third the total daily minimum wage and around 20% of average income, and thus does not exceed neither of these values.

Similar to our results, Lee et al. (2016) concluded that healthy diets consistent with the Australian Dietary Guidelines are actually cheaper than Australians' current diets, which

tend to be less healthy. All households, across a range of different household structures, were found to spend more buying current (unhealthy) diets than the amount required to buy healthy (recommended) diets. Depending on the household, the healthy diet cost between 66% and 99% of the money currently being spent on food and drinks. The study showed that healthy diets would be 12–15% cheaper than unhealthy diets for a family of two adults and two children. This percentage is very close to the calculated cost advantage of the EAT-Lancet diet as compared to the actual Lebanese consumption in our study. Moreover, households in all socioeconomic areas spend more on unhealthy food and drink choices than on healthy food and drinks. Lee thus explained that there is a perception that healthier foods are more expensive than unhealthy foods. However, when one compares the cost of what people are actually eating, the healthier diet is actually cheaper. Significantly, Lee et al.'s research found that while approximately 29% of the food dollar should be spent on fruits and vegetables to achieve recommended intakes, Australians are currently only spending 10-15%. Expenditure on other important foods such as wholegrain cereals, lean meats, poultry, fish, eggs, milk, cheese and yogurt was also less than what is required. Worryingly, more than half of the food dollar (53% to 64%) in both high and low socio-economic locations was being spent on discretionary choices including alcohol, takeaway foods (such as hamburgers and pizzas) and sugar-sweetened beverages. As for why people consume less healthy foods although they are more expensive, Lee's understanding from her findings is that food choice is driven by many other factors than just price. The researcher explained that the convenience and time-saving nature of discretionary choices can be important, and the ubiquitous advertising, promotion and availability of unhealthy products all drive consumption. Simply put, the researcher concluded that it is easier to eat

unhealthy profitable products which the global food system is designed to make people do. (Lee et al, 2016)

The total water use, energy and GHGE indices are higher in the Lebanese diet than in the EAT-Lancet diet (Table 13) with the following differences in water use, energy and GHGE respectively: 457.52 L, 2.68 MJ and 1.25 kgCo2eq. The one sample T test was statistically significant for all the EFP measures comparing the Lebanese national consumption and the EAT-Lancet diet (all p-values <0.001). This study highlights the fact that the EAT-Lancet diet has a lower environmental impact compared to the actual diet of the Lebanese population. This is linked to larger portion sizes and higher frequencies of consumption than those recommended in the EAT-Lancet, especially regarding red meat, added sugars and desserts, and refined grains.

In our study, decreasing the intake of meat to meet the EAT-Lancet recommendations would lead to around 25% decrease in water use than that of the current diet. Moreover, in the study done by Naja et al in 2018, the dietary pattern characterized by high intake of fruits, vegetables and legumes was associated with lower odds (approximately half) of energy use than that of the Western pattern, which is characterized by the high intake of meat, fast food and added sugars with significant differences. Our results show that adopting the EAT-Lancet recommendations would lead to around 12% decrease in energy use as compared to actual intake. Moreover, in our study, the decrease in the intake of meat in order to meet the recommendations of the EAT-Lancet diet would lead to around 39% decrease in total GHGEs. From an environmental perspective, the most important aspects that differentiate current national food based dietary guidelines from dietary patterns that

are within environmental limits, such as the EAT-Lancet diet, are the amounts of animal source foods, in particular red meat and dairy (Springmann, 2020).

As compared to the Mediterranean diet, the Lebanese individual consumes nearly half the amount of vegetables, and about 30% of the amount of fruits recommended by the MD. The national survey has also documented a lower consumption of fish, milk and yogurt. The Mediterranean diet model used in this study also has higher recommendations of bread and pasta/rice. However, the type consumed in the Lebanese national consumption is refined which is opposed to the whole grain recommendation by the MD. On the other hand, the amount of red and white meat consumed daily by the average Lebanese was found to be higher than that recommended by the Mediterranean diet, and so were the sugar and desserts groups.

Regarding the cost analysis of the Mediterranean diet (Table 15), comparing an individual's daily budget to afford the Mediterranean diet with the one actually sustained by the Lebanese population, it emerges that the MD would be 47.9% more expensive due mainly to differences in the volumes recommended by the MD compared to national consumption. This would be the case if we take into consideration all groups specified by the MD only without miscellaneous groups of the Lebanese actual consumption. In particular, the amount of fruits and vegetables recommended by the MD (450 g and 400 g respectively) are more than double the actual daily intake of the Lebanese population of these two food groups. Thus, to meet the MD guidelines, the average Lebanese individual would be spending daily 28.6% more of the budget to purchase fruits, 14.7% more to purchase vegetables, and 7.4% more to purchase fish. On the other hand, the Lebanese individual spends 13.5% more on meat and 9% more on desserts than the MD allows. Regarding

cheese, eggs, poultry, fats and oils, there are no substantial budget differences. If the Lebanese individual tends to consume less red meat, poultry, nuts, added sugars and desserts, and adhere to the amounts provided by the MD, this would then eliminate more than half the difference between the budgets of the MD and the Lebanese diet.

In contrast to our findings, Germani et al (2014) found no differences in the total budget between the actual monthly expense of the Italian family and that of the MD. This is despite the fact that we used in this study the same MD model used in the Germani et al study of 2014. Similar to our results, the budget allocated for vegetables, fruits, milk and eggs was less in the actual consumption than the recommended by the MD, whereas that allocated for red meat was more in the actual consumption than the recommended by the MD. Nevertheless, it should be noted here that the budget of the actual consumption of the Italians included an extra of 50 Euros monthly to purchase drinks, including water. If we were to place the budget for drinks in the actual Italian consumption under miscellaneous category, as we did in our study, the budget for drinks would not be included anymore when calculating the cost of actual Italian consumption. This way, the monthly budget of the MD would become 10% more than the monthly budget of the Italian population in the Germani et al study.

Looking at the affordability of the Mediterranean diet, our results show that the MD accounts for around 45% of minimum wage, and around 27% of average daily income per capita. If we compare the cost of the Lebanese diet to that of the MD, taking into account the food groups specified by the MD only (Table 15), we will have a diet that is high in added sugars and desserts, low in fruits and vegetables, and is less expensive than the MD. This diet would account for around 30% of minimum wage and 18% of average daily

income. These results are consistent with earlier studies that have shown that the Mediterranean dietary pattern is more expensive to follow than a Western dietary pattern (e.g.,Preedy and Watson, 2014). According to results that have emerged from a cohort of Spanish university graduates in 2009, subjects reporting highest scores for the Western dietary pattern spent less money on their daily food costs compared to those having highest adherence to Mediterranean dietary pattern (Lopez et al, 2009). In a study done in a large population in the UK, greater adherence to the Mediterranean diet was associated with higher dietary cost than the Western pattern in 2018 (Tong et al, 2018). However, food choice plays a critical role. In a study done in the US, food-price data for the key foods in the Mediterranean diet were gathered in three principal Seattle supermarkets, in 2006 (Drewnowski and Eichelsdoerfer, 2009). Exploring the relation between energy density and food cost per 100 g revealed a wide variation, both within and across food groups. For example, the price of fresh fruit varied widely from $0.05–0.10 per 100 g to as much as $3.00–5.00 per 100 g, stressing again the importance of food choices.

The Mediterranean diet model that was used in our study and in that done by Germani et al in 2014 was the revised edition of the Mediterranean pyramid based on the model of MD by Bach-Faig et al in 2011. While there is no one single definition of the Mediterranean diet, it is typically high in vegetables, fruits, whole grains, legumes, nut and seeds and olive oil, as mentioned previously in the literature review. This general definition, allows for the formation of several versions of the MD, as there are variations of the "Mediterranean diets" in different countries and among the individual populations of the Mediterranean basin, due to ethnic, cultural, economic and religious diversities. This calls for the need for a uniform MD model with specific recommendations in grams rather than

the current various models that are based on general distribution of key nutrients. This would allow for a more accurate comparison between actual consumption and that of the MD among different studies.

Most importantly, what has led to higher cost of the MD model used in this study is its higher recommendations of fruits, vegetables and fish compared to other dietary guidelines such as the WHO. A 2003 published WHO/FAO report recommended a minimum of 400g of fruits and vegetables per day (excluding potatoes and other starchy tubers) for the prevention of chronic diseases such as heart disease, cancer, diabetes and obesity, as well as for the prevention and alleviation of several micronutrient deficiencies, especially in less developed countries. Moreover, the report advocated for the intake of 1-2 servings of fish per week with each serving equal to 75 g of fish (WHO, 2003). The MD model used in our study contains around double the amount of fruits, vegetables and fish (450 g of fruits, 400 g of vegetables and 42.8 g of fish) that the WHO recommends. If we were to follow the WHO guidelines for fruits, vegetables and fish, while keeping the rest of items as they are in the MD model, the total daily cost of the diet would be 9,663.9 LL. This is around the same expense as the actual Lebanese consumption. Note that the cost of fruits, vegetables and fish would become 1,700 LL, 1,340 LL and 540 LL respectively.

Most of the cost studies available in the literature, some of which are presented in the literature review above, concluded that healthier diets are more expensive than less healthier ones. However, there appears to be limited research that bases the work on the comparison between the cost of a healthier diet and that of actual consumption. Instead, most studies worked on comparing hypothetical baskets or adjusted dietary patterns to their corresponding less healthier alternatives. On the contrary, in this study, the costs of two

healthier diets were compared to the cost of actual consumption of the population retrieved from the national survey that took place in Lebanon between 2008 and 2009, providing strength for this type of work.

Sustainability and food security are closely interrelated and major effects in public health nutrition studies are made to quantify, assess determinants and establish interventions related to such outcomes. The Mediterranean dietary pattern has been recognized over the last decade as a healthier dietary pattern with a lower environmental impact. A multidimensional framework of key sustainable benefits of the Mediterranean diet has been highlighted, including major health and nutrition benefits and low environmental impacts and richness in biodiversity (Grosso, 2018). The lower environmental impact of the Mediterranean diet depends on low consumption of animal products and small water footprint and lower greenhouse gas emissions. However in our study, the total indices of water use, energy use and GHGEs are higher in the MD than in the Lebanese diet; taking into account the groups specified by the MD without miscellaneous groups. In line with these results, in a study done in India in 2019 on the adoption of healthy diets that follow the national dietary guidelines, it was shown that the healthier scenario would lead to an increase of about 20% to 40% across agricultural GHGE, blue and green water footprints and land use (Aleksandrowicz et al, 2019). This was mainly due to higher volumes of intake recommended by the Indian national dietary guidelines compared to actual consumption. Moreover, in the study done by Tom et al in 2015 in the United States, it was shown that following a diet that reduces caloric intake to achieve normal weight, in addition to meeting the USDA Dietary Guidelines for a healthy weight, increases average energy use by 38%, the average blue

water footprint by 10%, and average GHGE by 6% (Tom et al, 2015). The authors concluded that their study's results demonstrate how the environmental benefits of reduced meat consumption may be offset by increased consumption of other relatively high impact foods, thereby challenging the notion that reducing meat consumption automatically reduces the environmental footprints of one's diet. Therefore, this shows that food consumption behaviors are more complex, and the outcomes more nuanced.

Again, few adjustments to the MD model in line with WHO guidelines can lead to lower environmental impact of the Mediterranean diet model used. The water use is 25% more in the MD than in the Lebanese diet and this is driven by higher intake of fruits and legumes. Energy and GHGEs are 63% and 52% higher respectively in the MD compared to the Lebanese diet. The differences in energy and greenhouse gas emissions are driven by higher intake of fruits and yogurt in the Mediterranean diet. If we were to take the WHO recommendations for fruits (200 g/day) and legumes (2-3 servings per week, with each serving equal to 75 g), the total water use of the MD would become 1,305.45 L/day, which is 20% lower than that of the Lebanese diet. Moreover, if we were to replace yogurt, due to its relatively high environmental footprints, with milk, in addition to following the WHO recommendation on fruits, the energy use and GHGEs would decrease by around 26% and 40% respectively compared to their values in the EFPs of the MD in Table 16. In the study by Springmann in 2020, most national food based dietary guidelines, as well as the WHO, recommended increasing dairy consumption relative to current diets, which resulted in substantial increases in environmental impacts across all environmental dimensions. In the same study, the environmental implications of dietary shifts towards national food based dietary guidelines were mixed, although they were associated with reductions in mortality

from NCDs. Therefore, the development of food based dietary guidelines that are healthy and sustainable is an important starting point for encouraging the uptake of healthy and sustainable diets at a population level.

The current investigated diet of the Lebanese adults consists of food products rich in animal proteins and added sugars, while it is extremely poor in fiber. This diet is also nutritionally incomplete as it lacks adequate amounts of several micronutrients, minerals and vitamins such as vitamin D (Chamieh et al, 2015). Moreover, this diet is not environmentally sustainable. There is thus a need for radical changes for the Lebanese population to have a healthy, affordable and environmentally sustainable diet. In particular, the EAT-Lancet and Mediterranean diet models suggest that there is a need for the substitution of high intake of meat with vegetal proteins (such as legumes), the substitution of intake of refined grains with whole grains, and a significant increase in fruit and vegetable consumption to achieve a nutrient adequate intake. The consumption of fish once or twice a week is recommended in order to consume sufficient polyunsaturated fatty acids (WHO, 2008). However, polyunsaturated fatty acids could be readily obtained also from plant foods, such as nuts. The evidence favoring nut consumption for reduction in CVD deaths, cancer deaths and all-cause mortality, is getting strong (Mozaffarian, 2016). Indeed, plant-based diets could be a healthy choice, favoring a balanced intake of macro- and micro-nutrient intake (Mozaffarian, 2016), as well as a more environmentally sustainable scenario. Despite this, if meat and fish were excluded from diet, a detailed assessment of micronutrients would be required.

Three different 7-day diets were identified in the study done by Donati et al in Italy in 2016. These diets were based on nutritional recommendations for the healthy Italian

adult population, and were characterized by different targets that optimize different impacts, which were previously mentioned in the literature review. The results suggested that the sustainable diet, where the environmental pressures and food expenditure are simultaneously minimized (SD), is not more expensive than the current Italian diet, and therefore is fully affordable for the population under study. This also confirms other findings that a healthier and more eco-friendly diet is not necessarily more expensive. This study can also be extrapolated to the Lebanese scenario, where a nutritionally adequate (complete in macro- and micro-nutrients), environmentally sustainable and affordable diet can be planned based on the adjustment of the current Lebanese national consumption.

Given these results, one can reasonably ask how we might motivate healthy, sustainable and affordable dietary patterns among the Lebanese. Diet selections are not merely based on individual choice. Many factors can influence choice at the individual level, including education, income level, health status, nutritional knowledge, cooking skills and personal habits such as television watching and sleep. Furthermore, these individual drivers are then influenced by many other factors, such as social and cultural norms, social support, social class and race/ethnicity. The surrounding physical environment can further alter eating patterns as for example the foods available at workplaces, schools, supermarkets and restaurants, proximity and accessibility to these outlets, access to transportation and neighborhood socioeconomic status. At the macro level, agriculture, market forces, land use, transportation, food production and distribution, issues of food safety, industry incentives, lobbying, marketing and the media can all impact food choices. Governments are also important actors as diet is shaped by their priorities, agricultural policies, food assistance programs, school lunch policies and the healthcare

system. Finally, global influences are relevant, such as multinational corporate lobbying, climate change, scientific research and trade agreements. Shifting the focus from calories and individual nutrients to foods and diet quality and redirecting efforts toward population interventions to address the root causes of poor diet and lifestyle can meaningfully reduce the global pandemics of diet-related diseases and disability. Rather than just telling people to decrease calories, public health efforts should be aimed at increasing the proportion of calories consumed from healthy foods, such as fruits, vegetables, beans, nuts, seeds, fish, vegetable oils, plain yogurt and minimally processed whole grains. At the same time, actions must be taken towards limiting calories from harmful foods, including processed meats, sweetened beverages, excess alcohol and foods rich in starches, refined grains, sugars, trans-fats and salt (Mozaffarian, 2017).

Policy-makers know that consumer behavior change would be central to any policy process aiming at integrating nutrition and sustainability. Policies aiming at stimulating healthy eating are usually divided into two broad categories: those aimed at supporting informed choice by consumers, mostly through the provision of information or education, and those aiming at changing the market environment, by influencing food prices or availability. Most measures adopted in the EU are those intended to promote informed choice, mostly through public information campaigns and nutrition education in schools. Because they have large audiences, television cooking shows have also been suggested as a way of enhancing cooking skills among young people. This has been tried on limited scale in the UK. The development and dissemination of guidelines promoting sustainable diets is also necessary and is currently taking place in some countries, like the US, Germany, France, the UK and Australia. The progressive abandonment of the healthy Mediterranean

diet pattern is another issue that Mediterranean countries must necessarily consider in the future. Measures aiming at modifying the food "environment" have mostly been focused on directly providing healthy foods in schools (such as fruits). Increasing the prices of foods and beverages high in fat, sugar and salt content through taxation is a potential policy measure which should discourage over-consumption. In recent years, a number of countries have introduced health-related food taxes. Hungary and Mexico have taxes on foods high in salt, sugar or fat content, Finland has a tax on sweets, ice cream and soft drinks, and France and the US California city of Berkeley have taxed sugar-sweetened beverages. Subsidies or voucher programs, which have also been developed in some countries to assist low-income families, may be more socially acceptable than taxes. Therefore, the combination of taxes to increase prices of less healthful foods and beverages and the reinforcement of subsidy strategies to lower prices of more healthful foods and beverages is necessary. This will be more economically neutral, especially in the case of low-income families, rather than simply imposing taxes on foods high in fat or sugar. Fiscal measures could thus be an effective tool for shifting current dietary patterns towards more sustainable ones. These regulatory tools might properly address and promote a nutritionally adequate, affordable and environmentally friendly diet. (Gorski and Roberto, 2015)

This study constitutes a step forward towards the formulation of sustainable diets for the Lebanese population. The expenditure of a Lebanese individual is currently higher than the necessary cost to adopt and follow the EAT-Lancet and is less environmentally sustainable. This input, along with nutritional education campaigns targeting all age groups, may find a basis on the EAT-Lancet model to be more appreciated by the modern consumer. Moreover, the MD model used in this study can be adjusted, in ways that are

compatible with the WHO recommendations, to make it more affordable and environmentally sustainable in Lebanon. Coupled to earlier findings of EAT-Lancet pattern's beneficial effects on health and the Western pattern's deleterious effects on health, the findings of this study lend evidence for the notion that what is healthy for people may also be healthy for ecosystems. The EFPs estimates associated with food consumption patterns in the country could be used to inform policies vis-a-vis agricultural production, type of production, food imports, subsidies and recommendations for sustainable food consumption in order to achieve this goal and help countries address the SDG.

Two main limitations of this study are the inflation rate affecting cost, and elements that were not considered in the EFPs analysis. According to the Central Administration of Statistics (CAS), the monthly inflation rate in Lebanon doubled from 3.17% in November to 6.96% at the end of 2019. The ensuing inflation rate in the first month of 2020 surged to 10.04%. Lebanon's protests and COVID-19 pandemic have had a substantial impact on the Lebanese leading to an inflation rate 89.74% by June 2020 according to the BLOM Bank Group. This therefore has highly affected the prices of food and beverages (inflation rate of 108.88% by June 2020 and more than 200% by July 2020), urging for the need to convert the prices, which we have collected during the spring and summer of 2019, to their corresponding values according to the inflation rate at the time of calculus. Another limitation of the study is that although it addressed three EFPs, other elements of environmental sustainability such as soil erosion, biodiversity, pollution, farm management and ecosystem services were not considered. It is important to note that the lack of a detailed inventory of agricultural and production practices in Lebanon, along with other

countries of the region limit the feasibility of a comprehensive assessment of environmental footprints of food consumption.

# CHAPTER V

# CONCLUSION

This study addressed two pillars of food security: accessibility and sustainability. It showed that, as may have been expected, the average food consumption of Lebanese adults is more expensive and has higher environmental footprints than the EAT-Lancet diet. Thus, consuming less meat and added sugars and desserts, as recommended by the EAT-Lancet diet, can easily offset the EAT-Lancet recommendations of higher intake of dairy foods, fruits and nuts in Lebanon, in terms of cost and environmental impact. In addition, this would also account for replacing refined grains with whole grains. On the other hand, the national Lebanese consumption was shown to be of lower cost and lower environmental impact compared to the Mediterranean diet model used. Although unexpected of a result, the reasons were mainly due to higher volumes of dietary intake recommended in the MD model used. This study can thus inform policy measures to recommend and advocate dietary guidelines that are healthy, affordable and environmentally sustainable. This study is a step forward towards the formulation of sustainable diets (both environmentally and economically) for the Lebanese population. More studies are required to examine the nutrition value, specific quantity and quality of the food items comprising the patterns of consumption identified in this study in order to achieve this goal and help the country address the SDG.

# APPENDIX

Appendix 1 is a comprehensive list of the food items that were used to collect prices. It was developed to cover foods across all major food categories (fruits, vegetables, cereals/grains, roots/tubers, meat/poultry, fish, dairy products, fats and oils, desserts and beverages) as well as selected prepared foods. Food items were specified by type, size and preferred brand (when relevant) to ensure consistency in data collection across stores. A preliminary version of the food items list was piloted in a grocery store prior to its wider use.

**Appendix 1. The comprehensive list of food items used to collect prices throughout the stage of data collection.**

| Food Classification | | | Brand | Recommended Size | Price (LL) - Recommended | Available Brand | Available Size | Price (LL) - Available | Notes |
|---|---|---|---|---|---|---|---|---|---|
| **Butter** | Salted | Packaged | Lurpak | 200 g | | | | | |
| | | | Tatra | 200 g | | | | | |
| **Gee** | Animal | Packaged | Golden Plate | 0.5 L | | | | | |
| | | Unlabeled | | 0.5 L | | | | | Availability is unkown |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plant | Packaged | Aseel | 0.5 L | | | | | |
| | | Unlabeled | | 0.5 L | | | | | Availability is unkown |
| **Vegetable oil** | Olive oil | bottled | AlWazeer | 0.5 L | | | | | |
| | | | Al Makhazen | 0.5 L | | | | | |
| | | bulk | | 16 L | | | | | Availability is unkown |
| | Sunflower oil | bottled | Afia | 1.8 L | | | | | |
| | | | Mazola | 1.8 L | | | | | |
| | Corn oil | bottled | Afia | 1.8 L | | | | | |
| | | | Mazola | 1.8 L | | | | | |
| | Canola oil | bottled | Lesieur | 2 L | | | | | |
| | | | Wesson | 1.89 L | | | | | |
| **Instant coffee** | Nescafe | homemade | Nescafe 3 In 1 Classic | 20 g | | | | | |
| | | Ready to go from the express | without Nestle condensed milk | 1 cup | | | | | |
| | | | with Nestle condensed milk | 1 cup | | | | | |
| | Espresso | homemade | Nescafe Espresso Coffee | 100 g | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Davidoff Café Espresso 57 | 100 g | | | | | |
| | | Ready to go from the express | Espresso regular | coffee cup | | | | | |
| | | | Espresso double | coffee cup | | | | | |
| | Cappuccino | homemade | Torabika Cappuccino | 25 g | | | | | |
| | | | Nescafe Cappuccino | 19.3 g | | | | | |
| | | Ready to go from the express | regular | 1 cup | | | | | |
| **Turkish coffee** | national brand | Najjar Classic (blue package) | | 200 g | | | | | |
| | | Café Abi Nasr Brazilian Coffee Regular | | 200 g | | | | | |
| **Cocoa hot drink** | pack | Galaxy Instant Hot Chocolate | | 25 g | | | | | |
| | Ready to go | Express | | 1 cup | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| **Bottled fruit juices** | Glass bottled | Tropicana Pineapple Slice | 1 L | | | | | | |
| | | Maccaw Pineapple | 1 L | | | | | | |
| | Carton packaged | Maccaw Orange Carton | 200 ml | | | | | | |
| | | Tropicana Premium Orange | 200 ml | | | | | | |
| **Fresh fruit juice** | orange | | 1 medium cup | | | | | | |
| | apple | | 1 medium cup | | | | | | |
| **Soft drink** | can | Pepsi or Coca-Cola | 330 ml | | | | | | |
| **Light soft drinks** | | Pepsi or Coca-Cola | 330 ml | | | | | | |
| **Olives** | unpackaged | green | 200 g | | | | | | |
| | | black | 200 g | | | | | | |
| | | seed free | 200 g | | | | | | |
| **Mayonnaise** | bottled | Lesieur | 475 g | | | | | | |
| | | Heinz | 430 g | | | | | | |
| **Low fat cheese** | light cheeses | Bihar Slice Light Cheese | 150 g | | | | | | |
| | | Light Philadelphia | 200 g | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Sylphide Fondant A L'emmental 12 Portion | | 200 g | | | | | |
| | | puck: Low far Mozerella shredded | | 200 g | | | | | |
| | double cream | Les Fermes Taanayel Double Cream | | 200 g | | | | | |
| | | from the deli counter | | 200 g | | | | | |
| | karishe | Masabki | | 500 g | | | | | |
| | | unlabeled | | 500 g | | | | | Availability is unkown |
| **Full fat cheese** | Packaged | Kashkaval | wadi al Akhdar Dairie Kashkaval Square | 350 g | | | | | |
| | | | Bihar | 350 g | | | | | |
| | | Cheddar | wadi al Akhdar Dairy Cheddar Slices | 200 g | | | | | |
| | | | Kraft Cheddar Singles | 216 g | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| | | Emmental | Al Wadi Al AkhdarDairie Emmental Slices | 200 g | | | | | |
| | | | Belle France Emmental Tranche | 200 g | | | | | |
| | | Halloum | Les Fermes Taanayel Halloum Vacuum | 250 g | | | | | |
| | | Akkawi | Les Fermes Taanayel Akawi Cheese Vacuum | 250 g | | | | | |
| | | Balade | Taanayel | | | | | | Availability is unkown |
| | | | Khoury | | | | | | Availability is unkown |
| | | Mozzarella | Kraft Shredded Mozzarella | 8 oz | | | | | |
| | | | Plein Soleil Shredded Mozzarella | 400 g | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| | | Feta | Puck Feta Cheese | 500 g | | | | | |
| | | | Bihar | 200 g | | | | | |
| | | Processed cheese | Puck | 240 g | | | | | |
| | | | Smeds | 240 g | | | | | |
| | | Goat cheese | Bihar Bulgarian Goat | 200 g | | | | | |
| | | | L'exquis Plain Goat Cheese | 150 g | | | | | |
| | Counter Cheese | Bihar Cow Kashkaval | | 200 g | | | | | |
| | | Singleton Cheddar | | 200 g | | | | | |
| | | Massabki Halloum | | 200 g | | | | | |
| | | Fermes Taanayel Nabulsi | | 200 g | | | | | |
| | | Fermes Taanayel Double Crème | | 200 g | | | | | |
| | | balade | | 200 g | | | | | |
| | | Puck Mozzarella | | 200 g | | | | | |
| | | Bridel Emmental | | 200 g | | | | | |
| | | (Feta) Khoury Fettina | | 200 g | | | | | |
| **Milk (skimmed)** | Packaged | Candia Ultra High temperature Milk Silhouette | | 1 L | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Fermes Taanayel Ultra High temperature Milk No Fat | 1 L | | | | | | |
| Milk (full fat) | Packaged | Candia Ultra High temperature Milk Entier | 1 L | | | | | | |
| | | Fermes Taanayel Ultra High temperature Milk Whole | 1 L | | | | | | |
| **Labneh (strained yogurt)** | Packaged | Fermes Taanayel Labneh Balade | 500 g | | | | | | |
| | | Candia Labneh Entier | 500 g | | | | | | |
| | | Candia Labneh 0% Matiere Grasse | 500 g | | | | | | |
| | unlabeled | | 500 g | | | | | | |
| **Yogurt (full fat)** | Packaged | Candia Laban Entier | 2 kg | | | | | | |
| | | Liban Lait Laban Entier | 2 kg | | | | | | |
| **Yogurt (skimmed )** | Packaged | Candia Laban 0% Fat | 1 kg | | | | | | |
| | | Fermes Taanayel Laban Zero Fat | 1 kg | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| **Nuts and seeds** | Roasted prepackaged | Mix 1 | Al Rifai Mix Kernels | 300 g | | | | | |
| | | | Krikita Gold Mix | 350 g | | | | | |
| | | | Castania Mixed Nuts (red bag) | 300 g | | | | | |
| | | Mix 2 | Al Rifai Smart Mix | 300 g | | | | | |
| | | | Krikita Silver Mix | 350 g | | | | | |
| | | | Castania Mixed Nuts Extra (green bag) | 300 g | | | | | |
| | Roasted outlets | Regular mix | shokre hamasne | 500 g | | | | | |
| | | | mahmaset al janna | 500 g | | | | | |
| | | Extra mix | shokre hamasne | 500 g | | | | | |
| | | | mahmaset al janna | 500 g | | | | | |
| | Sunflower seeds | Krikita | | 60 g | | | | | |

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|---|---|---|---|---|---|---|---|---|
| | Pumpkin seeds | Krikita salted | 40 g | | | | | |
| | Egyptian seeds (melon seeds) | Krikita salted | 40 g | | | | | |
| | Cashews | raw | 200 g | | | | | this is the one without any shell and usually used over stews |
| | Pine nuts | Chinese | 200 g | | | | | |
| | | Balade | 200 g | | | | | |
| | | Turkish | 200 g | | | | | |
| | Walnuts | Shelled (shell removed), halves | 200 g | | | | | |
| | | Shell not removed | 200 g | | | | | Not the green walnuts |
| | Hazelnuts | Shelled (shell removed), whole | 200 g | | | | | |
| | Chestnuts | Turkish | 1 kg | | | | | |
| | | Chinese | 1 kg | | | | | |
| | Almonds | Raw (white) | 200 g | | | | | This is the kind usually |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | used over stews |
| | | unsalted with red skin | | 200 g | | | | | |
| | Pistachios | Fresh green | | 1 kg | | | | | |
| | | Shelled (shell removed), raw | | 200 g | | | | | |
| | Peanuts | salted | Krikita Peanuts Fried Salted | 60 g | | | | | |
| | | unsalted | Krikita Peanuts Unsalted | 60 g | | | | | |
| **Deep yellow orange fruits** | Conventional | apricots balade (not ajame) | | 1 kg | | | | | |
| | | peaches (with fuzz) | | 1 kg | | | | | |
| | | mango Egyptian | | 1 kg | | | | | |
| | | cantaloupe | | 1 kg | | | | | |
| | | pineapple | | 1 kg | | | | | |
| | Organic | apricots balade (not ajame) | | 1 kg | | | | | |
| | | peaches (with fuzz) | | 1 kg | | | | | |
| | | mango Egyptian | | 1 kg | | | | | |
| | | cantaloupe | | 1 kg | | | | | |
| | | pineapple | | 1 kg | | | | | |

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|---|---|---|---|---|---|---|---|---|
| **Dried fruits** | Al Rifai | Kiwi | 200 g | | | | | |
| | | Mango | 200 g | | | | | |
| | | Figs | 200 g | | | | | |
| | | Strawberries | 200 g | | | | | |
| | | Prunes | 200 g | | | | | |
| | | Ginger | 200 g | | | | | |
| | | Apricots | 200 g | | | | | |
| | | Pineapple | 200 g | | | | | |
| | | Cranberries | 200 g | | | | | |
| **Bananas and Apples** | Organic | Bananas (balade) | 1 kg | | | | | |
| | | Bananas (Somali) | 1 kg | | | | | |
| | | Apples yellow balade | 1 kg | | | | | |
| | Conventional | Bananas (balade) | 1 kg | | | | | |
| | | Bananas (Somali) | 1 kg | | | | | |
| | | Apples yellow balade | 1 kg | | | | | |
| **Citrus fruits** | Organic | Oranges (abu sorra) | 1 kg | | | | | |
| | | Lemon | 1 kg | | | | | |
| | | Clementine | 1 kg | | | | | |
| | | Blood orange | 1 kg | | | | | |
| | | Mandarin | 1 kg | | | | | |

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|---|---|---|---|---|---|---|---|---|
| | | Grapefruit (yellow) | 1 kg | | | | | |
| | Conventional | Oranges (abu sorra) | 1 kg | | | | | |
| | | Lemon | 1 kg | | | | | |
| | | Clementine | 1 kg | | | | | |
| | | Blood orange | 1 kg | | | | | |
| | | Mandarin | 1 kg | | | | | |
| | | Grapefruit (yellow) | 1 kg | | | | | |
| **Strawberry** | Organic | | 1 kg | | | | | |
| | Conventional | | 1 kg | | | | | |
| **Grapes (with seeds) balade** | Organic | Red | 1 kg | | | | | |
| | | White (Taweel) | 1 kg | | | | | |
| | | Black | 1 kg | | | | | |
| | Conventional | Red | 1 kg | | | | | |
| | | White (Taweel) | 1 kg | | | | | |
| | | Black | 1 kg | | | | | |
| **Breakfast cereals** | Poppins choco pops | | 375 g | | | | | |
| | Nestle Nesquik Cereals | | 375 g | | | | | |
| | Kelloggs Corn Flakes | | 375 g | | | | | |
| | Poppins In Shape Original | | 375 g | | | | | |
| **Rice and rice products** | (white rice) packaged | Aoun Egyptian Rice | 1 kg | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Aoun Italian Rice | 1 kg | | | | | |
| | | Al Walima Basmati Rice | 2 kg | | | | | |
| | Brown rice | Tilda Indian Brown Basmati Rice | 1 kg | | | | | |
| | | India Gate | 1 kg | | | | | |
| | Rice cakes | Equia Rice Cake Wheat | 175 g | | | | | |
| | | Good Food Jumbo Rice Cake Cheese | 145g | | | | | |
| **Pasta** | Barilla (regular - not whole wheat, not gluten free) | lasagna | 500 g | | | | | |
| | | spaghetti | 500 g | | | | | |
| | | tagliatelle | 500 g | | | | | |
| | Barilla - whole wheat | lasagna | 500 g | | | | | |
| | | spaghetti | 500 g | | | | | |
| | | tagliatelle | 500 g | | | | | |
| | Barilla - gluten-free | lasagna | 500 g | | | | | |
| | | spaghetti | 500 g | | | | | |
| | | tagliatelle | 500 g | | | | | |

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|---|---|---|---|---|---|---|---|---|
| **Bulgur** | Conventional | Gardenia | 500 g | | | | | |
| | Organic | Suma Prepacks Organic Bulgar Wheat | 500 g | | | | | |
| **Desserts** | Arabic (outlet: Seasweet) | Baklavah | 1 kg | | | | | |
| | | Maamoulmad | 1 kg | | | | | |
| | | Kneffe | 1 kg | | | | | |
| | | Halwet eljebn | 1 kg | | | | | |
| | | Shaaybeyat | 1 kg | | | | | |
| | | Awamat | 1 kg | | | | | |
| | | Madlouka | 1 kg | | | | | |
| | | Znoud set | 1 kg | | | | | |
| | Arabic (outlet: Ikhlas) | Baklavah | 1 kg | | | | | |
| | | Maamoulmad | 1 kg | | | | | |
| | | Kneffe | 1 kg | | | | | |
| | | Halwet eljebn | 1 kg | | | | | |
| | | Shaaybeyat | 1 kg | | | | | |
| | | Awamat | 1 kg | | | | | |
| | | Madlouka | 1 kg | | | | | |
| | | Znoud set | 1 kg | | | | | |
| | Western | English Cake Marble Cake | 400 g | | | | | |

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|---|---|---|---|---|---|---|---|---|
| | | Nabisco Oreo Cookie | 44 g | | | | | |
| | | Haribo Candies Cherries | 200 g | | | | | |
| | | Cheesecake from pastry shops | 1 piece / slice | | | | | |
| **White bread** | Gluten-free | Pita | | | | | | Brand needs identification |
| | | Toast | | | | | | Brand needs identification |
| | | Baguette | | | | | | Brand needs identification |
| | Regular | Pita White Big (Wooden Bakery) | 900 g | | | | | |
| | | Club Sandwich White (Wooden Bakery) | 750 g | | | | | |
| | | French Baguette White (Wooden Bakery) | 270 g | | | | | |
| | | Saj | | | | | | |

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|---|---|---|---|---|---|---|---|---|
| | | Markook (Chamsine) | | | | | | |
| **Brown bread** | gluten free | | | | | | | Brand needs identification |
| | whole wheat | Wooden Bakery Pita Whole Wheat 7 loaves | 450 g | | | | | |
| | | Club Sandwich Multicereal | 750 g | | | | | |
| | | French Baguette Multicereal | 270 g | | | | | |
| | brown | Wooden Bakery Pita Brown Small 7 Loaves | 400 g | | | | | |
| **Manakesh** | saj | cheese | regular size | | | | | |
| | | cheese extra | regular size | | | | | |
| | | zaatar | regular size | | | | | |
| | | zaatar with vegies | regular size | | | | | |
| | | keshek | regular size | | | | | |
| | | keshek extra | regular size | | | | | |
| | forn | cheese | regular size | | | | | |
| | | cheese extra | regular size | | | | | |
| | | zaatar | regular size | | | | | |
| | | zaatar with vegies | regular size | | | | | |
| | | keshek | regular size | | | | | |
| | | keshek extra | regular size | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| **Pizza** | forn | vegetables | Medium | | | | | | |
| | | with mortadella | Medium | | | | | | |
| | | with soujuk | Medium | | | | | | |
| | fast food | classical | Medium | | | | | | |
| | | marguerite | Medium | | | | | | |
| | | pepperoni | Medium | | | | | | |
| **Luncheon meat** | Salami | Taghzia Beef Salami | 200 g | | | | | | |
| | Beef Mortadella | Taghzia Beef Mortadelle | 200 g | | | | | | |
| | | Zwan Luncheon Meat Beef | 200 g | | | | | | |
| | Turkey Mortadella | Taghzia Lunch Meat Turkey | 200 g | | | | | | |
| | | Zwan Lunch Meat Turkey | 200 g | | | | | | |
| **Sausages** | Makanek | from butchers / meat counter | 500 g | | | | | | |
| | Hot dogs | Maxim's hotdog (canned) | 430 g | | | | | | |
| | | Frankfurter (Zwan Hot Dog Jars) | 320 g | | | | | | |
| | Sojok | from butchers / meat counter | 500 g | | | | | | |
| **Eggs** | Organic | | 6 pcs | | | | | | Brand needs identification |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | packaged | farmer | Hawa Chicken White Eggs | 6 pcs | | | | | | |
| | | baladi | Hawa Chicken Eggs Red | 10 pcs | | | | | | |
| | unpackaged (in carton, not covered) | farmer (white) | | 6 pcs | | | | | | |
| | | baladi (Brown) | | 6 pcs | | | | | | |
| **Fish (Fresh)** | Fish Scottish Salmon whole | | | 1 Kg | | | | | | |
| | Fish Lokkoz Sakhri | | | 1 Kg | | | | | | |
| | Fish Sardine Bizri | | | 1 Kg | | | | | | |
| | Fish Aarmout | | | 1 Kg | | | | | | |
| | Fish Farride | | | 1 Kg | | | | | | |
| **Meat** | Organic | pork | minced | 1 Kg | | | | | | |
| | | | steak / chop | 1 Kg | | | | | | |
| | | beef | minced | 1 Kg | | | | | | |
| | | | steak / chop | 1 Kg | | | | | | |
| | | sheep | minced | 1 Kg | | | | | | |
| | | | steak / chop | 1 Kg | | | | | | |
| | | goat | minced | 1 Kg | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| | | | steak / chop | 1 Kg | | | | | |
| | Conventional | pork | minced | 1 Kg | | | | | |
| | | | steak / chop | 1 kg | | | | | |
| | | beef | minced | 1 Kg | | | | | |
| | | | steak / chop | 1 Kg | | | | | |
| | | sheep | minced | 1 Kg | | | | | |
| | | | steak / chop | 1 Kg | | | | | |
| | | goat | minced | 1 Kg | | | | | |
| | | | steak / chop | 1 Kg | | | | | |
| **Offals** | Chicken | liver | | 1 Kg | | | | | |
| | | heart | | 1 Kg | | | | | |
| | Beef | liver | | 1 Kg | | | | | |
| | | intestines | | 1 Kg | | | | | |
| | | heart | | 1 Kg | | | | | |
| | | tongue | | 1 Kg | | | | | |
| | Goat | liver | | 1 Kg | | | | | |
| | | intestines | | 1 Kg | | | | | |
| | | heart | | 1 Kg | | | | | |
| | | tongue | | 1 Kg | | | | | |
| | Sheep | liver | | 1 Kg | | | | | |
| | | intestines | | 1 Kg | | | | | |
| | | heart | | 1 Kg | | | | | |
| | | tongue | | 1 Kg | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| Poultry | Turkey | thighs, skinless with bones | 1 Kg | | | | | | |
| | | breast, skinless with bones | 1 Kg | | | | | | |
| | | wings, skinless with bones | 1 Kg | | | | | | |
| | Chicken | thighs, skinless with bones | 1 Kg | | | | | | |
| | | breast, skinless with bones | 1 Kg | | | | | | |
| | | wings, skinless with bones | 1 Kg | | | | | | |
| **Chocolate** | chocolate bars | Galaxy Milk Chocolate Bar | 40 g | | | | | | |
| | | Milka Alpine Milk Chocolate | 100 g | | | | | | |
| | swiss chocolate | Lindt Lindor Milk Chocolate | 100 g | | | | | | |
| | | Godiva Milk Chocolate Bars | 43 g | | | | | | |
| | speciality chocolate | Patchi milk chocolate | 1 kg | | | | | | could be removed because they are special cases of chocolate |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Rebbel milk chocolate | 1 kg | | | | | could be removed because they are special cases of chocolate |
| **Ice cream** | Packaged | London Dairy Ice Cream Vanilla | 1 L | | | | | |
| | | Mars ice cream bar | 41.8 g | | | | | |
| | | Cortina Giant chocolate flavor | 100 g | | | | | |
| | Frozen yogurt | | | | | | | not usually available in super markets |
| **Honey** | Organic | Kirkland Organic honey | 24 oz | | | | | |
| | Packaged | Al Shifa Natural Ural Honey | 250 g | | | | | |
| | | Attiki Greek Honey Tin | 455 g | | | | | |
| | original farmer made (balade) | | 1 kg | | | | | |
| **Jam** | Organic | Bonne Maman Strawberry Jam Organic | 370 g | | | | | |

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|---|---|---|---|---|---|---|---|---|
| | Al Wadi Al Akhdar | Alwadi Alakhdar Apricot Jam | 450 g | | | | | |
| **Sugar** | Brown (granulated) | SIS Brown Sugar | 1 kg | | | | | |
| | White (granulated) | Aoun Cristal Sugar | 1 kg | | | | | |
| | Powdered | Saint Louis Sugar In Powder | 75 g | | | | | |
| **Dark green yellow vegetable** | **Mloukheye** | | 1 kg | | | | | |
| | Parsley | | 1 kg | | | | | |
| | Mint | | 1 kg | | | | | |
| | Spinach | | 1 kg | | | | | |
| | Rocca | | 1 kg | | | | | |
| | Lettuce (not iceberg) | | 1 kg | | | | | |
| | Celery | | 1 kg | | | | | |
| | Chicory (hindbeh) | | 1 kg | | | | | |
| **Legumes** | Chickpeas (homos) | Gardenia Chick-Peas Extra (bagged) | 907 g | | | | | |
| | Peas (bazilla) | Alwadi Alakhdar Fine Green Peas (frozen) | 450 g | | | | | |

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|---|---|---|---|---|---|---|---|---|
| | Beans | Gardenia White Oblong Beans (bagged) | 907 g | | | | | |
| | | Gardenia White Broad Beans (bagged) | 454 g | | | | | |
| | Green beans | Alwadi Alakhdar Cut Green Beans (frozen) | 450 g | | | | | |
| | Fool | Alwadi Alakhdar Broad Bean Green (frozen) | 400 g | | | | | |
| | Canned | Deli Green Peas (canned) | 400 g | | | | | |
| | | Maxim's Red Beans & Kidney | 400 g | | | | | |
| **Potato** | Yellow - Organic | | 1 kg | | | | | |
| | Yellow - Conventional | | 1 kg | | | | | |
| **Potato chips** | Packaged | Masters Original salted potato chips | 175 g | | | | | |
| | | Lay's salt Potato Chips | 175 g | | | | | |
| **Fried potato** | french fries | | small basket | | | | | |
| **Tomato** | Organic - balade regular | | 1 kg | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Conventional - balade regular | | 1 kg | | | | | |
| | Conventional - cherry tomato | | 1 kg | | | | | |
| **Season salad** | Green salad to go | | small | | | | | |
| **Corn** | Organic - sold in its leaves | | 1 kg | | | | | |
| | Conventional - sold in its leaves | | 1 kg | | | | | |
| | AlWadi Alakhdar Golden Sweet Corn (canned) | | 340 g | | | | | |
| | Plein Soleil Baby Corn (canned) | | 425 g | | | | | |
| **Zucchini and eggplant** | Zucchini | Organic | 1 kg | | | | | |
| | | Conventional | 1 kg | | | | | |
| | Eggplant | Organic | 1 kg | | | | | |
| | | Conventional | 1 kg | | | | | |
| **Cauliflower** | Organic | | 1 kg | | | | | |
| | Conventional | | 1 kg | | | | | |
| **Falafel sandwiches** | To go | | small | | | | | |
| **Shawarma** | To go - chicken shawarma | | small | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **sandwiches** | To go - beef shawarma | | small | | | | | |
| **Hamburger** | Original no additions | | 1 burger | | | | | |
| Wine | Red wine | Ksara | 1 bottle | | | | | |
| | | Kefraya | 1 bottle | | | | | |
| | White wine | Ksara | 1 bottle | | | | | |
| | | Kefraya | 1 bottle | | | | | |
| Beer | Almaza | | 1 bottle | | | | | |
| | Beirut Beer | | 1 bottle | | | | | |
| Non-wine alcohol | Whisky | Johhny walker | 1 bottle | | | | | |
| | gin | Beefeater | 1 bottle | | | | | |
| | vodka | Smirnoff | 1 bottle | | | | | |
| | | Absolut | 1 bottle | | | | | |

Appendix 2 shows the prices per gram (LL) of all food groups studied as part of the Lebanese national consumption data. The Q refers to the quintile or area where the data collection of prices took place. Q1 represents the most expensive area in terms of real estate price, while Q5 is the cheapest. The n refers to the number of items studied under each food group. The Total column expresses the average price per g of each food group among all quintiles, while each of the other columns represents the prices per g of the food groups per each quintile.

**Appendix 2. Price per g in LL (1$ = 1515 LL) of each studied food group in the five quintiles in Lebanon.**

| Food Groups | PRICE (LL) PER GRAM | | | | | |
|---|---|---|---|---|---|---|
| | Total | Q1 | Q2 | Q3 | Q4 | Q5 |
| | MEAN±SD | | | | | |
| **Fats And Oils (n=195)** | 9.1±5.8 | 9.4±6.0 | 9.1±5.5 | 9.1±5.8 | 9.1±5.8 | 8.8±5.9 |
| Animal Fat (n=80) | 13.0±6.0 | 13.2±6.5 | 13.2±5.5 | 12.3±6.2 | 13.1±6.0 | 12.7±6.3 |
| Unsaturated Oils (n=115) | 6.4±3.8 | 6.6±3.7 | 6.5±3.6 | 6.8±4.5 | 6.3±3.8 | 6.3±4.0 |
| **Beverages (n=243)** | 20.1±29.3 | 23.4±35.6 | 19.9±27.2 | 21.0±29.7 | 18.7±27.8 | 17.6±26.0 |
| Hot Beverages (n=110) | 12.9±4.3 | 12.5±4.1 | 13.3±4.2 | 13.6±4.3 | 12.0±4.4 | 13.5±4.3 |
| Sugar Sweetened Beverages (n=69) | 2.2±0.4 | 2.3±0.4 | 2.2±0.4 | 2.1±0.4 | 2.2±0.4 | 2.3±0.6 |
| Unsweetened Beverages (n=14) | 2.3±0.0 | 2.3±0.0 | 2.3±0.0 | 2.3±0.0 | 2.3±0.0 | 2.3±0.0 |
| Alcoholic Beverages (n=50) | 21.0±15.6 | 21.0±16.2 | 21.0±16.2 | 21.0±16.2 | 21.0±16.2 | 21.0±16.2 |
| **Vegetables (n=289)** | 3.8±5.3 | 3.7±4.9 | 4.5±7.3 | 3.3±5.5 | 3.8±4.1 | 3.6±4.5 |
| Green Leafy Vegetables (n=131) | 1.8±1.6 | 1.6±1.5 | 1.9±1.8 | 1.6±1.5 | 1.9±1.5 | 1.9±1.8 |
| Red and Orange Vegetables (n=41) | 2.8±2.1 | 2.6±2.3 | 2.6±2.1 | 2.4±2.5 | 3.3±2.0 | 2.7±2.3 |
| Other Vegetables (n=117) | 6.5±7.3 | 6.9±6.4 | 8.3±10.4 | 5.7±8.0 | 5.8±5.4 | 5.7±6.1 |
| **Potato (n=25)** | 2.0±1.2 | 2.2±1.5 | 1.8±1.2 | 1.8±1.4 | 2.1±1.1 | 1.8±1.4 |
| **Potato Chips (Salty snacks) (n=27)** | 13.8±5.7 | 15.2±6.4 | 11.6±5.4 | 10.3±7.6 | 15.7±4.3 | 15.0±5.6 |
| **Corn (n=31)** | 5.2±1.6 | 5.3±1.0 | 6.3±0.8 | 6.1±1.7 | 4.1±2.0 | 5.1±1.2 |
| **Total Fruits (n=373)** | 8.5±10.9 | 7.3±9.8 | 8.5±11.2 | 11.1±13.6 | 7.5±8.9 | 8.7±11.3 |
| Whole Fruits (n=356) | 8.6±11.1 | 7.4±10.1 | 8.5±11.4 | 11.2±14.0 | 7.6±9.1 | 8.8±11.4 |
| Fresh Juices (n=17) | 6.6±2.9 | 6.1±1.3 | 7.5±4.3 | 8.3±4.7 | 5.6±0.7 | 5.0±0.0 |
| **Dairy Products (n=549)** | 14.5±9.4 | 14.9±8.9 | 15.7±10.3 | 13.6±8.4 | 14.5±9.4 | 13.5±9.4 |
| **Milk Derivatives (n=495)** | 15.8±9.0 | 16.4±8.3 | 17.2±9.8 | 14.7±8.0 | 15.8±9.0 | 14.07±9.2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Low Fat Cheeses (n=76) | 20.1±9.0 | 20.9±7.8 | 22.5±13.0 | 18.8±6.9 | 18.2±7.4 | 20.5±8.3 |
| Full Fat Cheeses (n=310) | 17.9±8.1 | 18.4±7.2 | 19.1±7.9 | 16.5±7.5 | 18.0±8.8 | 16.8±8.8 |
| Yogurt Full Fat (n=33) | 3.3±1.5 | 4.1±3.0 | 2.9±5.3 | 3.8±1.9 | 3.1±0.6 | 2.8±0.4 |
| Yogurt Zero Fat (n=27) | 4.4±0.2 | 4.4±0.1 | 4.4±0.2 | 4.3±0.1 | 4.4±0.2 | 4.4±0.2 |
| Labneh Full Fat (n=34) | 10.8±3.2 | 11.1±2.0 | 10.6±2.8 | 12.5±5.3 | 10.3±2.2 | 10.1±3.4 |

| | **PRICE (LL) PER GRAM** | | | | | |
|---|---|---|---|---|---|---|
| | **Total** | **Q1** | **Q2** | **Q3** | **Q4** | **Q5** |
| | **MEAN±SD** | | | | | |
| Labneh Zero Fat (n=15) | 11.5±1.7 | 11.4±0.8 | 11.9±0.3 | 11.1±0.8 | 11.8±2.8 | 11.0±2.7 |
| **Unsweetened Milk (n=54)** | 2.4±0.7 | 2.3±0.7 | 2.4±0.7 | 2.3±0.8 | 2.5±0.7 | 2.4±0.7 |
| Milk Skimmed (n=27) | 2.3±0.9 | 2.2±0.9 | 2.3±0.9 | 2.0±1.1 | 2.4±0.9 | 2.4±0.9 |
| Milk Full Fat (n=27) | 2.5±0.5 | 2.4±0.6 | 2.5±0.5 | 2.5±0.6 | 2.7±0.5 | 2.4±0.5 |
| **Nuts And Seeds (n=254)** | 26.0±17.4 | 26.2±19.1 | 28.6±20.7 | 25.3±14.5 | 26.3±17.3 | 22.5±12.5 |
| Nuts (n=212) | 28.3±18.0 | 28.7±19.8 | 31.4±21.2 | 27.8±14.2 | 28.4±18.1 | 24.3±13.2 |
| Seeds (n=42) | 14.1±5.2 | 13.±5.8 | 13.7±6.9 | 11.1±3.7 | 15.8±4.2 | 15.3±4.4 |
| **Legumes (n=102)** | 3.3±2.6 | 3.7±2.8 | 3.3±2.5 | 3.0±2.5 | 3.3±2.9 | 3.1±2.6 |
| **Grains & Starches (n=358)** | 7.8±9.8 | 7.5±7.4 | 8.7±14.6 | 8.3±9.2 | 7.1±7.2 | 7.6±7.4 |
| Refined Grains (n=70) | 6.9±4.3 | 7.4±3.6 | 5.8±3.4 | 7.6±4.3 | 6.5±4.8 | 7.7±5.9 |
| Whole Grains (n=288) | 8.1±10.7 | 7.5±8.0 | 9.5±16.2 | 8.5±10.0 | 7.2±7.7 | 7.3±7.8 |
| **Eggs (n=48)** | 12.5±6.2 | 13.5±4.7 | 16.4±7.4 | 11.1±3.4 | 11.0±6.5 | 10.2±4.9 |
| **Meat, Poultry, Sea Food (n=353)** | 20.6±17.2 | 21.1±13.4 | 20.2±16.1 | 19.2±10.4 | 22.1±23.6 | 19.3±13.9 |
| **Meat (n=229)** | 22.5±17.5 | 22.4±12.5 | 21.2±10.3 | 21.9±10.6 | 25.1±27.5 | 20.5±12.9 |
| Red Meat and Organs (n=122) | 30.2±20.3 | 29.9±11.4 | 27.0±9.3 | 29.1±10.0 | 34.4±33.0 | 28.4±13.7 |
| Red Meat (Beef, Sheep, Goat) (n=79) | 33.9±22.5 | 29.6±9.6 | 27.9±6.5 | 30.6±8.9 | 44.4±37.7 | 32.5±12.7 |
| Organs (Liver, Heart, Tongue and Intestines) (n=43) | 23.3±13.1 | 30.5±14.8 | 25.3±13.6 | 26.7±12.0 | 17.9±11.1 | 19.3±12.3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Processed Meat (n=107) | 13.8±6.8 | 15.0±8.5 | 13.0±4.6 | 14.7±5.2 | 12.5±6.0 | 14.6±8.6 |
| **Poultry** (n=65) | 9.9±6.7 | 11.1±11.2 | 9.6±5.1 | 10.4±5.7 | 9.7±5.5 | 8.1±5.5 |
| **Fish** (n=59) | 25.2±19.2 | 25.5±14.7 | 32.9±34.7 | 19.2±9.2 | 23.8±11.8 | 24.4±18.4 |
| **Desserts, Added Sugars (n=305)** | 24.9±19.2 | 25.7±19.3 | 26.6±25.7 | 24.0±14.9 | 23.6±17.0 | 24.0±15.9 |
| **Sweets (n=209)** | 28.3±18.6 | 29.1±18.2 | 30.0.±27.2 | 27.5±12.7 | 26.5±15.8 | 27.9±14.0 |
| Arabic and Western Desserts (n=101) | 20.8±9.3 | 21.3±7.4 | 17.8±8.3 | 25.9±11.0 | 18.3±9.1 | 20.9±8.3 |
| Ice cream and Chocolate(n=108) | 35.2±22.2 | 35.9±21.9 | 41.7±33.5 | 29.7±14.9 | 33.8±17.0 | 32.8±15.2 |
| **Added Sugars (n=96)** | 17.5±18.4 | 18.2±20.0 | 19.1±20.7 | 13.7±16.6 | 18.4±18.1 | 16.3±16.9 |
| Honey and Jam (n=57) | 27.9±17.4 | 29.0±19.4 | 31.3±20.0 | 23.9±17.0 | 27.4±17.0 | 26.4±15.2 |
| Sugars (n=39) | 2.3±1.4 | 2.1±0.7 | 2.9±2.5 | 1.9±0.7 | 2.5±1.5 | 1.9±0.6 |
| **Prepared / Ready to Eat Foods (Fast Foods) (n=154)** | 12.8±5.8 | 13.9±4.5 | 13.3±6.8 | 15.7±7.3 | 11.2±5.3 | 11.0±4.3 |

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